International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

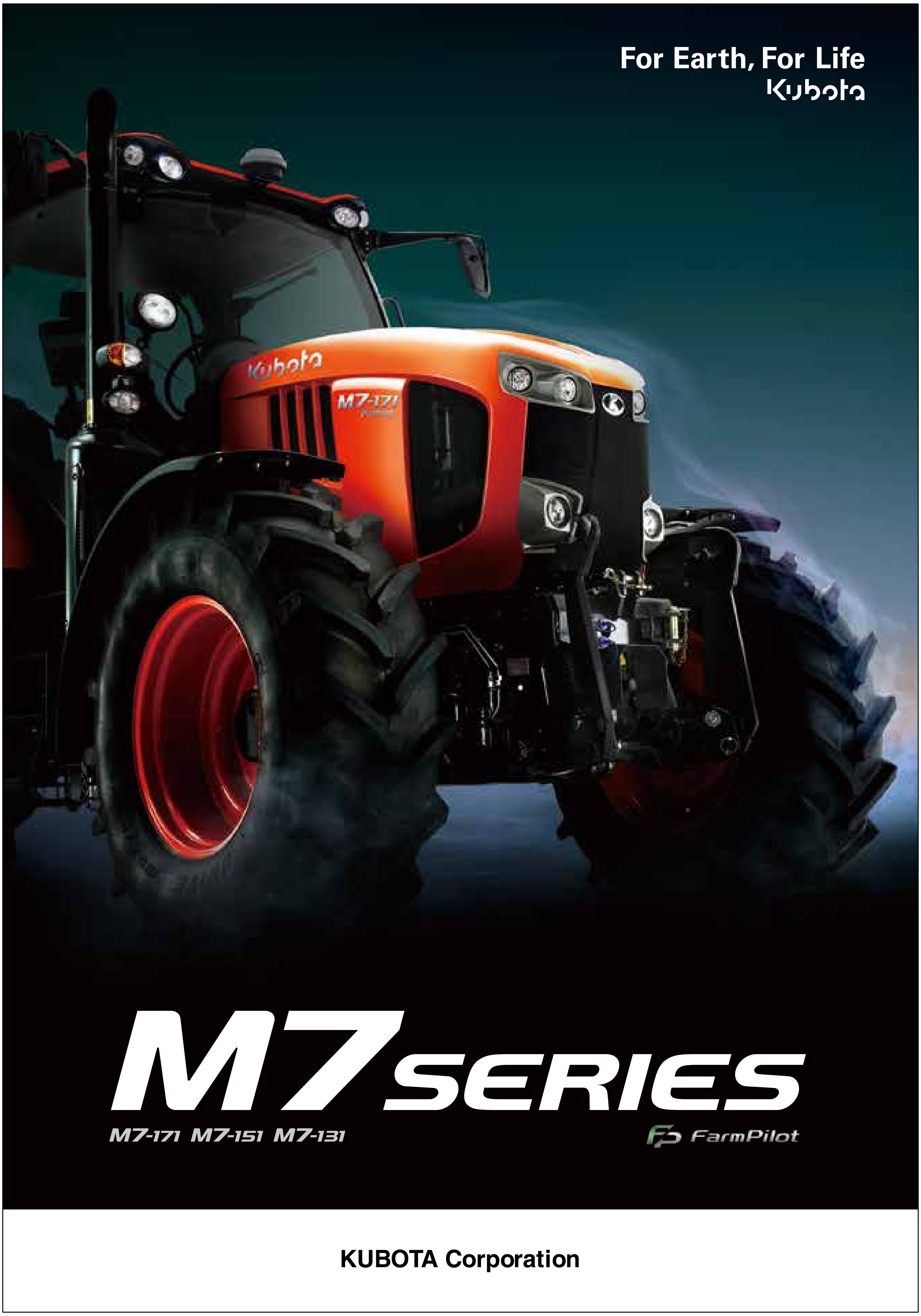
AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.49, No.2, SPRING 2018

SPECIAL ISSUE :

Agricultural Mechanization and Industry in Africa

FARM MACHINERY INDUSTRIAL RESEARCH CORP.


For Earth, For Life
Kubota
M7 SERIES
M7-171 M7-151 M7-131
FarmPilot
KUBOTA Corporation

WE ARE ECHO

100% PROFESSIONAL GRADE

ECHO only builds equipment to one standard – professional. We manufacture products to suit the environment in which they will be used and the job they will be doing, and each piece of equipment is as durable as we can make it. We test our products in punishing conditions to ensure that they are capable of whatever you demand from them. So even if you don't use ECHO equipment professionally, the products you buy are already being used by people who do.

JAPAN TECHNOLOGY

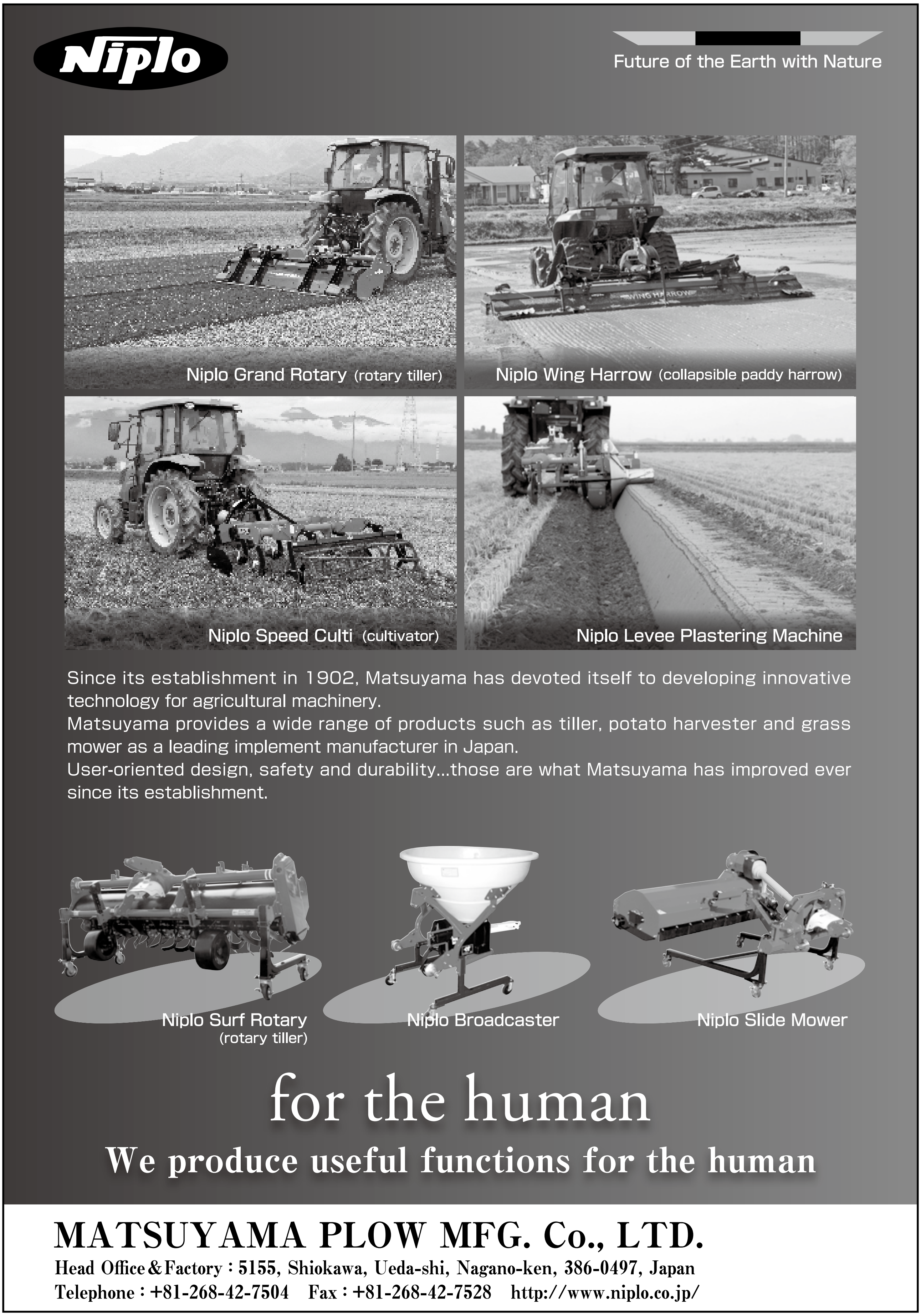
You know that equipment designed in Japan will be reliable. Well built. Dependable. Professional. Durable. Japan is the home of technological craftsmanship and the nation has won international respect for its manufacturing expertise. This global standard also extends to the equipment we manufacture and we are proud to be counted among those companies that help Japan maintain its reputation for the quality of its engineering and technology.

Visit our website for more information http://www.echotools.com/

Follow us on Facebook for the latest news https://www.facebook.com/echotools/

ECHO DEPEND ON IT

ECHO BY YAMABIKO CORPORATION
7-2, Suehirocho 1-Chome, Ohme, Tokyo, 198-8760, Japan
Email marketing@yamabiko-corp.co.jp


Niplo
Future of the Earth with Nature
Niplo Grand Rotary (rotary tiller)
Niplo Wing Harrow (collapsible paddy harrow)
Niplo Speed Culti (cultivator)
Niplo Levee Plastering Machine
Since its establishment in 1902, Matsuyama has devoted itself to developing innovative technology for agricultural machinery.
Matsuyama provides a wide range of products such as tiller, potato harvester and grass mower as a leading implement manufacturer in Japan.
User-oriented design, safety and durability...those are what Matsuyama has improved ever since its establishment.
Niplo Surf Rotary (rotary tiller)
Niplo Broadcaster
Niplo Slide Mower
for the human
We produce useful functions for the human
MATSUYAMA PLOW MFG. Co., LTD.
Head Office＆Factory : 5155, Shiokawa, Ueda-shi, Nagano-ken, 386-0497, Japan
Telephone : +81-268-42-7504 Fax : +81-268-42-7528 http://www.niplo.co.jp/

Pot system suitable for Organic rice crop

POT448

<Full size>

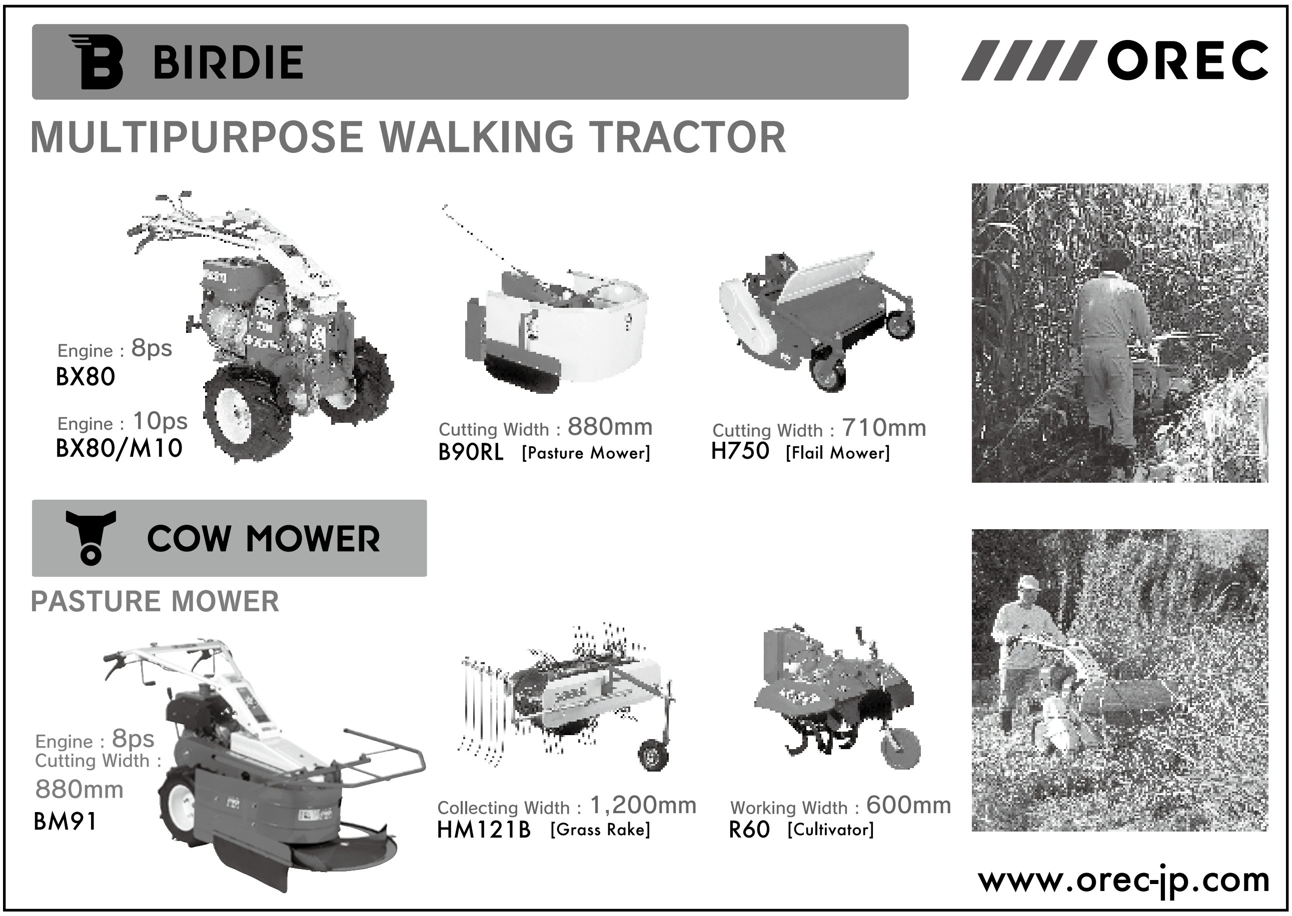
≪POT SYSTEM≫

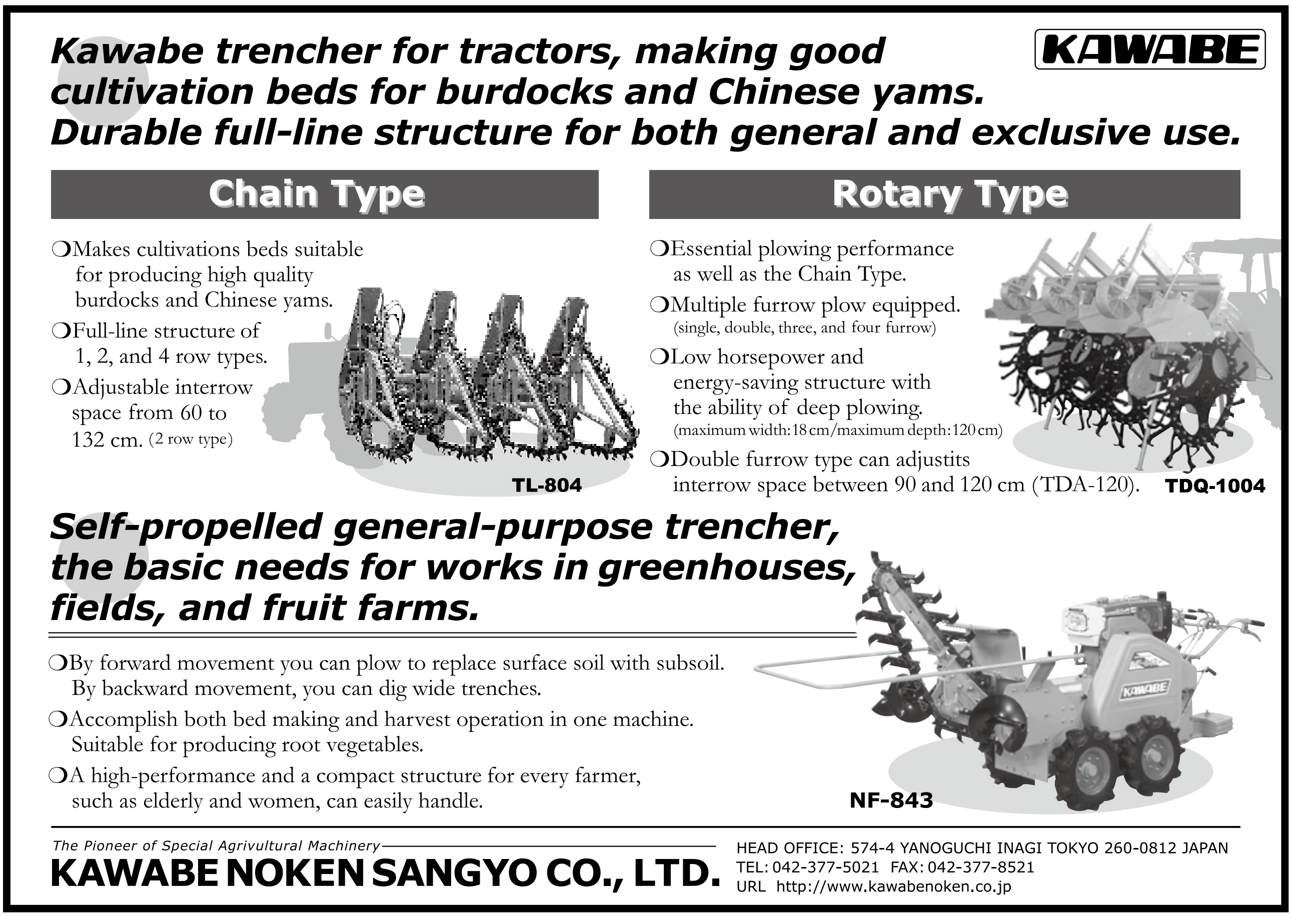
- Designed to use special nursery tray with 448 pots
- Seeding 2-3 rice seeds per pot
- Prepared seedlings for transplanting with more than 4.5 leaves each and 15 cm height are disease resistant and easy for flooding cultivation
- 33 cm row spacing assures wide space planting
- Maximum operating speed of weeder is about 1.2 m/s. Inter row space is weeded by forced rotor and inter plants is weeded by forced vibrating tooth

MINORU INDUSTRIES CO., LTD.

Head Office & Factory : 447,shimoichi,Akaiwa,Okayama,709-0892,Japan

URL http://www.minoru-sangyo.co.jp


BIRDIE
OREC
MULTIPURPOSE WALKING TRACTOR
Engine : 8ps
BX80
Engine : 10ps
BX80/M10
Cutting Width : 880mm
B90RL [Pasture Mower]
Cutting Width : 710mm
H750 [Flail Mower]
COW MOWER
PASTURE MOWER
Engine : 8ps
Cutting Width :
880mm
BM91
Collecting Width : 1,200mm
HM121B [Grass Rake]
Working Width : 600mm
R60 [Cultivator]
www.orec-jp.com


Kawabe trencher for tractors, making good
cultivation beds for burdocks and Chinese yams.
Durable full-line structure for both general and exclusive use.
KAWABE
Chain Type
❍Makes cultivations beds suitable for producing high quality burdocks and Chinese yams.
❍Full-line structure of 1, 2, and 4 row types.
❍Adjustable interrow space from 60 to 132 cm. (2 row type)
TL-804
Rotary Type
❍Essential plowing performance as well as the Chain Type.
❍Multiple furrow plow equipped. (single, double, three, and four furrow)
❍Low horsepower and energy-saving structure with the ability of deep plowing. (maximum width: 18 cm/maximum depth: 120 cm)
❍Double furrow type can adjustits interrow space between 90 and 120 cm (TDA-120).
TDQ-1004
Self-propelled general-purpose trencher,
the basic needs for works in greenhouses,
fields, and fruit farms.
❍By forward movement you can plow to replace surface soil with subsoil. By backward movement, you can dig wide trenches.
❍Accomplish both bed making and harvest operation in one machine. Suitable for producing root vegetables.
❍A high-performance and a compact structure for every farmer, such as elderly and women, can easily handle.
NF-843
The Pioneer of Special Agrivultural Machinery
KAWABE NOKEN SANGYO CO., LTD.
HEAD OFFICE: 574-4 YANOGUCHI INAGI TOKYO 260-0812 JAPAN
TEL: 042-377-5021 FAX: 042-377-8521
URL http://www.kawabenoken.co.jp


Spreading Japanese agricultural technology and community culture to the world.
Seeding machines
Gel-coated seeds
Food processing machines
Clean and secure near-sterile vegetable cultivation factory
Agriculture business
EarthSmile
Plant seeds of smile
AGRITECNO YAZAKI Group
AGRITECNO YAZAKI CO.,LTD. 〈Head Office: 6-5-12 Tsuchiyama, Himeji-City, Hyogo-Pref.,JAPAN 670-0996〉
Philippine Agritecno Yazaki Agency Representative Office 〈Philippine〉
Mizuta Kogyo Co.,Ltd. 〈Okayama-Pref.,JAPAN〉
Yume Farm Ukan Co.,Ltd. 〈Okayama-Pref.,JAPAN〉
Arrow Farm Oita Co.,Ltd. 〈Oita-Pref.,JAPAN〉
Korea Agritecno Yazaki Co.,Ltd. 〈KOREA〉
Shanghai Yazaki Trading Co.,Ltd. 〈CHINA〉
URL https://www.agritecno.co.jp/


TAISHO
Changes from technology to HUMANOLOGY to live with nature
Minimize set-up time of nursery trays
NURSERY TRAYS SET-UP MACHINE
Belno
Eliminate back pain
BW-3A
Properly blend fertilizers with different specific gravity
BLEND BROADCASTER
ATLAS
• Suitable for organic soil preparation !
DSB-1630
FERTILIZER SPREADER
GRAND SOWER NPD
NPD-170
• Attached in front or rear
Accurate spreading based on GPS
FERTILIZER SPREADER
GRAND SOWER UH
UH-140MT-GP
• Car speed-interlocking type with a GPS antenna
Assist germination even under low temperature
STEAM GERMINATION DEVICE
FCX-1000
• Fit for forklift. Easy to take seeding box in and out
Broadcast various type of fertilizer(granular, sandy, organic pellet) properly without waste
TAISHO Co., Ltd.
1027 Motoyoshidacho, Mito City, Ibaraki, 310-0836, Japan
TEL : +81-29-247-5411 FAX : +81-29-248-2172 URL http://www.taisho1.co.jp/


OTAKE
FURROW OPENER
Here comes steering !
With the steering system, you can turn NORUTAN EVO while riding it !
The minimum turning radius 1.5m
The video is here !
NTH-1
For favorable growth of paddy rice
MINI CULTI NORUTAN EVO
Imperative Shaking Sorter
Rice Husker
Try imperative super technique!
Magic Eye®
Well Done!
No need to adjust shaking plate
OTAKE AGRICULTURAL MACHINERY CO., LTD.
[Head Office/Factory] 265 Gonaka, Nakajima, Oharu-cho, Amagun, Aichi-ken, 490-1145 JAPAN
TEL: +81-52-444-2525 FAX: +81-52-443-0348 http://www.otake-ss.co.jp/


SPEED and PERFORMANCE
Speediness with HST. Performance like hammer knife.
WADO
since 1941
Japan Quality
M708HST
Output: 7.0 ps
Cutting width: 700 mm
Efficiency: 31.5 a/h
Happy life with WADO Mower
WADO
WADOSANGYO Co.,Ltd.
410 Jissoji, Hanamaki, Iwate, 025-0035 Japan
E-mail:wado@wadosng.jp
https://www.wadosng.jp/

International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.49, No.2, Spring 2018

Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

Yoshisuke Kishida, Publisher & Chief Editor

Contributing Editors and Cooperators

AFRICA
Kayombo, Benedict (Botswana)
Fonteh, Fru Mathias (Cameroon)
Ndindeng, Sali Atanga (Cote d'Ivoire)
Abdallah, Said Elshahat (Egypt)
El Behery, A. A. K. (Egypt)
Addo, Ahmad (Ghana)
Bani, Richard Jinks (Ghana)
Djokoto, Israel Kofi (Ghana)
Some, D. Kimutaiarap (Kenya)
Gitau, Ayub N. (Kenya)
Houmy, Karim (Morocco)
Oyelade, O. A. (Nigeria)
Bindir, Umar B. (Nigeria)
Igbeka, Joseph C. (Nigeria)
Odigboh, E. U. (Nigeria)
Oni, Kayode C. (Nigeria)
Opara, U. L. (South Africa)
Kuyembeh, N. G. (Sierra Leone)
Abdoun, Abdien Hassan (Sudan)
Saeed, Amir Bakheit (Sudan)
Khatibu, Abdisalam I. (Tanzania)
Tembo, Solomon (Zimbabwe)

AMERICAS
Cetrangolo, Hugo Alfredo (Argentina)
Nääs, Irenilza de Alencar (Brazil)
Ghaly, Abdelkader E. (Canada)
Hetz, Edmundo J. (Chile)
Roudergue, Marco Antonio Lopez (Chile)
Aguirre, Roberto (Colombia)
Ulloa-Torres, Omar (Costa Rica)
Mesa, Yanoy Morejón (Cuba)
Rondon, Pedro Paneque (Cuba)
Luna-Maldonado, A. I. (Mexico)
Magaña, S. G. Campos (Mexico)
Ortiz-Laurel, H. (Mexico)
Bora, C. Ganesh (U.S.A.)
Goyal, Megh Raj (U.S.A.)
Mahapatra, Ajit K. (U.S.A.)

ASIA and OCEANIA
Farouk, Shah M. (Bangladesh)
Hussain, Daulat (Bangladesh)
Mazed, M. A. (Bangladesh)
Ali, Rostom (Bangladesh)
Wangchen, Chetem (Bhutan)
Basunia, M. A. (Brunei)
Luo, X. (China)
Ilyas, S. M. (India)
Kulkarni, S. D. (India)
Mani Indra (India)
Mehta, C. R. (India)
Michael, A. M. (India)
Nath, Surya (U.S.A.)
Pathak, B. S. (India)
Salokhe, Vilas M. (India)
Singh, Gajendra (India)
Verma, S. R. (India)
Abdullah, Kamaruddin (Indonesia)
Behroozi-Lar, Mansoor (Iran)
Minaei, Saeid (Iran)
Mahdavian, Alireza (Iran)
Abdul-Munaim, Ali Mazin (Iraq)
Hasegawa, Hideo (Japan)
Snobar, Bassam A. (Jordan)
Chung, Jong Hoon (Korea)
Lee, In-Bok (Korea)
Bardaie, Muhamad Zohadie (Malaysia)
Gonchigdorj, Enkhbayar (Mongolia)
Pariyar, Madan P. (Nepal)
Jayasuriya, Hemanatha P. W. (Oman)
Khan, Alamgir A. (Pakistan)
Mughal, A. Q. A. (Pakistan)
Mirjat, Muhammad Saffar (Pakistan)
Abu-Khalaf, Nawaf A. (Palestine)
Lantin, Reynaldo M. (Philippines)
Venturina, Ricardo P. (Philippines)
Al-suhaibani, Saleh Abdulrahman (Saudi Arabia)
Al-Amri, Ali Mufarreh Saleh (Saudi Arabia)
Illangantileke, S. G. (Sri Lanka)
Chang, Sen-Fuh (Taiwan)
Chen, Suming (Taiwan)
Krishnasreni, Suraweth (Thailand)
Phongsupasamit, Surin (Thailand)
Senanarong, Akkapol (Thailand)
Soni, Peeyush (Thailand)
Ertekin, Can (Turkey)
Haffar, Imad (United Arab Emirates)
Hay, Nguyen (Viet Nam)
Lang, Pham Van (Viet Nam)

EUROPE
Katardjiev, Tihomir Hristov (Bulgaria)
Kic, Pavel (Czech)
Müller, Joachim (Germany)
Ferentinos, Konstantinos P. (Greece)
Sigrimis, Nick (Greece)
Gasparertto, Ettore (Itaty)
Hoogmoed, W. B. (Netherlands)
Pawlak, Jan (Poland)
Marchenko, Oleg S. (Russia)
Martinov, Milan (Serbia)
Jaime, Ortiz-Cañavate (Spain)
Sims, Brain G. (U.K.)

EDITORIAL STAFF
(Tel.+81-(0)3-3291-3674)
Yoshisuke Kishida, Chief Editor
Haruna Iwase, Managing Editor
R. Lal Kushwaha, Editorial Consultant

ADVERTISING
(Tel.+81-(0)3-3291-3674)
Yuki Komori, Director (Head Office)
Advertising Rate: 300 thousand yen per page

CIRCULATION
(Tel.+81-(0)3-3291-3674)
(Fax.+81-(0)3-3291-5717)
Editorial, Advertising and Circulation Headquarters
1-12-3, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
URL: http://www.shin-norin.co.jp/english/
E-Mail: ama@shin-norin.co.jp

Copyright © 2018 by
FARM MACHINERY INDUSTRIAL RESEACH CORP.
in SHIN-NORINSHA Co., Ltd
Printed in Japan

This is the 175th issue since its maiden issue in the Spring of 1971

EDITORIAL

This issue is a special issue, one which features agricultural mechanization in Africa. Its publication was made possible by cooperation of the contributors and our Cooperating Editors. We would like to express our sincere gratitude for all of their help.

Now, the population of the world has reached 7.3 billion and is still increasing. Of which African region experiences the most rapid increase. Especially, the speed of the one in Nigeria is impressive. In line with Sustainable Development Goals (SDGs) set by United Nation, we are trying to make agriculture sustainable. To achieve our goal, we need considerable higher efforts and cooperation by many people including improved policies by Governments. We have to do that with limited resources such as arable land and pure water. In order to supply enough food to ever increasing population, we have to improve productivity. As I said many times before, the most effective way to improve productivity is to increase the amount of agricultural machinery usage per ha for timely and precise operations.

The ways to promote agricultural mechanization in these days are different from the ones in the past. The most noticeable differences are that we not only have sophisticated information technology, but also can use it at a low price. This new situation made it possible for us to access new information wherever we are and communicate with almost anyone in the world. Smart phones are diffusing all over the world and are now used by many people in Africa also. Moreover, the ability is there to continue to acceleratedly improve its applications in agricultural productivity. Since the agricultural mechanization in Africa is still in an embryonic stage, there are a lot of challenges to be faced. However, I believe that the development of agriculture and spread of agricultural machinery in African region can advance more rapidly than any other regions. To realize this, we need to make it clear that what challenges we have to deal with and make a list of priorities for each countries and regions including training of people in use of new equipment. It means we need to make individual strategies for agricultural mechanization at the country, regional and continental level.

It would be great if this issue could help agricultural mechanization in Africa.

We were not able to cover all the countries in Africa in this issue. However, we are going to keep our interest in agricultural mechanization in Africa at a high level.

Yoshisuke Kishida
Chief Editor
March, 2018

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.49, No.2, Spring 2018

Yoshisuke Kishida	11	Editorial
G. C. Mrema, J. Kienzle, J. Mpagalile	13	Current Status and Future Prospects of Agricultural Mechanization in Sub-Saharan Africa [SSA]
S. Singh	31	Strategy, Current Activities and Future Prospect for Advancing Indian Agricultural Machinery into the African Market
Y. Li	43	Chinese Agricultural Machinery Enterprises in Africa
K. Shoji, A. Utsunomiya	46	Current Status and Potentials for the Use of Agricultural Machines in Rice Production in Madagascar
N. Kabaki	54	Rice Cultivation and Agricultural Machinery in Madagascar
K. Yamaguchi, A. Mwangamilo	60	Outlook on Agricultural Mechanization in Tanzania Regarding to the Improvement of Rice Industry
E. O. Díaz, S. Kawamura, S. Koseki	68	Physical Properties of NERICA Compared to Indica and Japonica Types of Rice
S. E. Abdallah, W. M. Elmessery	74	Current Status and Future Prospects of Agricultural Mechanization in Egypt
T. Kadah, R. Mohammed R. K. Ibrahim, H. Radwan, A. El behery	77	Current Situation of Agricultural Tractors and Equipment in Egypt
A. Addo, S. K. Amponsah	87	Present Status and Future Prospects of Agricultural Machinery Industry in Ghana
A. B. Saeed	95	Farm Mechanization in Sudan: Historical Development, Present Status and Future Prospects of Industry, Research and Policies
A. N. Gitau, S. N. Wilba, D. O. Mbuge S. T. Mwangi	104	Modelling Variable Cost of Tractors: A Case Study of Ten Tractor Models in Juba of South Sudan
D. Herbel, K. Nouwogou, G. C. Bagan	112	Producers Get Together to Step Up Mechanization of Their Family Farms—The Mechanization Cooperatives in Benin
O. E. Omofunmi, A. M. Olaniyan	118	Present Status and Future Prospects of Farm Mechanization and Agricultural Machinery Industry in Nigeria
J. C. Adama, C. A. Ezeaku B. N. Nwankwojike	125	Government Policies and Programmes Involved with Agricultural Mechanization in Nigeria: A Case Study of Selected Agencies
M. Y. Kasali	135	Present Status and Future Prospects of Agricultural Machinery Research Activities in Nigeria
M. C. Ndukwu, S. N. Asoegwu I. E. Ahaneku	150	Status of Research on Agricultural Machinery Development in Nigeria: A Case Study of Cassava Tuber Processing Machineries
K. L. Adeniji	156	Mechanizing Nigerian Agriculture for an Improved Economy: A Case Study of Niji Group
S. N. Asoegwu, N. R. Nwakuba S. O. Ohanyere	160	Effective Use of Indigenous Farm Machinery and Implements in Soil Tilling, Planting and Weeding in Nigeria

★ ★ ★

News 168
Event Calendar 167
Subscription Information 176
Co-operating Editors 169
Instructions to AMA Contributors 175

Current Status and Future Prospects of Agricultural Mechanization in Sub-Saharan Africa [SSA]

by
G. C. Mrema
Professor of Agricultural Engineering
Sokoine University of Agriculture (SUA)
P.O. Box 3233, Morogoro
TANZANIA

J. Kienzle
Agricultural Engineer
FAO Headquarters, Rome
ITALY

J. Mpagalile
Agricultural Engineer
FAO Regional Office for Africa
Accra
GHANA

Abstract

In this paper, data on the demand for mechanization inputs (and potential for its growth) including availability of tractors in countries in sub-Saharan Africa [SSA]* is presented. Overall, the Southern Africa region has the highest number of tractors in use while the Central Africa region relies on human muscle power for primary land preparation on about 85% of the cultivated land. The annual level of importation of tractors and other agricultural mechanization inputs in many SSA countries is quite low and this raises the issue of the sustainability and viability of the franchises and supply chains for agricultural machinery, implements and spare parts. Due to the small size of the market for mechanization inputs in many countries, it is important to consider sub regional mechanisms and cooperation in order to establish viable agricultural machinery supply chains and manufacturing entities.

Acronyms	
AUC	African Union Commission
CA	Conservation Agriculture
CT	Conventional Tillage
DAP/T	Draft Animal Power/Technology
FARA	Forum for Agricultural Research in Africa
LAC	Latin America and Carribean
LSFs	Large-Scale Farmers
MNCs	Multinational Corporations
MSFs	Medium-Scale Farmers
PSFs	Peasant Subsistence Farmers
RECs	Regional Economic Communities
SAM	Sustainable Agricultural Mechanization
SCFs	Small-scale Commercial Farmers
SME	Small & Medium Scale Enterprises
THS	Tractor Hire Services
2+4WT	2+4 Wheel Tractor

*The *FAO Regional Office for Africa (RAF)* caters for 57 member countries in SSA. Further, there are four FAOs' Offices in SSA: (i) *Office for Central Africa (SFC)* covering Cameroon, Central African Republic, Chad, Republic of the Congo, Democratic, Republic of the Congo, Equatorial Guinea, Gabon and Sao Tome and Principe; (ii) *Office for Eastern Africa (SFE)* for Burundi, Djibouti, Ethiopia, Kenya, Rwanda, Somalia, South Sudan and Uganda; (iii) *Office for Southern Africa (SFS)* for Angola, Botswana, Comoros, Eritrea, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe; and (iv) *Office for Western Africa (SFW)* covering Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo.

Sustainable agricultural mechanization [SAM] is key to the development of the agricultural sector in SSA. A holistic approach is essential, as SAM contributes to environmental sustainability through the adoption of sustainable land preparation and crop husbandry techniques; to commercial sustainability through the use of business models which efficiently and profitably provide mechanization inputs and services to farmers at competitive and affordable prices; and to socio-economic sustainability through improved access to higher levels of mechanization inputs and services by smallholder farmers (including women, youth and the elderly). It is equally important to provide training in basic technical and business skills to farmers and mechanization service providers at all levels on how to safely use improved implements and power units in mechanized crop and livestock production systems on the farms and at homes.

Introduction

Progress in agricultural mechanization in much of sub-Saharan Africa [SSA] stalled for approximately three decades, from1985 to 2015. This resulted in limited visibility in national agricultural development programmes and often dropping off the agenda of international development organizations and donor agencies. The negative trend affecting the pace of agricultural development in SSA during this period included the decline of food production per capita, agricultural value addition and exports, and an increase of agricultural imports (FAO, 2015). The use of agricultural machinery such as tractors declined, and in several areas animal traction shifted back to hand hoeing due to, among other reasons, loss of draught animals to droughts, increased outbreaks of livestock diseases and deteriorating animal health service.

Agricultural mechanization is widely supported in SSA by farmers, local leaders, policy makers and politicians, although it has been subject to controversy in some circles. The SSA region was and is still considered to be a land surplus region with comparatively low population density and in most countries, wages remain low (Binswanger, 1986; IBRD, 1987). However, the factors that drove mechanization in other regions of the world may not be present in many areas of SSA (FAO, 2008 &2014). Africa's experience with oxen and tractor mechanization has, in general, not been very successful (Eicher and Baker, 1982; Pingali *et al.,* 1987; Mrema, 1991). Government investments in tractor support and supply schemes without sound mechanization strategies and policies may worsen the situation at field and farm level (FAO, 2008 & 2016; FAO/UNIDO, 2009).

This paper provides a review of the role of agricultural mechanization in agricultural and economic development of SSA, specifically on the current status and future prospects of agricultural mechanization. It includes an analysis of current and future potential markets for agricultural machinery and implements. This paper will focus on the technical constraints to effective and efficient utilization of agricultural machinery, implements and equipment in SSA including recommendations on the needs to be addressed by research and development institutions.

If agricultural growth and overall development is to occur in SSA, it is important that farming undergoes transformation and is geared towards increasingly competitive local, regional and international markets, with machines and implements in line with the other major inputs—improved seeds, fertilizers, water and pesticides—, all of which play an integral part in increasing agricultural productivity and overall production. In this regard, the role of the public sector should be to facilitate an enabling environment for promoting private sector initiatives which are key in the area of agricultural mechanization. This paper focuses on crop production as the core area of agricultural development—since livestock production and aquaculture are all interlinked with crop production.

This paper covers demand issues, including (1) area under production, types of farmers and major crops; (2) farm power typology; (3) the sta-

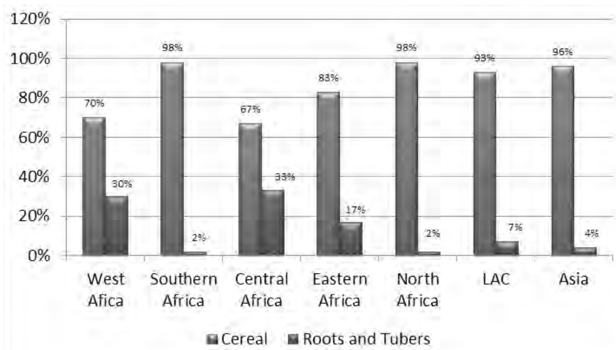


Fig. 1 % of Areas for food crops cultivated in SSA and Other Regions [2000] (Source: FAOSTAT/IFPRI -2014)

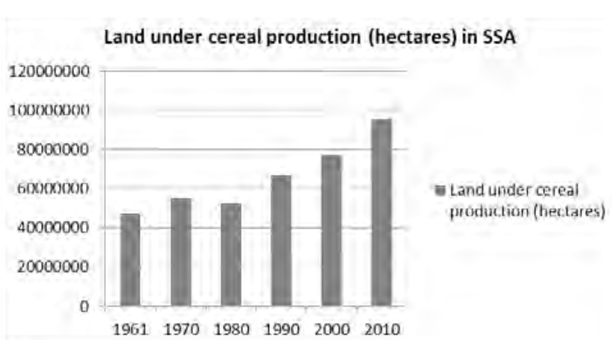


Fig. 2 Land under cereal production (hectares) in SSA (Source: FAOSTAT/IFPRI, 2014)

tus of agricultural implements and equipment; (4) the sustainability of agricultural mechanization systems in SSA; and supply issues, including (5) franchises for distribution of agricultural machinery, implements and equipment; (6) manufacturing of agricultural machinery and implements; and (7) research and development issues.

Types of Crops

In SSA, there are substantial areas where crops, such as roots and tubers are cultivated and dominate the food sector, unlike in Asia or Latin America & Carribean (LAC) where the dominant food crops are cereals. As shown in **Fig. 1**, in 2000 the area cultivating cereals, as a percentage of the total area cultivated, ranged from 67 percent in Central Africa to 98 percent in Southern Africa. On the other hand, roots and tubers ranged from 2 percent in Southern Africa to 33 percent in Central Africa. The data for Southern Africa is comparable to that of North Africa at 98 percent for cereals and 2 percent for roots and tubers, while corresponding figures for Asia and Latin America were respectively 96 percent and 4 percent and 97 percent and 3 percent of total cultivated land. Therefore, it is no wonder that Southern Africa and, to a lesser extent, Eastern Africa (both dominated by cereal-based systems) have much higher intensities of tractor use than either West or Central Africa.

The total area under cereals in SSA increased from 45 million hectares in 1961 to 96 million in 2010 (**Fig. 2**). The potential for further increasing the area under cultivation is high due to the fact that Africa has the highest area of uncultivated arable land (202 million hectares) in the world, about 50 percent of the global total. However, productivity lags far behind other developing regions with yields being only 56 percent of the international average (FAO, 2011; AfDB, 2016). In 2015, the total land area under cereals in SSA was about 68 percent of the 142 million ha under cultivation in India (Singh, 2016). Further, 40% of the cultivated land in India is irrigated compared to only 7 percent in SSA (FARA, 2014; AfDB, 2016). These statistics demonstrate the challenges of mechanizing agriculture in SSA, especially where small holder farmers dominate.

Types of Farmers

The agricultural sector in many countries in SSA has largely been dualistic, with a medium- and large-scale farm (MSF & LSF) sub-sector co-existing with a small-scale farm (SSF) sub-sector. The MSF & LSF sub-sector has been involved in producing cash and/or industrial crops—such as coffee, sisal, tobacco, pyrethrum, flowers and horticultural products, tea, maize, rice, wheat, dairy, beef, sugar cane, etc. (Wood, 1950; Mayne, 1954 & 1956; Eicher & Baker, 1982). At independence in the 1960s, the MSF & LSF sub-sectors were dominated by settler farmers and/or transnational corporations. After independence of numerous African countries during the 1970s and 1980s, a number of government owned state farms were established in many countries even though the private sector remained the dominant force. Also in some countries (such as Kenya, Tanzania, Zambia, Zimbabwe) which had large settler population, some of the large scale farms were acquired by the governments and sub-divided for re-distribution to small-holder farmers. After the economic structural adjustment programmes of the 1990s, most of the state farms were privatized. The LSFs have been highly mechanized and, in most countries, owned and operated a significant proportion of the four-wheel tractor [4WT] fleets in the various countries at any one time.

From a mechanization perspective, the farm power typology [FAO, 2005 & 2008] can be categorized under the following farmer groups:

- Peasant Subsistence Farmers (PSFs) cultivate less than 2 ha and rely on family labour and hand-tool technology for all field land preparation and crop husbandry tasks (e.g. primary tillage/hoeing; planting; weeding; harvesting and post-harvest processing; shelling; threshing). They may hire tractors or draft animal power [DAP] for land preparation—to break the hard pan or facilitate timeliness in field operations—if they have off-farm income and if the hiring cost is affordable.
- Small-scale Commercial Farmers (SCFs) cultivate 2 to 10 ha of land and would normally use DAP where it is available (either owned or for hire) or tractors (either two-wheel tractor [2WT] owned or for hire and/or 4WT for hire) for land preparation. Other tasks may be mechanized, including planting for maize, harvesting for paddy, shelling and threshing for maize and paddy. A few such SCFs may own 4WT bought second hand, in which case, they have to offer tractor hire services [THS] to other SCFs and PSFs to attain effective and commercial annual utilization rates of their machinery.
- Medium-Scale Farmers (MSFs) cultivate more than 10 ha and up to 100 ha. These farmers would normally have their own 2WT bought new and/or 4WT bought new or second hand and an assortment of implements. They may opt not to own their own equipment and instead rely on hired services where these are available, efficient and timely provided. If they own their own 4WT, they are unlikely to attain commercially optimum utilization rates on their farms alone and are in most cases forced to either offer THS to SCFs

or the PSFs, or engage in off-farm hire activities, such as in transportation, etc.

- Large-Scale Farmers (LSFs) cultivate more than 100 ha and up to 2,000 ha and will normally own a complete range of 4WT with their assorted implements. They may have to hire specialized machinery, such as combine harvesters. These LSFs may also offer machinery hire services to the MSFs on a contract farming basis for harvesting and so on. These could be state farms or privately owned commercial farms that grow both food and cash crops and are often linked to downstream agro-processing value chains (e.g. tea and sugar cane processing, seed production).

During the 1960s, and immediately thereafter, nearly all land under cultivation was, in most countries, owned by the small scale farmers [PSFs and SSFs], with the exception of the countries that had large settler populations (e.g. Angola, Kenya; Namibia, Mozambique, Zambia, Zimbabwe). In this regard, South Africa is the special case with MSF and LSF dominating its agriculture and land ownership. A recent survey of several countries shows that since the beginning of the twenty-first century, the ownership pattern of farms is changing and the role of medium scale farmers [MSF] is increasing. This is illustrated in **Fig. 3** where land owned by SSF in 2015 in Ghana, Tanzania and Zambia was respectively 49 percent, 53 percent and 34 percent of total cultivated land.

From a mechanization perspective, the land owned by MSFs in Ghana, Tanzania and Zambia was at 33, 38 and 54 percent respectively. In addition, large-scale farmers respectively owned 18, 9 and 12 percent of total cultivated land in these three countries. Only in Kenya is the situation slightly different, with land owned by the SSFs, MSFs and LSFs at respectively 66, 19 and 15 percent of total cultivated land. This situation reflects the impact of the land settlement programmes in Kenya of the 1950s and 1960s under the Swynnerton Plan, the independence era land reform, and the commercialization of the SSF sector through the growing of high-value cash crops (such as coffee, tea, dairy, horticulture) [Swynnerton, 1954; Clayton, 1973]. There is therefore considerable transformation of the farming system, which will significantly influence the pace of agricultural mechanization as well as demand of agricultural machinery and implements in SSA (FAO, 2008; AASR, 2016).

The Farm Power Typology

Agricultural mechanization in SSA has remained at the first stage of the mechanization process, referred to as the Power Substitution Stage. This is the earliest developmental stage involving the substitution of the use of animate power (either from muscles of humans or draft animals) with mechanical power from internal combustion engines and/or electric motors used in performing energy-intensive and often back-breaking tasks, such as primary land tillage, and grain milling (FAO, 1981; Rijk, 1983; Singh, 2001).

The extent of available farm power plays an inordinate role in defining the level and process of agricultural mechanization in a country and has been a major indicator of progress attained. In this regard, the role of farm power in increasing agricultural productivity globally was first hypothesized in 1965 by Prof. Giles '….farm power with fertilizers, improved seeds [HYVs], irrigation and pesticides are interdependent for growth in agricultural productivity and overall growth….' (Giles, 1966).

Success of the green revolution (GR) of the 1970s in Asia was attributed mostly to the increased use of HYVs, fertilizers and irrigation but the role of farm power was not examined. The mechanization experience of developed countries, such as the United States of America and European countries from 1925 to 1965 demonstrated the criticality of farm power:

- According to White (2000; 2001), the tractor was the "Unsung Hero" of twentieth century economic growth of the United States of America. It replaced 24 million draft animals from 1925 to 1955 and significantly transformed agricultural productivity and land-use patterns.
- Similar developments occurred in Europe between 1945 and 1965, facilitated in large part by Marshall Plan, when millions of draft animals were replaced by tractors (Carillon & Le Moigne, 1975; Promsberger, 1976; Gibb, 1988).

When most countries in Africa,

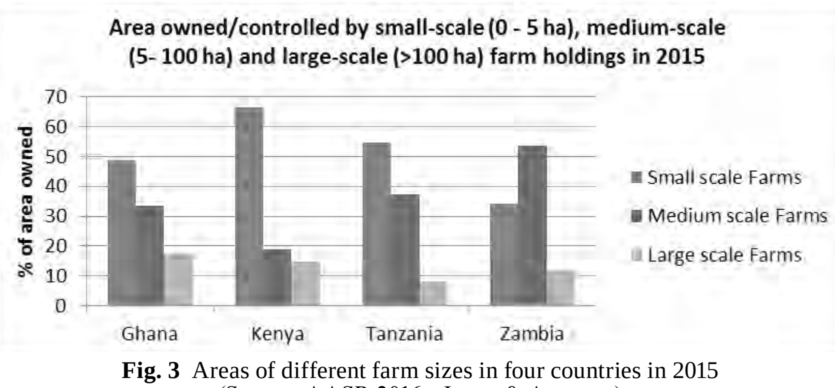


Fig. 3 Areas of different farm sizes in four countries in 2015 (Source: AASR 2016 - Jayne & Amayew)

south of the Sahara gained political independence during the 1960s, the advent of mechanization in developing countries (e.g. Asia, Africa, and LAC) was therefore equated to "tractorization," which became the prevailing development paradigm accepted by most development experts, politicians, and major development organizations which were supporting agricultural development in SSA countries (IBRD, 1960; GoG 1962; FAO, 1966; de Wilde, 1967; Gemmill and Eicher, 1973). The number of tractors in use in any country, therefore, has been the main indicator of levels of mechanization represented in the databases of the major development agencies such as FAO, UNIDO and the World Bank.

The significant role of farm power is even more prominently demonstrated by the situation in Asian countries where significant progress in agricultural mechanization has been achieved over the past fifty years—from a farm power availability level of less the 0.2kW/ha in the 1960s to in 2013 a level of 2.5, 2.02, 1.7 and 1.32 kW/ha for Thailand, India, Viet Nam and Cambodia respectively (Singh and Zhao, 2016). The increased utilization of farm power has been achieved by increased investments in mechanically powered machinery and equipment—tractors, irrigation pumps, harvesters, etc.—and significant reduction in use of animate power from draft animals and human muscles. In India the use of animate power has declined from 90 percent of power available per hectare in 1961 to less than 10 percent by 2014 whereas the mechanical power availability increased from less than 10% to over 90% by 2014 [Singh, 2016].

Hand-tool Technology and Ergonomics of Human Muscle Power

Agriculture in SSA is still carried out using hand-tool technology with almost entire reliance on human muscle power on about 60 to 80 percent of the cultivated land (**Fig. 4**). Ergonomically, primary land preparation by hand-hoeing is the most difficult task, demanding excessive power input from human muscles with the level of energy expenditure being 8 to 10 kilo calories per minute (kcal/min) in the tropics (Passmore & Durnin, 1955; Fluck & Baird, 1979; Nag & Pradhan, 1992). Planting and weeding demand about 25 to 40 percent of the power required for hand hoeing. Although the time taken to perform a task is essentially linked to the energy demanded by that task, the rate at which energy is required is critically important (Boshoff & Minto, 1974; Mrema, 1984; Nwuba & Kaul, 1986). Therefore, the engineering design efforts have been directed at reducing the rate of energy demand. It is particularly desirable, if energy required to operate a piece of equipment is reduced to approach the ergonomically tolerable level of 3 kcal/min. As it has been observed elsewhere this level of energy demand by human powered equipment will be preferable even if there is no dramatic increase in the work output per unit time (Boshoff & Minto, 1974; Mrema, 1984; Nag & Pradham, 1992).

It is no wonder therefore, that many 'appropriate' or 'intermediate' technologies designed during the 1970s & 1980s and powered entirely by human muscles were not adopted by farmers notwithstanding their perceived better work output. As noted in several ergonomic studies, if the equipment does not offer noticeable improvement in the rate of energy demand from the operator it is unlikely to be favorably received by farmers (Boshoff & Minto, 1974; Makhijani, 1979; Stanhill, 1984; Fluck, 1992). It is for this reason, among others, that agricultural mechanization which liberates the African farmer from the drudgery associated with using the hand hoe as a basic tool in agriculture has strongly been supported by African leaders and politicians as well as farmers (Eicher & Baker 1982; FAO, 2008; FAO, 2013).

Unlike in Asia where DAP has been used for centuries, SSA is the only region in the world where the difficult and arduous tasks like primary tillage are being performed with entire reliance on human muscle power on over 60 percent of cultivated land. Hand hoeing has been regarded by the judicial system in most countries of the region as a deserving punishment for the worst crimes, when one is sentenced to serve a term in prison with 'hard labour'. Other regions in the world have long-ago liberated their farmers, through draft animals and/or machines, from this burden of tilling the land by hand hoeing.

Liberation of the African farmer from the drudgery associated with using the hand hoe, as a basic tool

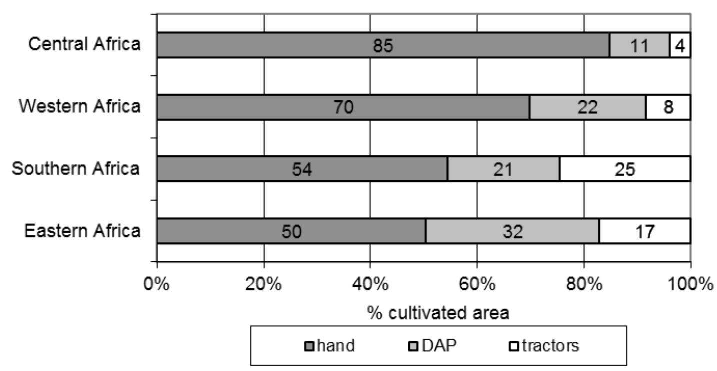


Fig. 4 Source of power for primary land preparation in sub-Saharan Africa (2005) (Source: FAO, 2008)

in agriculture, is therefore a high priority item as enunciated in the Malabo Declaration of 2014 and Vision 2063 of the African Union (AUC, 2016). This is also consistent with the strategies of a number of countries to significantly reduce, by 2035, the area tilled by the hand hoe. One could also argue that the slash and burn system of cultivation was/is a response of the African farmer to tackling the problem of the drudgery associated with primary tillage by reducing the energy required for land preparation, from the 8 to 10 kcal/minute expended using a hand hoe to a more tolerable level of 3 to 5 kcal/min required for slashing (AUC/FAO; 2017). In this regard, ergonomics may be more important in mechanization policy considerations than merely looking at the issue from the perspective of economics of unemployed labor.

Draft Animal Power [DAP] and Associated Technologies

In other regions of the world, agricultural mechanization has evolved through three power stages—the hand-tool technology, draft animal technology (DAT), and mechanical technologies. In most cases, the intermediate stage of DAT lasted for several generations and centuries. Furthermore, farmers had a long tradition of keeping livestock for other products and services (meat and milk; transportation) before using the same for tillage. It has therefore been expected that SSA will evolve through the same three stages in so far as farm power is concerned.

This has not been the case due largely to the fact that in much of SSA those who own much of the livestock that could be used for draft purposes are essentially pastoralists and are traditionally not involved in crop production (e.g. Maasai in Tanzania and Kenya). In addition, almost two-thirds of the land area of SSA is infested with tsetse flies, which makes it difficult to keep livestock. Unfortunately, tsetse infested areas are in the humid tropics of Western, Central, Eastern and Southern Africa with large tracts of uncultivated land which could potentially be used for crop production [**Fig. 4**]. Rendering these areas tsetse fly-free, involves massive land clearing which inevitably leads to severe environmental degradation (Ford, 1971; Tiffen *et al*., 1994).

With the exception of countries like Ethiopia and Mali, where DAP has been used for centuries and where it has been considered as a possible intermediate stage of mechanization, in other countries its development and dissemination have encountered challenges (Kjoerby, 1983; Ehui & Polson, 1992; Mrema & Mrema, 1993). While DAP has been promoted in such countries for more than a century, its adoption has largely been confined to the drier areas where the farmers have both a livestock and a crop husbandry tradition—in Tanzania this is confined to five regions in the North West out of 26 (Mrema, 2016; Mrema & Kahan, 2017). Consequently, tillage and transport services by draft animals (mostly cattle and donkeys) will remain important only in these regions.

Also, DAT is challenged by the growing demand for livestock products (including donkey skin) and recurrent costs associated with keeping livestock for draft purposes (human resources for herding and shortage of grazing land). Furthermore, heavy soils found especially in the humid zones of SSA makes it necessary to use two to three pairs of oxen, thereby increasing the investment cost and complicating the training required. The demand for livestock products is increasing rapidly throughout SSA due to urbanization—expected to reach more than 50% of total population by 2040 in all SSA countries (UNFPA, 2016)—and improved living standards.

Notwithstanding, the massive dissemination effort of DAP by the public extension services and many NGOs, it is also regarded by some, especially the youth, as a “BC” (Before Christ) technology and not a technology for the twenty-first century. This perception is heightened by the unprecedented pace of technological transformation which has occurred in other sectors like ICT (mobile telephones) and transportation (2- & 3-wheel motorcycles and pickups) in the last 20 years. The ubiquitous expansion of the use of motorcycles and tricycles, as well as second-hand vehicles, has created a vast institutional and physical infrastructure for motorized equipment which was not there in the 1970s and 1980s. This has made DAT look like an obsolete technology and not appealing especially to the youth of the 21st Century

The key question therefore, is whether the agricultural mechanization strategy in some areas of SSA should aim at leapfrogging the DAP stage. For quite some time, this has been an issue of debate, among development experts having in some cases diametrically opposite views (de Wilde, 1967; Kline *et al.,* 1969; FAO, 1975, 2008; Eicher & Baker, 1987; IBRD, 1987; Pingali *et al.*, 1987; Panin, 1994; Starkey, 1998). Since DAT has only been adopted mostly in the drier areas and only by farmers who have a livestock and crop husbandry tradition, it may well be time to consider leapfrogging this stage of mechanization development. There are however a number of experts who advocate the continued promotion of DAT, ostensibly due to the perception that it is a renewable source of power/energy and more environmentally friendly (Dikshit & Birthal, 2010) as well as being more socially sustainable and equitable [Binswanger, 1978]. This should be scientifically and objectively assessed and the issue resolved as some have noted (Fluck & Baird, 1979; Adams, 1988; Stanhill, 1984).

Mechanical Power

Four types of mechanical power technologies are used in agriculture in SSA with varying degrees of success:

i) Tractors including:

- Traditional two-axle, four-wheel tractors (4WT) in either the two-wheel drive (2WD) or four-wheel drive (4WD) versions,
- Specially designed, for the developing world, four-wheel low-horse power tractors developed between the 1960s to 1980s, such as the Kabanyolo, Tinkabi, etc. (Boshoff, 1966),
- The power tiller or two-wheel tractor (2WT), which is a single-axle tractor developed initially for cultivation in irrigated areas in Asia;
- Crawler Tractors for land clearing and construction work.

ii) Motorized pumps and other water lifting devices;

iii) Motorized harvesting, post-harvest handling and on-farm processing equipment (including combine harvesters, threshers, shellers, etc.);

iv) Grain milling equipment (such as hammer mills, disc attrition and roller mills).

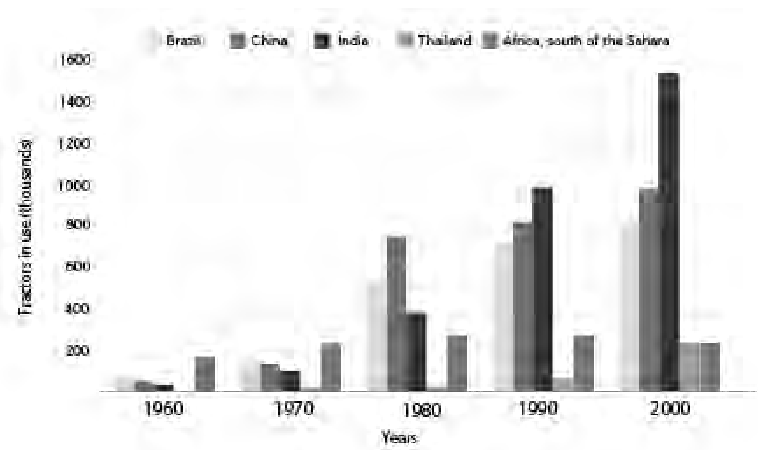
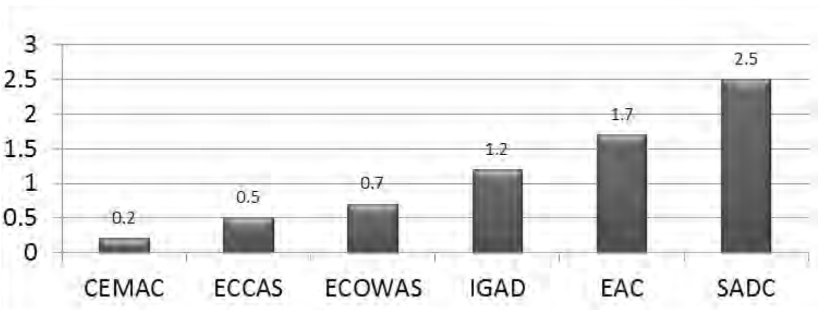


Fig. 5 Tractors in use in SSA cf. Other developing countries (Source: FAOSTAT/AGS, 2004; FAO, 2008)



(i) *Central African Economic and Monetary Community (CEMAC)*: Cameroon, Central African Republic (CAR), Chad, Equatorial Guinea, Gabon and Republic of Congo; (ii) *Economic Community of Central African States (ECCAS)*: Angola, Burundi, Cameroon, Central African Republic, Chad, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Rwanda and Sao Tome and Principe; (iii) *Economic Community of West African States (ECOWAS)*: Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo; (iv) *Intergovernmental Authority on Development (IGAD)*: Djibouti, Ethiopia, Kenya, Somalia, Sudan, Uganda, Eritrea and South Sudan; (v) *East African Community (EAC)*: Kenya, United Republic of Tanzania, Uganda, Rwanda, Burundi and South Sudan; and (vi) *Southern Africa Development Cooperation (SADC)*: Angola, Botswana, Comoros, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe.

Fig. 6 Number of tractors per 1,000 ha of land in different RECs (Source: FAOSTAT)

From a mechanization perspective, the tractor (mostly 4WT) and hammer mills used for grain milling represent the two main types of agricultural machinery technologies disseminated over the past seven decades on a relatively large scale in SSA, with varying degrees of success. This equipment is expensive and unaffordable for a majority of farmers. Therefore, rental mechanisms are the main route through which farmers, in particular the small-scale ones, have been availed use of such machinery services. In most countries in SSA, services offered under tractor hire services [THS], include primary land preparation and transportation, making the plow (disc, moldboard and chisel), the harrow and the trailer, the most important implements in use (Kolawole, 1974; Seager & Fieldson, 1984).

Recently, from 2005, there has been increasing interest in 2WT as a solution to the mechanization problem of SSA. The success of the 2WT in mechanization of rice-based farming systems in Asia has catalyzed efforts to introduce it to similar systems in SSA. New manufacturers and suppliers—mostly from Asia—have emerged and established supply chains for 2WTs, their accessories and spare parts on the continent. Significant adoption has occurred in a number of districts in different countries, largely in rice-based irrigated farming systems. Over 70 percent of the 2WT in use in SSA in 2010 were in three countries (Madagascar; Tanzania and South Africa) with the remaining 25 percent spread in the rest of the continent (AUC/FAO, 2017).

Specially designed tractors for agriculture in the developing world were tested in several parts of Africa during the 1970s and 1980s. Notable in this respect, were the thousands of Swaziland-designed and manufactured Tinkabi tractors. Thousands of these specially-designed tractors were imported by some countries in Southern Africa in the 1970s & 1980s. However the testing with this type of farm power was not successful and stopped in the mid-1990s (Boshoff, 1966; Holtkamp, 1989 & 1991; Dihenga & Simalenga, 1989).

There has been some experience of using and operating tractor hire services (THS) for both the traditional tractor (4WT) and more recently and to a lesser degree—the power tiller (2WT). Both the public and private sectors have been involved in offering THS. Many public sector THS of the 1960s to 1980s failed and this significantly influenced policy decisions on the use of tractors in Africa during the last two decades of the 20th Century (Kolawole, 1974; Seager & Fieldson 1984; FAO/UNIDO, 2009).

The hammer mill used for grain milling is a case of successful development and dissemination of mechanical technologies in SSA, from which lessons on operating machinery hire services can be learned. The issue of agricultural machinery hire services on a commercially sustainable basis, therefore, has been and will remain high priority in any strategy for sustainable agricultural mechanization in SSA. Mechanization of grain milling has occurred in most SSA countries through the introduction and operation of hammer and disc-attrition mills operated by small and medium scale entrepreneurs [SME] who offer hire services to the farmers and other consumers. This has led to a rapid transformation of the grain milling sector—the shift from traditional tools (such as grinding stones and/or pounding in a mortar and pestle) to milling using hammer mills powered by electric motors or small engines. This transformation has been particularly of relief to women and youth who were the main power sources for the traditional tools. The same model is being applied in dehulling of rice in many rice growing areas.

Other powered machinery includes crawler tractors used in land clearing and road construction—these are operated by private sector contractors although in a few countries government fleets have been used for infrastructure work including for construction of irrigation as well as soil and water conservation infrastructure. Combine harvesters are used especially in those countries with a significant number of medium and large scale farms. There is also an increasing number of farmers using irrigation pumps powered by small engines especially for production of fruits and vegetables.

The changes in the farm power situation (as denoted by the total number of 4WT in use) from 1960 to 2000 in SSA is given in **Fig. 5** where it is also compared to the situation in Brazil, China, India and Thailand. As noted in FAO, 2008, the trend in tractor use in SSA has been quite different as compared to other developing countries during 1960 to 2000. While the number of tractors in use in SSA in 1961 was more than in both Asia and in the Near East regions (at 172,000 versus 120,000 and 126,000 units, respectively), it increased very slowly thereafter, peaking at only 275,000 by 1990 before declining to 221,000 units by 2000. The number of tractors in use in SSA in 2000 was about 3.3 percent, 11 percent and 12 percent of corresponding numbers of tractors in use in Asia, Latin America & Caribbean (LAC) and Near East regions, respectively.

While in 1960, SSA had 2.4, 3.3 and 5.6 times more tractors in use than in Brazil, India and the People's Republic of China respectively, by 2000, the reverse was the case, and India, the People's Republic of China, and Brazil had respectively 6.9, 4.4, and 3.7 more tractors in use than in the entire SSA region (including South Africa) [**Fig. 6**]. Similarly in 1960, SSA had approximately 3.4 times more tractors in use than in Thailand; however, by 2000 Thailand had the same number as in SSA. Furthermore, the tractors in use in SSA in 2000 were concentrated in a few countries, with 70 percent being in South Africa and Nigeria.

The number in use per 1,000 ha of arable land is shown in **Fig. 7** for the different Regional Economic

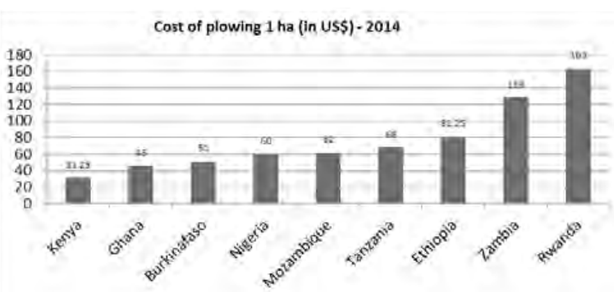


Fig. 7 Cost of plowing 1 ha (in US$) - 2014
(Source: FAOSTAT/IFPRI-2014)

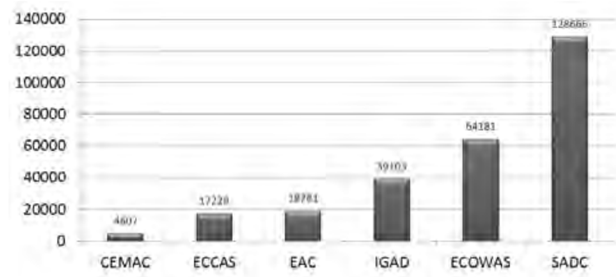


Fig. 8 Number of 4WT imported during 2000-2007 in different RECs
(Source: FAOSTAT, 2000-08)

Communities (RECs) in SSA. The lowest number is 0.2 tractors per 1,000 ha in Central Africa (CEMAC) and the highest is 2.5 in Southern Africa (SADC). These figures compare very unfavorably with the global average of 13 tractors per 1,000 ha. It is no wonder therefore that the cost of ploughing a hectare of land in many countries in SSA is quite high ranging from $31 in Kenya to $163 in Rwanda [**Fig. 8**]. These high costs reflect the scarcity of farm power services in the countries of SSA and need to be reduced if mechanization services are to be affordable to the small-scale farmer and farming is to remain a competitive business.

Agricultural Implements and Equipment

The source of farm power and its use by small-scale farmers was a notable feature of the debate on agricultural mechanization in Asia and Africa during the second half of the twentieth century. Mechanization studies in Asia and in SSA in the 1960s and 1970s were not very concerned about the environmental impacts of tillage implements being hitched to the draft animals and/or tractors until much later. Research on tillage then was more focused on the need to reduce draft power requirements and increase the versatility of the implements for multipurpose use, such as ploughing, harrowing, planting and weeding (Maher, 1950; Willcocks & Twomlow, 1992; Lal, 1998; Starkey, 1988).

On the other hand, mechanized tillage was one of the major contributors to the dust bowls in the United States of America in the mid-1930s. This led to a large long-term research programme focused on better tillage implements and practices. It is in this context that minimum tillage practices and conservation agriculture (CA) gained traction in North and South America (Troeh *et al.*, 1980; Lal, 1998; Friedrich, 2013). CA is an approach to manage agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment [Friedrich, 2013]. The environmental impact of mechanization, especially of tillage implements and practices, became an issue of concern in Asia and Africa only in the late 1990s and at the beginning of the twenty-first century. This led to the introduction of Conservation Agriculture (CA).

According to the African Conservation Tillage (ACT) Network, the adoption of CA practices in sub-Saharan Africa has occurred more on large scale farms. For example, out of a total of 2.679 million hectares under CA in 2016, about 1.835 million ha were under large farms in South Africa, Zambia, Mozambique, Malawi and Zimbabwe, using technologies similar to those developed for North America and Australia (ACT, 2017). Adoption is highest in South Africa with 65.3 percent of the total area under CA in Africa followed by Zambia at 11.8 percent, Malawi at 7.9 percent, Mozambique at 5.7 percent and Zimbabwe at 3.7 percent. These five countries have 94 percent of the total CA area in Africa. Adoption of CA on small scale farms in these countries has been promoted through donor-funded projects. The percentage of cultivated land where CA has been adopted in Africa, south of the Sahara is still very small compared to where conventional tillage [CT] is used (ACT, 2017; Friedrich, 2013, Houmy *et al.,* 2013). There is also concern on the use of herbicides, increased through the adoption of CA, especially in the smallholder sector where environmental and food safety safeguards are not that well developed.

The major challenge of agricultural mechanization in SSA remains the need to increase the farm power available for, among other reasons, relieving the African small-scale farmer of the drudgery associated with hand hoeing. CA is focused on the second problem, which involves the type of implements and crop husbandry practices to be adopted. It is important these two problems are handled in the right sequence. Today, CT implements (e.g. disc, and/or moldboard plows and harrows) are being used on most of the cultivated land in the region where mechanical technologies have been adopted. Also, most of the land cultivated by small-scale farmers has not been completely de-stumped, thus making use of other types of implements difficult [e.g. CA implements].

Other implements and equipment include:

- Crop protection equipment—both manually operated as well as powered ones.
- On-farm produce handling and processing equipment such as threshers, decorticators, shellers, cream separators and cooling tanks, etc.
- Rural transportation of agricultural produce and input supplies through animal drawn carts where draft animals are available or through wheeled equipment (bicycles, two and three wheel motorcycles and pickup trucks—especially second hand trucks imported from Europe and Japan—and tractor trailers).

These may be owned by the individual farmer although in recent years there are quite a number of entrepreneurs who offer implement/equipment hire services (e.g. maize shelling, threshing of paddy and sorghum, sprayers) to farmers including small-scale farmers.

Sustainability of Agricultural Mechanization Systems in SSA

Successful agricultural mechanization is historically linked to market-oriented enterprises, which generate the necessary cash flow to cover capital costs and facilitate loan repayments. Effective demand for outputs of farming translates into effective demand for equipment and machinery services, only if farming is profitable (FAO, 2008). If farms are not profitable before mechanization, the likelihood of them becoming profitable as a result of mechanization alone is low. In most circumstances, as noted in FAO (2008), it is perhaps more realistic to view farm profitability as a condition that makes mechanization feasible, rather than as an outcome of mechanization.

In SSA, the low profitability of many small farms coupled with the levels of investment required, places medium- and large-scale (5 to 200 ha) commercial farmers to be in the most favorable position to mechanize first, as has happened in Asia (FAO, 2008 & 2014; Singh, 2013; Wang, 2013). Even medium-scale commercial farmers face constraints that limit the profitability of their farming enterprises and may find it difficult to maintain and replace equipment. Furthermore, costs of hiring machinery for plowing are extremely high in Africa (**Fig. 8**). Increasing the profitability of medium-scale commercial farming would undoubtedly boost effective demand for mechanical technologies, augment the supply of machinery hire services to small-scale farmers, and reduce unit costs of hiring machinery (Mpanduji, 2000; Agyei-Holmes, 2014). It is therefore important to identify such farmers and encourage the development of viable commercial farming operations, which also would have the potential of providing mechanization services to smaller-scale farmers (FAO, 2008; 2013).

In order to facilitate the commercial sustainability of agricultural mechanization systems, there is need to adopt a holistic approach and to consider the entire agri-food chain, including financing of capital investments required to support the acquisition of farm machinery and implements, off-farm uses of mechanization inputs, and value addition activities on the produce. Mechanization technologies for agri-food chains can also contribute significantly to programmes for reducing losses along entire food chains and for maintaining rural infrastructure and increasing employment opportunities in rural areas, especially for the youth and women.

Coupled with this is the need to achieve efficient utilization rates of agricultural machinery as well as the timeliness of performing field operations. Studies in several parts of SSA show that delayed planting can lead to reduction in yields in rain fed cereal systems in the semi-arid areas of up to 100 kg/ha for each day planting is delayed beyond the optimum date (Kosura, 1983). Further, the number of days available for field operations in such semi-arid areas is limited to about 30 days and hence timeliness is critical in most farming systems in SSA (Simalenga, 1989; Simalenga & Have, 1992). This limits the effective annual utilization rates, of say tractors [4WT], to 300 to 400 hours as opposed to the recommended 800 to 1,200 hours (Crossley & Kilgour, 1983; Hunt, 1983; Culpin; 1988; Kepner *et al.*, 2005). This will remain a major challenge to the commercial viability and profitability of powered mechanization investments in SSA. This calls for cross border services, for example for bordering countries within the same regional economic community (RECs).

There is also the issue of policies and strategies for agricultural mechanization, including for financing of agricultural mechanization inputs and services and for research and development. This involves, in particular, the roles of the public and private sectors in these areas, including which sector should take a lead, and where joint action is required. The failures which occurred in the 1960s and 1970s were caused by, among other reasons, the lack of clear policies and agreement on the roles of each of the sectors.

While it is agreed that the private sector should take a lead in agricultural mechanization initiatives, it is also important to recognize that the private sector works best if there is a large enough demand for mechanization inputs and services. Some of the past public sector actions were a result of low demand in most countries, which led to the sub-sector being unattractive to the private sector. As shown in **Fig. 8**, the number of 4WT imported annually in the different RECs over the eight years period 2000-2007 is quite low. It is only in Southern Africa [SADC] and West Africa [ECOWAS] where the numbers are substantial to attract significant private sector investments. At the same time, there is also a lack of critical mass on an individual country basis (for R & D, testing and standards, etc.) and this may necessitate some cross country cooperation especially for capacity building to achieve economies of scale and scope.

When adopting a more holistic approach, the sustainability of agricultural mechanization systems in SSA takes into consideration sustainability from a commercial, environmental and socio-economic perspectives. Sustainability includes environmental sustainability, in particular the contribution which agricultural mechanization interventions can reduce soil erosion and compaction by adopting sustainable land preparation and crop husbandry techniques; commercial sustainability through business models which offer mechanization services to farmers not only efficiently and profitably but also at competitive and affordable prices; and socio-economic sustainability that recognizes the dominance of smallholder farmers in SSA agriculture and other groups who may be disadvantaged by higher levels of mechanization (including women, youth and the elderly). Sustainable agricultural mechanization strategies will need to cater for all these issues to ensure that, to the extent possible, the interests of all these groups are addressed and they contribute effectively and efficiently to the national economy (ILO, 1973; FAO/OECD, 1975).

Franchises and Supply Chains for Agricultural Machinery and Implements

Timely availability of machinery, equipment, spare parts and other supplies is essential for successful and sustainable agricultural mechanization. Agricultural mechanization includes the development of local industries for production of machinery and implements. Where production is not feasible, the establishment and development of local franchise holders are needed to import them. Even more important is the need to establish efficient and effective distribution channels for equipment, spare parts and repair services and supplies, such as fuel and lubricants. Mechanization should include the development of supply chains and the associated logistical services in order to ensure a better choice of equipment for particular types of users and uses.

During much of the second half of the 20th century, the manufacture and supply of agricultural machinery was dominated by suppliers from the western world (Kurdle, 1975; Burch, 1987). From the turn of the 21st century, however, new suppliers of agricultural machinery and implements have emerged from Asia. The People's Republic of China and India, in particular, have become important global suppliers of low-cost appropriate equipment (Singh, 2013; Wang, 2013; Renpu, 2014). Further, most of the machinery and implements available from the high-income industrial countries are too expensive and too complicated, with often a high power rating and adapted for extremely large-scale farms. Brazil, India, the People's Republic of China, Pakistan, and other developing countries produce and export agricultural machinery and implements at lower prices than prevailing prices of equipment imported from developed countries.

Elimination/reduction of import duties on agricultural machinery and equipment, except in countries that have a thought-out plan to develop local production capacity, could significantly increase access to agricultural mechanization inputs. Opportunities exist in rural settlements and in urban centers and towns to harness the potential entrepreneurial talent available in SSA for promoting the development of input supply chains and agribusinesses focused on the provision of services to producers and processors. The impact could be considerable and the number of jobs created, indirectly through manufacturing and dealer operations, could be substantial.

The issue of efficiencies of the franchises and supply chains for agricultural machinery and implements is critical. According to the available data 26 countries in SSA have less than 1,000 tractors in use, and 6 had between 1,000 to 2,000 tractors, with 10 having between 2,000 and 10,000 units and only 6 with between 10,000 and 30,000 units. South Africa stands out with over 67,700 tractors in use [**Fig. 9**]. Given that these usually represent several brands and sizes of tractors—this implies that the numbers of a particular brand and size imported each year in most countries is quite small, thus raising the issue of sustainability and viability of the franchises and supply chains for agricultural machinery, implements and their spare parts. This is a critical issue related to sustainability of mechanization in many countries in SSA and requires regional collaboration under the regional economic commissions.

Manufacturing of Agricultural Machinery and Associated Services

Coupled with the viability of franchises and supply chains for agricultural machinery and implements is the issue involving manufacturing and testing of agricultural machinery, implements and equipment in the region. Given the small size of the market for mechanization inputs in most countries this is likely to require cooperation at the sub regional level to attain economies of scale and scope if viable manufacturing entities are to be established. A start could be made by developing sub-regional protocols for setting standards and testing of agricultural machinery and implements under the regional economic commissions. Many of the agricultural machinery manufacturing units established in the 1970-1990 period became uncompetitive as a result of the global trade liberalization agreements implemented since the turn of the century.

Under the RECs, the development of local industry for manufacturing of machinery, implements and equipment is a feasible option in quite a number of countries. It has the advantage of generating alternative employment, reducing dependence on imports, saving foreign exchange and facilitating the supply of parts and services. Some of the machinery and equipment needed (fodderchoppers and threshing machines, as well as a range of implements), whether powered by human or draft animal muscles or engines and motors, could be manufactured and serviced locally in many of the countries of Africa, south of the Sahara.

Implements specific to the local

circumstances (agricultural conditions, soil types, etc.) can best be made by small-scale industries, thereby reducing manufacturing and transportation costs and generating employment. To the extent possible, most hand tools and animal drawn implements should be manufactured in the country where they are to be used. It is unlikely that the agricultural machinery for medium and large-scale commercial farmers could be manufactured locally in many countries, it is conceivable that some countries could start by assembling them from Semi Knocked-Down [SKD] parts and Completely Knocked-Down [CKD]

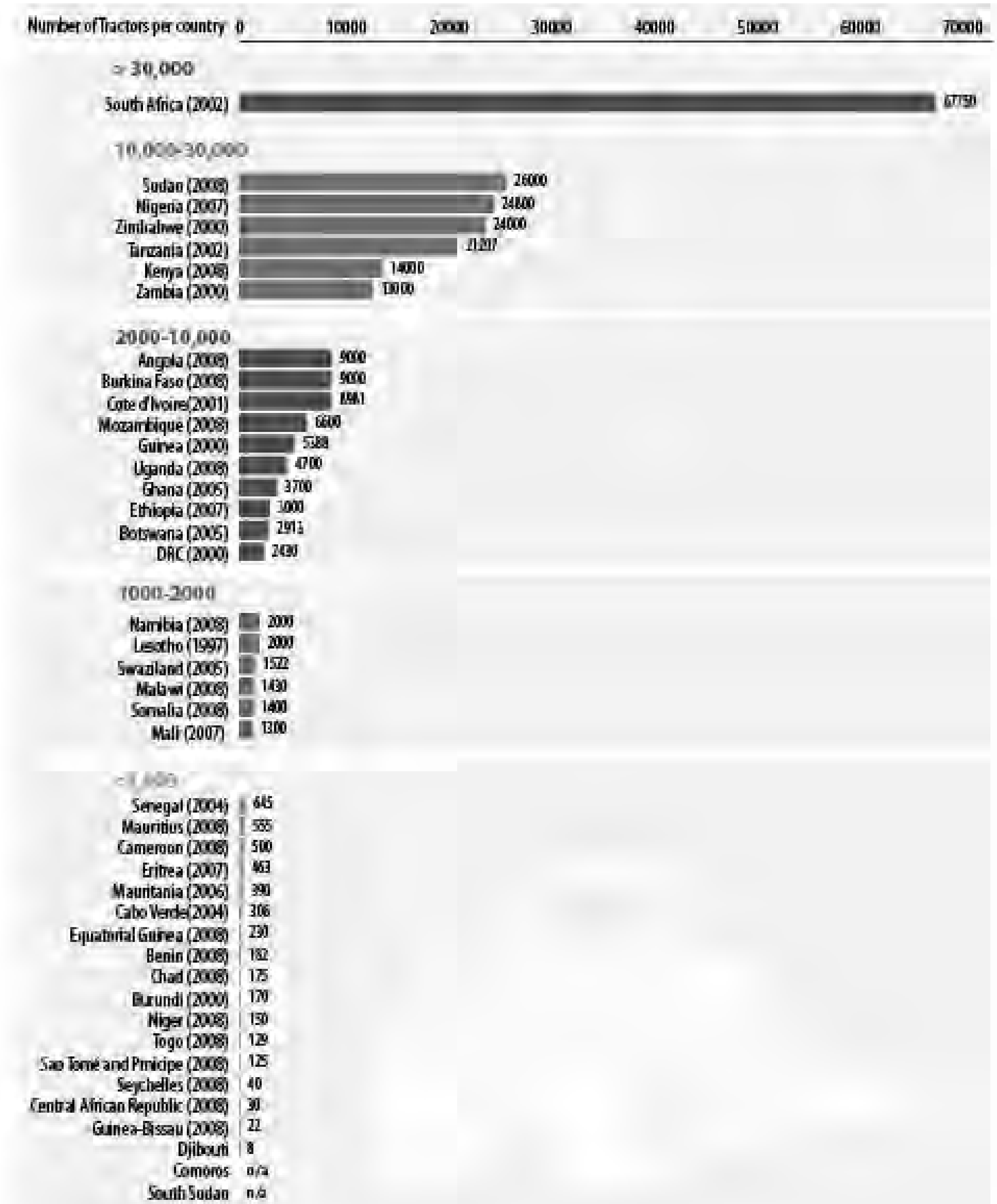


Fig. 9 Number of tractors [4WT] per country – Viability of agricultural machinery franchises (Source: FAO-STAT; World Bank Stat -; AUC/FAO, 2017)

parts.

Such arrangements should be facilitated through the RECs, as the demand in most countries is small and a sub-regional market should be considered (**Figs. 8** & **9**). Also, testing and certification of agricultural machinery and implements, to the extent possible, should be considered at the regional/REC level. Most countries in Africa, south of the Sahara will not likely be able to establish and finance adequately equipped and resourced testing centers at the national level. The RECs should consider facilitating the establishment of regional centers of excellence and networks for standard setting and testing of agricultural machinery and implements.

Research and Development

Public sector research and development activities on agricultural machinery and implements, including sustainable mechanization, are normally handled, in most countries, by several government departments, often lacking coordination between them. These include: Agriculture (mechanization research, soils, post-harvest, irrigation, etc.); Trade and Industries (industrial research; manufacturing; patenting; standards; trade licensing, etc.); Energy (energy generation and distribution, alternative fuels, etc.) and Higher Education (research and education on all aspects of mechanization in schools of agriculture and engineering). Globally, the private sector has undertaken much of the research and development work as well as technology transfer for agricultural machinery and implements in the developing countries.

The private sector is also responsible for the manufacture and distribution of agricultural machinery, implements and equipment to farmers. Some of these private sector entities are branches of multinational Corporations (MNCs), while others are local companies that have established themselves over the past one to two decades. Coordinating and regulating the activities of all these entities, and those of the public sector research and development centres, is an issue of concern for most countries in the developing world. This applies both to activities at the national and regional levels.

In a majority of SSA countries, the strongest in-country capacity for R & D resides in the agricultural engineering departments in the schools of agriculture and/or engineering of the universities. These departments are responsible for training human resources in three critical disciplines: agricultural engineering and mechanization; irrigation and water resources engineering; and post-harvest process engineering. The departments also are the main units responsible for post-graduate training and research in these areas. Together with the departments of agribusiness and farm management, they form the critical mass for effective action within a country, if properly enabled.

The centres for research in agricultural mechanization and rural technologies, in countries where they exist, constitute the important country node for any regional networking in agricultural mechanization. If there is going to be any regional mechanism for agricultural mechanization, then its primary role should be to facilitate the coordination of efforts of the national centres to work together in a structured regional network to achieve economies of scale and scope.

Training and Capacity Building

Smallholder farmers including small scale commercial farmers do not have the necessary capital, either as savings or via access to financial credit, to invest in the expensive farm power and machinery that is essential for increasing land and labor productivity. Moreover, poorly selected or misapplied agricultural machinery can damage, rather than enhance, environmental resources, especially soils. Smallholder farmers require specialized mechanization services that are both environmentally friendly and productivity-enhancing: mechanization service providers who are well trained and appropriately equipped can meet this demand (FAO/CIMMYT, 2018).

FAO, research organizations, private sector and NGOs are working jointly to develop training and capacity building materials for farmers to enhance their business skills in offering mechanization services. Training materials are designed to help train actual and potential farm mechanization service providers, with the aim of increasing access to sustainable farm power and raising the productivity of smallholder farmers. In this regard, the focus is on two crucial aspects: the provision of farm mechanization services as a viable business opportunity for entrepreneurs, and the essential criterion of raising productivity in an environmentally sensitive and responsible way. Increased agricultural production combined with environmental conservation—conservation agriculture—is a viable way forward (FAO/CIMMYT, 2018).

Moreover, agricultural mechanization can be integrated at field level into farmer field schools (FFS) and farmer business schools (FBS). This provides a sound basis for peasant subsistence farmers' competency development in agricultural mechanization and acts as a source of data and information to feed into bigger programmes.

In order to implement short and longer term training for mechanization services providers, commercial farmers, mechanics, dealers and extension services, longer term and broader training programs are required. It is therefore important to encourage and support SSA's existing centers of expertise in agricultural mechanization and engineering to offer such programs. Yet there may also be the need of a new type of regional centers of agricultural mechanization that would rather focus on delivering the new private sector and business esteem that is required to get sustainable agricultural mechanization initiatives going and grounded in many areas of SSA (FAO, 2016).

Conclusions

Given its potential role in agricultural development, mechanization needs to be given higher priority by African governments and development agencies. At the local level, agricultural mechanization can help improve rural livelihoods by breaking labor bottlenecks that constrain productivity and rural income growth while reducing the drudgery associated with hand-tool land preparation and other household tasks (Bishop-Sambrook Clare, 2003). At a larger level, mechanization can be viewed as a necessary dimension of development strategies that promote the commercialization and modernization of small-, medium- and large-scale farms and entrepreneurs in order to accelerate agricultural development and initiate sustained poverty-reducing economic growth. While the benefits of mechanization generally depend on the availability of complementary, improved biochemical inputs as well as water availability and control, the intensification of agriculture requires an adequate supply of power during peak periods, for which a high degree of mechanization is essential.

At a level of extreme generality, history suggests that mechanization should be viewed and supported within the context of a transformation approach to agricultural development. In part, the transformation focuses on larger-scale enterprises with lower unit costs and effective management, viewed within the supply chain. Thus the focus of attention for mechanization would initially be placed on medium-scale farmers and agribusinesses. These farmers and entrepreneurs can provide mechanization services to small-scale farmers and processors. They are the ones who spearheaded the mechanization revolution in Asia over the past 50 years. There is an immediate need to develop the managerial and entrepreneurial capacity of such farmers and managers in SSA, and to provide the necessary planning and logistical support (FAO, 2008; Collier and Deacon, 2009).

While mechanization strategies might initially focus on medium- to large-scale farms and firms, there is clearly not a single pattern or pace of mechanization. There are mechanization options and opportunities suitable for smaller-scale farmers, although realistic consideration needs to be given to the key success factors identified above, namely, effective demand, economic use rates, efficient machinery and equipment supply chains and services. In many cases, the most promising mechanization options for small-scale farms and entrepreneurs may be agro-processing, transport or related non-farm tasks. The preoccupation in SSA with promoting animal traction and tractors for land preparation should give way to flexible strategies for promoting diverse types of mechanical technologies along the value chain that are compatible with local economic, social and developmental conditions.

Also the historical record indicates that successful and sustainable mechanization cannot be established by direct public sector provision of mechanical technologies and services. There are signs that this lesson has not yet been learned, with the corresponding risk that the failures of the 1960s may be repeated. The public sector can nevertheless effectively promote mechanization processes, by, among other things, establishing of enabling environments, training and human resources development, the strengthening of local organizations, and research and development. Particularly important will be targeted efforts to provide public goods and services that create incentives to ensure that large areas and segments of the population are not left behind as agricultural sectors become more modern, commercial and mechanized.

REFERENCES

AASR. 2016. African Agriculture Status Report 2016: Progress towards Agriculture Transformation in Sub Saharan Africa. (Various chapters). AGRA, Nairobi, 2016.

ACT. 2017. African Conservation Tillage Network Annual Report 2016. ACT, Nairobi, Kenya.

Adams, N. 1988. A New Plan for Africa: Development Agencies Should Think Big. New Scientist, London.

AfDB. 2016. Feed Africa. Strategy for Agricultural Transformation in Africa, 2016-2025. African Development Bank, Abidjan.

Agyei-Holmes, A. 2014. Tilling The Soil in Tanzania: What do Emerging Economies Have to Offer? PhD Dissertation: International Development Economics: The Open University, UK. August 2014.

AUC/FAO. 2016. Opening Speech at the Inception Workshop for Sustainable Agricultural Mechanization in Africa: Sending the Hoe to the Museum held in Addis Ababa, Ethiopia 30th June 2016 By Commissioner for Rural Economy and Agriculture; Africa Union Commission.

Baker, C. J., K. E. Saxton, W. R. Ritchie, W. C. T. Chamen, D. C. Reicosky, M. F. S. Ribeiro, S. E. Justice and P. R. Hobbs. 2006.

No-Tillage Seeding in Conservation Agriculture. 2nd Ed. Oxford, UK: CAB International/Food and Agriculture Organization of the United Nations.
Binswanger, H. P. 1978. The Economics of Tractors in South Asia: An Analytical Review. International Crops Research Institute for the Semi-Arid Tropics. (ICRISAT), Hyderabad, India, and ADC, New York, USA.
Binswanger, H. P. 1986. Agricultural Mechanization: A Comparative Historical Perspective. World Bank Research Observer, 1(1): 27-56.
Bishop-Sambrook Clare. 2003. Contribution of Farm Power to Smallholder Livelihoods in Sub-Saharan Africa. Contribution of Farm Power to Smallholder Livelihoods in Sub-Saharan Africa, FAO Rome Italy.
Boshoff, W. H. and J. L. Joy. 1966. Small Tractors in Small-Scale African Farming. In J.L. Joy, Ed. Symposium on Mechanical Cultivation in Uganda, 108-114. Makerere Univ. Press, Kampala.
Boshoff, W. H. & S. L. Minto. 1974. Energy Requirements and Labour Bottlenecks and their Influence on the Choice of Improved Equipment. In Proceedings of Workshop on Farming Equipment Innovation for Agricultural Development and Rural Industrialization (Edited By S.B. Westley and B.F. Johnston). Institute for Development Studies, University of Nairobi, Kenya 238 Pgs.
Burch, P. 1987. Overseas Aid and Transfer of Technology: The Political Economy of Agricultural Mechanization in the Third World Averbury Gower Publishing Co. Harts, UK 370 pgs.
Carillon, R. and M. Le Moigne. 1975. The Evolution of Agricultural Equipment in France: Lessons which may be Learned from it for Developing Countries: In Effects of Farm Mechanization on Production and Employment: FAO/OECD. Rome: Pgs. 279-308.
Clayton, E. S. 1973. Mechanization and Employment in East African Agriculture. In ILO (1973) Pgs. 19-44.
Collier, P. and S. Deacon. 2009. African Agriculture in 50 Years: Smallholders in A rapidly Changing World. Expert Meeting on How to Feed the World in 2050. ESA Division; FAO, Rome. Italy.
Culpin C. 1988. Profitable Farm Mechanization. 2nd Ed. Granada Publishing, UK.
De Wilde, J. C. 1967. Experiences with Agricultural Development in Tropical Africa. Volume 1.The Synthesis. Johns Hopkins University Press for IBRD, Baltimore.
Dihenga, H. O. and T.E. Simalenga. 1989. Evaluation of the Tinkabi Tractor in Tanzania. Research Report. Sokoine University of Agriculture, Morogoro, Tanzania.
Dikshit, A. K and P. S. Birthal. 2010. Environmental Value of Draught Animals: Saving Fossil-fuel and Prevention of Greenhouse Gas Emission in Agricultural Economics Research Review 23(2):227-232.
Ehui, S. and R. Polson. 1992. A review of .the economic and ecological constraints of animal draught cultivation in sub-Saharan Africa Soil and Tillage Research 27: 195-210.
Eicher, C. K. and D. Baker. 1982. Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey. MSU International Development Paper Number 1. Department of Agricultural Economics, Michigan State University, USA.
FAO. 1966. Agricultural development in Nigeria 1965-1980. Rome.
FAO. 1975. Effects of Farm Mechanization on Production and Employment: Report of the Expert Panel Held in Rome, 4-7 February 1975, Rome. FAO/OECD.
FAO. 1981. Agricultural Mechanization in Development: Guidelines for Strategy Formulation, By R.C. Gifford, FAO Agricultural Services Bulletin, No. 45. Rome.
FAO. 2005. Contribution of Farm Power to Sustainable Rural Livelihoods in Sub-Saharan Africa, By C. Bishop-Sambrook, Agricultural and Food Engineering Technical Report No.2, Agricultural Support Systems Division. Rome.
FAO. 2008. Agricultural Mechanization in Sub Saharan Africa: Time for a New Look: AGSF Occasional Paper No. 22: Rural Infrastructure and Agro-Industries Division; FAO; Rome, Italy 54 Pgs. Edited by Mrema, G.C.; D. Baker & D.G. Kahan
FAO. 2011. Save and grow, a policy maker's guide to the sustainable intensification of smallholder crop production. Rome
FAO. 2013. Mechanization for Rural Development: A Review of Patterns and Progress around the World. Kienzle, J; J. E. Ashburner & B.G. Sims (editors) (2013): Mechanization for Rural Development: A review of patterns and progress from around the world. AGP Division - ICM Vol.20 - 2013; FAO Rome, Italy. 336 pgs.
FAO. 2016. Agricultural mechanization, A key for Sub-Saharan African smallholders; Integrated Crop Management (Vol. 23). Rome
FAO. 2014. A Regional Strategy for Sustainable Agricultural Mechanization: Sustainable Mechanization Across Agri-Food Chains in Asia and the Pacific Region; Edited by Geoffrey Mrema; Peeyush Soni & Rosa S. Rolle. FAO/RAP Publication 2014/24.FAO Bangkok, Thailand.
FAO/CIMMYT. 2018. Hire Services as a Business Enterprise: A training manual for small-scale mechanization service providers; FAO Rome (forthcoming)
FAO and UNIDO. 2009. Agricultural Mechanization in Sub Saharan Africa: Time for Action. Proceedings of a Workshop held in Arusha Tanzania, July 2009. FAO, Rome & UNIDO, Vienna,

Austria.
FARA. 2014. Science Agenda for Agriculture in Africa (S3A): “Connecting Science” to Transform Agriculture in Africa. Forum for Agriculture Research in Africa (FARA), Accra, Ghana.
Fluck, R. C. and C. D. Baird. 1979. Agricultural Energetics. AVI Publishing Co., Westport.
Fluck, R. C. 1984. Energy in Human Labor pgs. 31-39 of Fluck, R.C. (1992): Energy in Farm Production Elsevier.
Ford, J. 1971. "The Role of Trypanosomiasis in African Ecology". Clarendon Press Oxford.
Friedrich, T. 2013. Agricultural Mechanization and the Environment; In: Kienzle, J., Ashburner, J.E., Sims, B. (Eds.): Mechanization for Rural Development: A Review Of Patterns And Progress From Around The World; Integrated Crop Management Vol. 20-2013, Chapter 10, FAO, Rome, Pp. 181-204.
Gemmill, G. and Eicher, C. K. 1973. A Framework for Research on the Economics of Farm Mechanization in Developing Countries. MSU African Rural Employment Paper, No. 6.Michigan State University, East Lansing.
Gibb, A. C. 1988. Agricultural Engineering Perspective—Celebration of Golden Jubilee 1938-88. Silsoe Bedford, UK, Institution of Agricultural Engineers. Silsoe, UK.
Giles, G. W. 1966. Agricultural Power and Equipment, Pp. 175-216. In: The World Food Problems, Vol. III. A Report of the President’s Advisory Committee; Washington, D. C., USA.
GoG. 1962. Government of Ghana: First Ghana’s Seven-year development plan 1963-69: Ministry of Economic Planning Accra.
Holtkamp, R. G. 1989. Small 4-Wheel Tractors for the Tropics and Sub-Tropics”. Margraf Scientific Publishers, Weikersheim (FRG). 242 Pgs.
Holtkamp, R. G. 1991. Small Four-Wheel Tractors for the Tropics and Subtropics: Their Role in Agricultural and Industrial Development. In G. C. Mrema, ed. (1991): pg. 217-249.
Houmy, K., J. E. Ashburner and J. Kienzle. 2013. Agricultural Mechanization in Sub-Saharan Africa: Guidelines for Preparing a Strategy. Integrated Crop Management Vol. 22-2013
Hunt, D. R. 1983. Farm Power and Machinery Management. Iowa State University press, Ames, Iowa.
IBRD. 1960. The Economic Development of Tanganyika. Baltimore, USA, Johns Hopkins University Press for IBRD.
IBRD. 1987. Agricultural Mechanization: Issues and Options. A World Bank Policy Study World Bank Washington D. C. 3 pgs.
IFPRI. 2014. Small Survey of Power Tiller Owners in Kpong Irrigation Scheme, Ghana. Computer Disk. Washington, D. C.
ILO. 1973. Mechanization and Employment in Agriculture: Case Studies from Four Continents. Geneva, Switzerland. International Labour Organization.
IRRI. 1983. Consequences of Small-Farm Mechanization. IRRI & ADC Publication 184 Pgs. Manila, Philippines.
Kepner, R. A., R. Bainer and E. L. Barger. 1978. Principles of Farm Machinery. 3rd Edition. AVI Publishing Company, Inc. Westport, USA.
Kjoerby, F. 1983. Problems and Contradictions in the Development of Ox Cultivation in Tanzania. Res. Report No. 66; Scandinavian Institute of African Studies; Uppsalla, Sweden 164 Pgs.
Kline, C. K., D. Green, R. L. Donahue and B. A. Stout. 1969. Agricultural Mechanization in Equatorial Africa. Research Report Number 6. Michigan State University.
Kolawole, M. I. 1974. Economic Aspects of Private Tractor Operations in the Savanna Zone of Western Nigeria. Journal of Agricultural Engineering Research, 19(4): 401-10.
Kosura-Oluoch, W. 1983. “An Economic Analysis of Small Farm Mechanization in Western Province, Kenya”. A Ph.D. Thesis, Cornell University, May, 1983.
Kurdle, R. T. 1975. Agricultural Tractors: A World Industry Study Ballinger Publishing Co. Cambridge.
Lal, R. (editor) 1998. Soil Quality and Agricultural Sustainability. Ann Arbor Press; Chelsea, MI 48118; USA. 378 Pgs.
Maher, C. 1950. Soil Conservation In Kenya Colony: Part 1 Factors Affecting Erosion, Soil Characteristics And Methods Of Conservation; Part II: Conservation Practice: Organization and Legislation: Present Position and Outlook. In the Empire of Experimental Agriculture: Vol. XVIII (1950): No. 71:137-149; No. 72: 233-248.
Mayne, J. E. 1954. Progress in the Mechanization of Farming in the Colonial Territories. Tropical Agriculture, 31 (3) 178-187.
Mayne, J. E. 1956. Progress in the Mechanization of Farming in the Colonial Territories. Tropical Agriculture, 33 (4) 272-7.
Mpanduji, S. M. 2000. Repair Cost of Tractors and Comparison of Mechanization Strategies under Tanzanian Conditions. PhD Dissertation, Technical University of Munich, Germany.
Mrema, G. C. and E. Odigboh. 1993. Agricultural Development and Mechanization in Africa: Policy Perspectives. In NAMA Newsletter: Discussion Essay: Vol. 1 (3) December 1993. Network for Agricultural Mechanization in Africa (NAMA), COMSEC, London.
Mrema, G. C. 1991. Agricultural Mechanization Policies and Strategies in Africa: Case Studies from Commonwealth African Countries. London, UK. Common-

wealth Secretariat Publications.
Mrema, G. C. 1984. "Energy in Agriculture". Proc. of Reg. Workshop on Energy for Development in Eastern and Southern Africa. Vol. II. Editors Mwandosya, M. *et al*. IDRC/Foe: UDSM/SIDA pgs. 207-231.
Mrema, G. C. and M. J. Mrema 1993. Draught Animal Technology and Agricultural Mechanization in Africa: Its Potential Role and Constraints. In NAMA Newsletter Vol. 1 pgs. 12-33 [May 1993].
Mrema, G. C. 2016. A Report of a Scoping Study on the Impact of agricultural Mechanization in Tanzania under ASDP1 2005-2015. Ministry of Agriculture and Food Security & PAPAC/RESAP-CC—ILRI Dar es Salaam.
Mrema, G. C. and D. G. Kahan 2017. A Case Study of Tractor Hire Services in Tanzania 2005-15: A presentation to an IFPRI/CIMMYT Workshop on THS Addis Ababa, Ethiopia. November 2017.
Nag, P. K. and C. K. Pradhan. 1992. Ergonomics in the Hoeing Operation. Int. J. Industrial Ergonomics 1992 (Special Issue: Agricultural Ergonomics); Vol. 10: 341-50.
Nwuba, E. I. U. and R. N. Kaul. 1986. The Effect of Working Posture on the Nigerian Hoe Farmer. Journal of Agric. Engineering Res., Vol. 33: 179-185. Academic Press, London.
Panin, A. 1994. Empirical Evidence of Mechanization Effects on Smallholder Crop Production Systems in Botswana. Agricultural Systems, 47: 199-210.
Passmore, R. & Durnin, J.V.G.A. (1955), "Human Energy Expenditure". Physiology Reviews: 35: 801-840.
Pingali, P. L., Y. Bigot and H. P. Binswanger. 1987. Agricultural Mechanization and the Evolution of Farming in Sub-Saharan Africa. Johns Hopkins University Press, Baltimore.
Promsberger, W. J. 1976. A History of Progress in Mechanization. Paper No. 76-1046.American Society of Agric. Engineers. St. Josephs.
Renpu, Bai. 2014. Analysis of Trends of Agricultural Mechanization Development in People's Republic of China.2000-2020. CSAM—Policy Brief, January.
Rijk, A. G. 1983. Role of Agricultural Mechanization in Asia. Asian Development Bank Staff Study Paper. October, (1983), Agricultural Services Department, ADB.
Seager, P. J. and R. S. Fieldson 1984. Public Tractor Hire and Equipment Hire Schemes in Developing Countries. Research Unit Report, No. ARU 30. World Bank, Washington D.C.
Simalenga, T. E. 1989. Simulation Model to Predict Field Work Days and Its Use in Machinery Selection under Tropical Conditions. Copenhagen, Denmark: Unpublished PhD Thesis, Institute of Agricultural Engineering, Royal Veterinary and Agricultural University.
Simalenga, T.E. & Have, H. (1992), Estimation of Soil Tillage Workdays in Semi-Arid areas. Journal of Agricultural Engineering Research. Vol. 51, 1992.
Singh, G. 2001. Relationship between Mechanization and Agricultural Productivity in Various Parts of India. In Agricultural Mechanization In Asia, Africa And Latin America, 32(2), Spring 2001.
Singh, G. 2013. Agricultural Mechanization in India. In: Mechanization for Rural Development: A Review of Patterns and Progress from Around the World- J. Kienzle, J.E. Ashburner, and B.G. Sims, Eds. Integrated Crop Management Vol. 20-2013. FAO. ISSN 1020-4555.
Singh, S. 2016. Agricultural Machinery Industry in India in AMA Vol. 47:No.2 Spring 2016 pgs 26-35.
Singh, G. and B. Zhao. 2016. Agricultural Mechanization Situation in Asia and the Pacific Region in AMA Vol. 47: No.2 Spring 2016 pgs 15 -25.
Stanhill; G. (1984), Agricultural Labor: From Energy Source to Sink Chapter 6 of Stanhill, (ed) (1984): Energy and Agriculture; Springer-Verlag, Berlin 1984.
Starkey, P. 1988. Animal-Drawn Wheeled Tool Carriers: Perfected Yet Rejected. Braunschweig, Germany, Vieweg, Deutscheszentrum Fur Entwicklungstechnologien.
Starkey, P. (Ed). 1998. Integrating Mechanization into Strategies for Sustainable Agriculture. Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen.
Swynnerton, R. J. M. 1954. A Plan for Intensification of African Agriculture in Kenya. Government Printer. Nairobi.
Tiffen. M., M. Mortimore and F. Gichuki. 1994. More People, Less Erosion. Environmental Recovery In Kenya. John Wiley & Sons Publishers. New York.
Troeh, F. R., J. A. Hobbs and R. L. Donahue. 1980. "Soil and Water Conservation for Productivity and Environmental Protection". Prentice Hall, New Jersey. 718 Pgs.
UNFPA. 2016. World Population Trends; Urbanization. UNFPA
Wang, R. 2013. A Review of Agricultural Mechanization in the Peoples Republic of China. In Kienzle, Ashburner & Sims (eds) (2013). In Mechanization for Rural Development: A Review of Patterns and Progress from Around the World. Integrated Crop Management Vol. 20-2013. FAO. pg 121-139.
White, W. A, 2001. The Unsung Hero: The Farm Tractor's Contribution to the 20th Century USA Economic Growth in J. Economic History 61/02/493-496.
White, W. A. 2000. The Unsung Hero: The Farm Tractor's Contri-

bution to the 20th Century USA Economic Growth. PhD Dissertation Department of Economic History, Ohio State University, Columbus 127 Pgs.
Willcocks, T. J. and S. J. Twomlow. 1992. A Review of Tillage Methods and Soil and Water Conservation in Southern Africa. Soil and Tillage Research, 27:73-94.
Wood, A. 1950. "The Groundnut Affair", Bodley Head, UK.
Yeboah, F. K., and T. S. Jayne. 2016. Africa's Evolving Employment Structure. International Development Working Paper. East Lansing, Michigan: Michigan State University.

■■

Strategy, Current Activities and Future Prospect for Advancing Indian Agricultural Machinery into the African Market

by
Surendra Singh
Technical Advisor
Agricultural Machinery Manufacturers' Association
(AMMA-India)
Professor Retd. & Former Project Coordinator AICRP
on Farm Implements & Machinery (ICAR)
INDIA
ammaindia10@gmail.com; ssingh6116@gmail.com

Abstract

Africa is the world's second largest continent. It has the wide diversity across its different countries. A few are fairly well developed, but the majority is still developing. Within the continent, there is a noticeable difference in the degree of agricultural development between Africa and North Africa. India-Africa partnership for overall growth of the agriculture sector is moving towards one common goal—food security, and both economies have been flexible in their approach towards achieving the same. Therefore, there exists significant potential for both India and Africa to explore and leverage from various agricultural technologies that have been successful in increasing the productivity of small-scale farming. With Africa's economic growth gaining momentum, now is the time to evolve and collaborate for the agriculture sector to develop as a whole. The major innovations that can help increasing productivity include mechanical innovations such as the development of new seed varieties; fertilizer/pesticides; agronomic innovations, for examples, novel agricultural management practices such as no-till/zero-till agriculture and inter-cropping. To help crop yield and achieve the larger goal of food security, interventions from all value chain stakeholders are required. For instance farm input manufacturer needs to develop appropriate tools and technologies to better respond to diverse soil and changing climate types, whereas investments in processing infrastructure are required to reduce post-harvest losses. The African governments should have Policies and Regulations for better mechanization options that is to create conducive environment for successful agricultural mechanization, remove restrictions to choice, leasing or credit programmes for imported machinery as well as locally produced machines, support information for better decision making by farmers, legislation for safe, durable and reliable machinery and equipment. Increasing land and labour productivity should be adhering too as agricultural productivity is positively correlated with farm power. Conservation agriculture (no-till/reduced-till, permanent organic soil cover, crop rotations), multi-cropping, precision agriculture, controlled traffic farming and permanent raised beds with residue retention are some of the priority area for sustainable agriculture. The Policy priorities should be to enhance mechanization demand, stabilizing mechanization supply, strengthening institutions needed for mechanization development, Private-Public Partnerships for mechanization development, integrate mechanization and good agronomic practices for environmental sustainability and special focus on increasing agricultural mechanization among smallholders.

Introduction

Africa is the world's second largest continent. It has the wide diversity across its different countries. A few are fairly well developed, but the majority is still developing. Within the continent, there is a noticeable difference in the degree of agricultural development between Africa and North Africa (NA); **Table 1** (Snobar *et al.*, 2016). North Africa includes seven countries lying north of the Saharan Desert i.e. Algeria, Egypt, Libya, Morocco, Sudan, Tunisia and Western Sahara. Africa has a large population (about 1.07 billion) with a majority in rural areas (60%), where most (49.3%) are engaged in agricultural production. Whereas the North Africa has 0.17 billion population with 44.8% population living in rural areas and 23.5% are engaged in agriculture. The arable area represents 19.8% of the total agricultural area. Many regions in Africa are sandy and arid that makes it less suitable for agricultural production. Soil degradation in this region is one of the root causes of either the stagnation of the agricultural productivity or declining. The soil changes viz. soil erosion; soil organic matter decline, soil nutrient depletion, and loss of soil biological diversity in the African region pose major threats to agriculture. Currently, the value addition in the agricultural sector supply chain is very low in Africa when compared to other regions. The yields of major crops are significantly lower than those of the world. The reason for such low yields is attributed to the extremely low rate of fertilizer use and low rates of irrigation and mechanization.

Agriculture accounts for more than 25% of the GDP in most African countries and employs more than 70% of the workforce (Anonymous, 2011; FICCI, 2016). Africa has approximately 783 million hectares of arable land (27% of the world total), which is adequate to effectively feed its population. However, the output is highly concentrated with Egypt and Nigeria accounting for approximately one-third of total agricultural output and the top 10 countries in the continent producing nearly 75%. Africa is the only region in the world where agricultural productivity has not grown noticeably. In fact, the Green Revolution, which enhanced agricultural growth in many Asian countries including India, is yet to take place in Africa. The African agricultural sector has potential to improve local economies and leave a lasting impact on the livelihood of its large populace. Increased agricultural output and income also has a multiplier effect on the economy because of its links with markets for the output of the manufacturing and services sector. Agriculture has been at the forefront of the recent transition in India-Africa relations. Various African nations perceive the success of the Green Revolution in India a role model. Moreover, India remains focused on capacity building, human resource development and the transfer of technology and skills as a key ingredient of its policy.

Table 1 Comparisons of population and agricultural data for all of Africa and North Africa

Items	Africa	North Africa
Population:		
Total (2012) (billion)	1.07	0.17
Rural (% of total) (2011)	60.00%	44.80%
Agricultural (% of total) (2012)	49.30%	23.50%
Total GDP current US$ (2012) (trillion)	1.928	0.666
Agricultural Land (% of total) (2011)	37.90%	17.60%
Forest Land (% of total) (2011)	22.00%	1.40%
Arable Agricultural Area (2011)	19.80%	19.10%
Permanent Crops (% of total) (2011)	2.60%	2.80%
Crop Land per Capita (ha/cap)(2011)	0.24	0.17
Fertilizer Consumption/ha of arable land and permanent crops (kg/ha) (2011):		
Nitrogen	13.26	40.59
Phosphate	9.11	34.43
Potash	1.63	1.96
Value of food production (US$/cap)	179	246
Cereal yield (t/ha) (2011)	1.48	2.91
Coarse grain yield (t/ha) (2011)	1.25	2.44
Pulse yield (t/ha) (2011)	0.62	1.18

Source: Snobar *et al.* (2016)

Agricultural Mechanization in Africa

With increasing agricultural labour movement to urban areas, a shift to mechanization is a logical response. The agriculture sector value chain includes all the steps involved from preparation of soil to harvesting, threshing and post-harvest operations. For every step in crop production lifecycle use of farm implements and machinery enhances the man-machine efficiency. Farm mechanization not just reduces labour and time but also reduces post-harvest losses and also cuts down production cost (Singh, 2015). Not only does mechanization support the optimal utilization of resources (e.g., land, labour, and water) and expensive farm inputs (seeds, fertilizers, chemicals), it also helps farmers to save valuable time. Judicious use of time, labour and resources helps facilitate sustainable intensification (multi-cropping) and timely planting of crops, which can give crops more time to mature leading to increase in productivity. Farm mechanization in association with improved crop inputs have shown improved yields by 10-15% (Singh, 2016). It has been further estimated that the use of proper equipment can increase the productivity by up to 30% and reduce cost of cultivation by about 20% (Anonymous, 2015; Singh, 2016). It is also observed that 15-30% saving is experienced in seeds and fertilizers, 20-30% in saving time and labour and enhances 5-10% cropping intensity through farm mechanization. There are various benefits of farm mechanization such as it helps in conversion of uncultivable land to agricultural land through advanced tilling techniques, decrease work load on agricultural work force, improvements in safety of farm operations and encouraging youth to join farming and attract more people to work and live in rural areas. Extension workers are the key persons in technology transfer. They need not to have only interpersonal communication skills, but technical qualifications as well. Besides, these workers might be lacking the capability to integrate the mechanization technology in the total farming system. They too, might be lacking in trainings particularly dealing with agricultural mechanization.

The agro-industry in Africa needs farm mechanization that will facilitate increase in productivity. The production boost in agriculture is the only way to initiate the agro-industry in Africa. It should be clear to all that once there will be surplus production of food in Africa, the agro-industry will get the input of raw materials to produce different food products and cater to the needs of urban as well as rural areas. Approximately 80 Indian companies have collectively invested US$ 2.3 billion in Ethiopia, Kenya, Madagascar, Senegal and Mozambique (Anonymous, 2011; FICCI, 2016). Some African countries are offering land on lease for 99 years to overseas farmers, and several farmers from Punjab and other parts in India have already migrated to these countries and begun farming (Anonymous, 2011). Such investments are expected to generate local employment as well as create opportunities for local skill development.

Governments of some of the African countries have tried to push agricultural mechanization in 1970s and 1980s without success. At that time, the demand for intensification of agricultural mechanization did not exist and plenty of agricultural labor was available (Anonymous, 2012a). Use of agricultural machinery was costlier than using human and animal labour. As a result, mechanization didn't gain any popularity. One study by Ngeleza *et al.* (2011) in Northern Ghana shows that manual cost of plowing was 19.76 US$/ha against 14.48 US$/ha by tractor. On the other hand in the same area, Akramov and Malek (2012) found manual plowing 9.39 US$/ha compared to 18.11US$/ha by tractor. World Food Program Survey 2008 revealed that 44 percent of Northern Ghana farmers rented tractor for plowing. Ngeleza *et al.* (2011) interviewed 219 maize farmers nationwide and found that 35 percent of them hired tractor for plowing in 2009, but in the North, 77 percent farmers used tractor. Akramov and Malek (2012) interviewed 174 farmers in the North in 2010 and found that 95 percent of interviewed maize farmers hired tractor service. It was concluded that due to population growth, urbanization, and access to international market, intensification in agricultural land and labour use have created demand for mechanization in land preparation and threshing in Ghana. The price of tractors and its maintenance cost and unavailability of spare parts make it difficult for small farmers to own a tractor.

Several countries in Africa have developed their agricultural mechanization policies; however, the biggest challenge is to put the good plans into actions. Countries face challenges on the implementation, including how to effectively enable the private and public sector to work together in transforming agriculture through sustainable mechanization in their countries. Manufacturers of agricultural machineries have an important role to play in supporting the development and promotion of agricultural mechanization in Africa. It is important that they understand the needs of sustainable agricultural mechanization along the value chain in Africa, including challenges associated with after sale services. Furthermore, all efforts should be considered under the umbrella of sustainability. Efforts to promote agricultural mechanization in Africa need to ensure that different tiers of farmers, starting from small-scale to large-scale farmers are taken into consideration and that the proposed solution correctly targets the intended audience. Cooperatives have a role to play in promoting agricultural mechanization in Africa. However, transparency with clear rules and strategies including a clear roadmap are key to the success. PPP arrangements could help to promote agricultural mechanization in Africa by ensuring that both private and public sectors address challenges that impede promotion of agricultural mechanization, such as the finance challenges. Furthermore, all partners must see a value and benefit in the collaboration for them to continue to participate.

Agricultural Mechanization in Sub-Saharan Africa (SSA)

The large potential for agricultural production in Sub-Saharan Africa (SSA*) has still not been realized (Anonymous, 2017). One of the key development paradigms

*Note: Sub-Saharan Africa is, geographically, the area of the continent of Africa that lies south of the Sahara. According to the UN, it consists of all African countries that are fully or partially located south of the Sahara. ("http://www.africa.undp.org/content/rba/en/home/regioninfo.html"). The UN Development Program lists 46 of Africa's 54 countries as "sub-Saharan," excluding Algeria, Djibouti, Egypt, Libya, Morocco, Somalia, Sudan and Tunisia. The World Bank further added Sudan and Somalia to total 48 countries under the label ("http://data.worldbank.org/region/sub-saharan-africa").

for long-term increased agricultural production in SSA is sustainable agricultural mechanization (SAM). The benefits are multi-faceted ranging from reducing drudgery, improving the timeliness of agricultural production operations, increasing the efficiency of input use, to facilitating the implementation of sustainable intensification of production systems, and making agriculture more resilient to increasingly extreme and unpredictable climatic events. Sustainable agricultural mechanization (SAM) can also be applied to the development of improved post-harvest, processing and marketing activities, enabling more timely, and concise operations, with value added to primary products. This can foster the delivery of more nutritious foods and higher value products to final consumers. Moreover, SAM has the capacity to contribute to entrepreneurial activities in rural and remote areas, through hire services that can provide much needed mechanization services to those involved in the agro-food sector. In addition, farm-based sustainable mechanization hire services can also contribute to wider development efforts, such as rural-urban transport of goods, rural road construction and maintenance, power for irrigation water pumping, provision and distribution of drinking water as well as the collection of bio-waste in rural, peri-urban and urban areas.

Sub-Saharan Africa (SSA) has a history of strong public sector leadership in agricultural mechanization development with weak participation from the private sector (Anonymous, 2017a). Procurement, mechanization services (hire services) and spare parts supply have mostly been in the realm of the public sector. Over the years, differences in the priorities, perspectives and approaches between the public and private sector towards the development of agricultural mechanization have led to agricultural mechanization in SSA being largely led and run by the public sector with the private sector playing a minor role. In the long run, this approach is not sustainable as important stakeholders such as private sector agricultural machinery manufacturers, suppliers, and service providers are neglected.

Initiatives for applying SAM to growing more food and other functions and activities designed to increase sustainability of the food system, require new thinking and perspectives. There is a primary need to see mechanization in a wider and more holistic context. There are numerous cross-cutting and cross-sectorial factors that can contribute to well-functioning, inclusive and sustainable mechanization systems. These need to be ascertained, assessed and elaborated upon and the important experiences and lessons learned need to be shared with wider audiences that can facilitate and enable a more holistic framework to support the design, formulation and implementation of targeted SAM policies.

New Models for Sustainable Agricultural Mechanization in sub-Saharan Africa include local manufacturing; institutional support for agricultural mechanization and promote greater inclusion of the private sector in public activities through PPPs. New PPP business models should include: (i) agricultural guarantee funds support access to finance for mechanization, (ii) mechanization Demo farms, (iii) focus on farmers, and (iv) field testing of machinery. Labour in SSA smallholder farms is provided mostly by women, children or the elderly who carry out the work (mainly with hand tools). SAM involves the application of different forms of power sources in conjunction with appropriate equipment able to do useful work in agricultural production and along the agro-food value chain (Josef and Brian, 2014). Thus mechanization must meet farmers' needs efficiently and effectively and result in improved farm productivity and reduced drudgery, while contributing to the development and competitiveness of the food supply chain. To be sustainable, mechanization must take economic, social, environmental, cultural, and institutional issues into account. SAM can make farming more attractive for the rural youth and therefore contribute to job creation and prosperity in the rural areas of SSA. Challenges associated with agricultural mechanization in Africa include Africa far behind in farm mechanization, most parts of Africa have two cropping systems, there is a need for labour saving technologies especially for women, there is a need to improve the value chain integration and youth employment is another challenge and a key concern for Africa. Africa agricultural development cannot move forward if key challenges are not met.

Financing for Sustainable Agricultural Mechanization in Sub-Saharan Africa

One of the main issues for mechanization is to translate the demand for mechanization into reality. There are many challenges observed in African countries. Farmers perceive mechanization as a risk to their livelihoods as it changes, for example, the common risk management strategies applied of mixed cropping systems on small-scale farms. Thus mechanization requires new risk management strategies to be defined at the small-scale level that may not be easy to define as many farmers do not know what outcomes on their farms, and to their livelihoods, mechanization will provide. Farmers and other actors in the agro-food value chain do not know how to turn their need for power (traction, transport, etc.) into effective demand for mechanization. There is a lack of business and financial literacy. There is a lack of credit as a consequence of lack of collateral on small-scale farms. Many financial institutions seemingly lack knowledge of the specifics of the agro-food sector and in particular of credit products and their risks related to mechanization. There is a lack of effective communication between stakeholders.

Effectively though there are a number of existing financial models that can support the financing of mechanization i.e. savings contract based securities, loan guarantee schemes, joint liability groups, and leasing, matching grants and subsides. Some examples can be found: myAgro in Mali and Senegal uses savings, CUMA in Benin uses cooperative purchases where farmers contribute financially based on farm size and buy equipment for joint use, Hello tractor in Nigeria provides services to smallholders via mobile communication technologies, while NWK agri- services in Zambia provides to be an intermediary between farmers and banks. The shared usage and ownership models can be a solution to some of the main obstacles to mechanization as financing becomes economically viable, purchase and maintenance can be done jointly, improved use of machinery through training and specialist operators can be provided and financial institutions are more enabled to reach small-scale farmers. However in considering the financial perspective to mechanization, the effects of mechanization must also be considered, as it can potentially improve quality of life, increase productivity of labour and land, provide for income and employment, have effects on women and a reduction in hard manual labour.

There is an overall lack of financing to the agri-food industry in sub-Sharan Africa. In the Feed Africa programme, mechanization is seen as a key to raising food production in the continent and has the potential to convert it into a net exporter (Anonymous, 2018). Limited access to adequate financing is crippling agricultural development which is viewed as high cost and high risk by commercial lending institutions together with the perceived lack of capacity. Proposed improvements in the system include risk sharing capacity (giving the bank guaranty if their loss can be compensated); increase loan scheme; create finance facility; scale out soft commodity and financing; Non-Bank SME finance; and lower lending rate for commercial banks. Developing business models that involve private and public partners to enable access and utilization of sustainable mechanization services, for the benefit of smallholders is one of the key challenges to transform agricultural production in the context of SSA. All stakeholders have a role in these PPP schemes; for example, the government develops policies, the public sector designs financial support schemes in rural areas (where mechanization is needed the most), the private sector invests in rural mechanization and related support systems, and producer associations and cooperatives are registered to represent farmers. There is a need for special and more flexible finance schemes, especially for women and youth who want to engage in mechanization services. There is a global need for comprehensive information on existing demand, especially for machinery suppliers, since current platforms do not have this information. The priority should also be to meet farmers and farmers' associations' demands. The knowledge platform should offer technology and include machinery that has the potential to be sustainable. It would be ideal if the proposed platform be an ICT-level site that manages information and can link to other Information and Communication Technologies (ICTs) serving the farming community. Regarding the role of farmers, it includes primary producers, processors/value addition, marketing, create demand for services. The role of the private sector includes machinery manufacturers and suppliers (distributers), machinery services, repairs and maintenance, providing training on use and cares of equipment and provides financing. The role of government is to create an enabling environment through stimulation of demand for services, Policy and regulations, quality assurance and safety, legislation, infrastructure development, trade facilitation, provision of date and usage information and provision of incentives. There should be an integrated approach to Policy and Strategy development which should encompass, consider and incorporate the points such as sustainable development goals, National development plans, strategy for increasing production and food security, environmental sustainability, economic diversification, employment creation, women and youth employment, land tenure and holding size, trade relations, citizen empowerment and skills development.

Status of Agricultural Machinery in Africa

The use of farm machinery in agriculture in the Africa in general is at a low level compared to other continents. However, North African countries enjoy higher levels of farm mechanization than sub-Saharan Africa (SSA). The ratio of farm power source utilization in sub-Saharan Africa (SSA) is 65% manual, 25% animal and 10% engine (Snobar *et al.*, 2016). The use of tractors is very low in SSA compared to other regions (including the Near East and North Africa regions). Hoe cultivation is common practice still in many countries resulting in smaller areas under cultivation that results in lower labour productivity, reduced total output, reduced cash cropping, increased food insecurity, reduced farm incomes and a higher incidence of poverty. Hoe households typically cultivate 1-2 ha per year, households owning draft animal power cultivate 3-4 ha, household hiring tractors cultivate about 8 ha, and households owning tractors cultivate more than 20 ha (Snobar *et al*., 2016). Many farming activities being carried by women worker consider as burden such as weeding, tillage and land preparation, harvesting & threshing and transport of agricultural produce. Hiring labour and the use of draft animal power are the most common ways to reduce labour burdens across many countries in Africa. Women play a major role through their active participation in agriculture. Women work force in agriculture and allied sectors is estimated at about 35-45% of the total rural workers. They take care of crop production and food processing operations as well as in animal husbandry and dairy and fishery activities. Rural women are employed in sowing, transplanting, weeding, harvesting and threshing. They are also employed for cleaning/grading, drying, milling, grinding and decortications. Women workers are also preferred in commercial agriculture like tea, coffee, tobacco and plantation crops. They are also preferred in lac cultivation, cotton picking, sugarcane cleaning/detopping and spices picking. Special efforts have to be made to develop farm tools and equipment which can easily be operated by women worker.

Table 2 Wide range of simple technologies that can be manufactured locally

S. No.	Name of farm equipment
1	Seed treatment drum
2	Rotary dibbler
3	Seed drill/planters
4	Rice seed drum
5	Rice transplanter
6	Cono weeder
7	Long handle weeder
8	Wheel hand hoe
9	Fertilizer broadcaster
10	Improved sickle
11	Sugarcane stripper
12	Maize sheller
13	Pedal operated thresher
14	Grain cleaner
15	Hand ridger
16	Wheel cart
17	Cotton uprooter
18	Groundnut decorticator

There is a very wide range of simple technologies that can be manufactured locally which can ease the work load, reduce drudgery, and allow people to increase their output with less energy expenditure (**Table 2**). Superior and quality hand tools especially hand-hoes, weed control with sprayers, and low-cost carts for human, animal and motorized power sources are available commercially. They need to be procured and promoted. Where rainfall and/or irrigation permits, cultivation of multiple crops per year on the same plot of land can be taken. Mechanization can play a vital role in facilitating multi-cropping through increasing the speed and efficiency of harvesting one crop and ensuring that the land is prepared for the next crop and sowing is done in time. Crop harvesting can be greatly speeded up with mechanization. For example, Cassava (one of the main crop of Africa) can be lifted by a tractor-mounted blade in a mere fraction of the time which is presently arduous manual lifting. The rice harvesting system comprising a two-wheel tractor-operated reaper/reaper binder plus thresher plus cleaner is being replaced by combine harvesters which accomplish all three tasks in one pass. One of the outstanding ways to reduce the turn-around time between harvesting one crop and sowing the next is through the adoption of no-till or direct-seeding. If other power sources such as draft animal power and engine power are not available then a logical approach is to consider whether hand-tools can be made more ergonomically efficient to improve the performance and productivity of the operator and the quality of work, reduce or eliminates the discomfort, fatigue and stress felt by the operator, and reduce the incidence of accidents or injuries.

Increasing land productivity is a sensitive and limited option in Africa. It is important to explore ways of increasing land productivity despite its sensitivity. The current agricultural production practices are, to a large extent, contributing to poor land productivity by reducing the ability of the soil to recycle nutrients. In addition, some harvesting practices used by farmers lead to an almost total removal of the residues from the field, which completely breaks down the cycle. Technologies should be complemented with other good practices such as integrated pest management (IPM), integrated pest and plant nutrient management (IPNM), biodiversity/genetic resources management, system of rice intensification (SRI), and sustainable mechanization. Promotion and eventual use of conservation technologies by farmers would help to ensure that the prevalent soil degradation resulting from the lack of recycled nitrogen (N2), phosphorus (P), and carbon (C) and other nutrients, caused by the removal of crop residues, is improved. However, for this to be realized, the issue of the availability of mechanization equipment suitable for conservation agriculture (CA) based farming systems needs to be addressed. Experience shows that it will be difficult to achieve a wider adoption of technologies such as CA if the associated mechanization equipment is not available. India has a range of such CA equipment i.e. zero-till drill/planter, strip drill, roto till drill, straw chopper, happy seed drill and many more. Resource saving equipment for conservation agriculture leads to higher productivity and profitability, soil and residue management, energy conservation through minimum tillage and crop residue management and equipment for dryland conservation agriculture. The role of mechanization is crucial to the promotion and practice of conservation agriculture in Africa. According to the World Bank, conservation agriculture in countries like Zambia has had a significant impact on yields, which have doubled for maize and increased the yield of cotton by 60% (Anonymous, 2017a). The need for promotion of conservation agriculture in Africa calls for countries to develop strategies to increase the use of CA as capacity building, including training in technical and business management skills of farmers, operators, service providers and input suppliers as well as extension officers.

Many farmers, operators and owners of farm machinery and equipment in the smallholder and emerging farmer sectors of Africa lack key skills that are necessary to enable them to realize the full benefits of mechanization and mechanization services. For example, the proper servicing and maintenance of agricultural equipment continues to be a major challenge in many African countries. This has contributed to the poor utilization and management of agricultural machinery. It is important to build capacity through the training of farmers, service providers and operators of agricultural machinery on both technical and sustainable agricultural mechanization matters. Training programmes will also need to address the subject of service provision as a sustainable business for individual entrepreneurs wishing to embark on the provision of mechanization services to smallholder farmers.

Hand tool technology and manually powered machines are the most commonly used farm machinery used by small holders in Africa, particularly sub-Saharan Africa. Availability and use of farm power is a major limiting factor affecting intensification of agriculture in sub-Saharan Africa. Africa should replace the power source for crop production from muscles (both human and animal) to tractor or other mechanized farm power sources as i) mechanisation provide the ability to perform right operations at the right time to achieve the production potential by raising productivity levels; ii) mechanization reduces human drudgery and can compensate for seasonal shortage, in fact, mechanization allows human to be freed for more productive work; iii) mechanized farm power is multi-functional by characteristic and can also be deployed for transport and stationary power applications as well as in infrastructure improvement (drainage, road works, etc.); and iv) use of irrigation machinery is also expected to increase in the near future. Despite of these perceived benefit, farm mechanization in Africa is extremely low. Major challenges faced by the Africa farm machinery sector are low farmer income results in low demand of agricultural inputs, including quality seeds, fertilizer and farm machinery and low demand of farm machinery leads to supply-side challenges limiting the mechanization supply. Such supply-side challenges include high capital and operating costs of farm machinery at the macro level. This in turn leads to low demand for farm machinery. These challenges exacerbated by the lack of agro-finance mechanisms for both farmers and machinery suppliers.

Indo-African Business

'Today, national development issues incorporate agriculture sector as prerequisite to country's progress and prosperity in Africa (Anonymous, 2018). Indo-Africa is pursuing mutual cooperation under the theme of 'Today's Investment-Tomorrow's Prosperity. The development and mutual partnership covers self-reliance schemes avoiding huge debt as a result of this brotherhood. Indo-Africa partnership policy persuades African willingness and mutual benefit to implement the common development partnership programmes in different parts of continent. African government's national development Programme cannot function in isolation. Africa needs a mutual cooperation and development programme from outside world and Indian mutual economic brotherhood and political understanding kick out all western propaganda about India's policy of New Colonialism in Africa. The idea of today's investment will nourish a debt free Africa and strengthen economic development as tomorrow's prosperity. African politics cannot ignore international relations to build up national development and this partnership is a way towards Today's Investment, Tomorrow's Prosperity' (Kumar, 2008).

India and Africa have recently emerged as strategic trading partners. There are huge opportunities for businesses in India and Africa. These opportunities are complementary and capable of strengthening the respective economies. Despite the enormous mutually beneficial opportunities for businesses in India and Africa, there are challenges, too. Unfortunately Indian and African exporters face major problems in accessing clients. These problems are lack of market knowledge, apprehensions, complex regulations, delay, high transaction costs, etc. Africa and India reaffirm their commitment to cooperate for increasing agricultural output and achieving the Millennium Development Goal of having the proportion of people who suffer from hunger and malnutrition. They emphasize the importance of harnessing the latest scientific research for raising productivity and for the conservation of land and the environment in order to ensure food security for their people and to bring down the currently rising cost of food prices so as to make food affordable for all. In this respect, they agree to collaborate in the implementation of the Comprehensive Africa Agricultural Development Programme (CAADP).

India's leading tractor manufacturer Mahindra & Mahindra (M&M) plans to set up assembly plants in South Africa, Kenya, Ethiopia, Zambia, Tunisia, and Morocco. The auto giant already has satellite plants in Gambia, Tchad, Mali, Ghana & Nigeria for manufacturing farm equipment. These facilities will now be used to assemble three-wheelers, light commercial vehicles and utility vehicles to drive volumes in a fast-growing economy in South Africa with rising disposable incomes. M&M currently has a presence in 24 out of the 53 African countries and is amongst the few in the world to have set up tractor assembly facilities in Africa. On the non-tractor farm equipment business, the focus is on the emerging markets of India, China, Africa and Latin America. North India-based International Tractors Ltd., the third largest tractor manufacturer in India has established two assembly lines in South Africa. Sonalika tractors is expected to set up five centres in the continent, which will cater to about 40 countries. South Africa features strongly on the list of locations that the company is finding lucrative along with Mozambique, Kenya, Tanzania, Zimbabwe and Namibia.

Ahmedabad based Entrepreneurship Development Institute of India (EDI) has set up Entrepreneurship Development Centers (EDCs) in African countries. EDI has been asked by the Ministry of External Affairs, Govt. of India to set up the EDCs in five selected African countries which is to be identified in discussion with the Association of African Countries. The idea is to help create entrepreneurs in the continent where there is immense opportunity towards exporting basic technologies from India to African countries. For example, it has been observed that the farmers in Africa still use wooden ploughs thereby making it possible for export of agricultural machinery and tools from India. Indian Institute of Foreign Trade (IIFT) is setting up a foreign trade institute at Kampala, Uganda which will host a pan-Africa campus. Objective of this initiative is to enable a world-class trade policy and research facility in Africa. The campus would initially accommodate over 100 students and will be expanded to house over 1,200 the next five years.

India is considered to be the largest tractor market in the world. While the country produces a large volume of tractors, also exports tractor units to other countries across the world. On an average, the country exports more than 60,000 tractors annually (FICCI, 2016). In year 2009, India exported 42,380 units of tractors that increased to 65,650 in year 2014 (**Fig. 1**). India's tractor export markets majorly African countries and ASEAN countries where soil and agro-climatic conditions are similar to India. Similar is case for combine harvester (**Fig. 2**) and seeder/planters/transplanters (**Fig. 3**). While domestic companies cover major part of the market, foreign players are gradually picking up. Import has increased with a CAGR of 15.1% between year 2009 and 2014 while export has declined by 4.5% annually. The largest tractor manufactures not only cater to the Indian market, but are also

Fig. 1 Tractor trade (units)
Source: FICCI (2016)

Fig. 2 Combine harvester trade (Units)
Source: FICCI (2016)

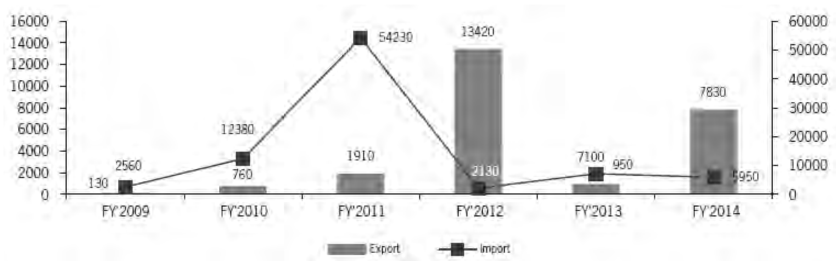


Fig. 3 Seeders, planters and transplanter trade (units)
Source: FICCI (2016)

major exporters of tractor to region such as the US, China, Australia, Latin America, the Middle East and South Asia. Power Tiller market is dominated by two Indian companies collectively catering to more than 65 percent of the market. The remaining market is catered to by small firm and primarily by those importing Chinese power tillers. The key Indian power tiller manufactures also cater to the export market, exporting to region such as the Middle East, Africa, Russia, Turkey, the European market and other parts of Asia. The Indian rotavator market is also dominated by a number of smaller firms. The top four rotavator manufactures hold more than 80 percent of the market. The majority of the thresher market in India remains unorganized.

Two-day 'India-Africa Agribusiness Forum' was organized at New Delhi on 10 February 2016 (Anonymous, 2017a). The India-Africa engagement needs to move up the value chain in knowledge sharing, technology transfers, institutional capacity building and skills development. Key 'high-impact' partnership opportunity areas include agricultural input and farm machinery, milk and meat products, technology transfer and capacity building, food processing, and developing institutional innovations for improving farmers' access to output markets. Capacity building and sensitization of farmers are critical in ensuring adoption of new technologies. Policy-level changes are also required to attract and sustain investments in the African agricultural sector. Thirteen African countries have signed a series of partnership agreements with India to enhance the supply of agricultural machinery, credit advancement to farmers and scientific cooperation (Anonymous, 2017a). Among other deals, the farm machinery suppliers from the Indian state of Gujarat signed agreements with their counterparts in Ghana, Zambia, Mozambique and Togo for the supply of farm machinery, training on the use of the machinery in mechanized agriculture and cooperation in the use of the machinery. These partnerships were announced as African Ministers of Agriculture, private sector associations and industry representatives from India and Africa, converged for crucial sessions of deal-making at the 52nd session of the African Development Bank (AfDB) Annual Meetings in India, on May 24, 2017 to rapidly advance cooperation.

There is a new economic growth story emerging from Africa. Africa possesses all the prerequisites to become a major growth pole of the world. India will work with Africa to realize its vast potential. India believes that a new vision is required for Africa's development and participation in global affairs. Both will enhance the development partnership between the two regions, which is founded on the pillars of mutual equality and common benefit. India's exports to Africa have risen from US$ 10.3 billion in 2006-07 to US$ 21.1 billion in 2010-11, primarily due to increase in exports of transport equipment and petroleum products, wherein India's imports from Africa have more than doubled from US$ 14.7 billion in 2006-07 to US$ 32.3 billion in 2010-11, with the African continent now accounting for 9.1 percent share in India's total imports (Anonymous, 2012). Consequently, due to large imports from the region, India's trade deficit with Africa has also increased to US$ 11.2 billion in 2010-11, implying that India has become a major market for African products.

Export-Import Bank of India (EXIM Bank) has in place Line of Credit (LoC) to enhance agriculture sector in Africa. Currently, 105 LoCs are earmarked for agriculture, infrastructure and related projects amounting to more than US$ 4 billion covering over 47 countries in the African region. Some of the LoCs beneficiaries' African countries dealing with agriculture sector particularly agricultural machinery are Burkina Faso for rural electrification / agricultural equipment and Cyber city project; Chad for setting up of cotton yarn plant, plant for assembly of agricultural equipment; Lesotho for export of tractors, pump sets, consultancy services and irrigation equipment; Malawi for cotton processing/irrigation & threshing plant/one-village one-project; Mali for rural electrification, and setting up of agro machinery and tractor assembly plant; Sierra Leone for procurement of tractors, harvesters and pesticides/potable water project; and Tanzania for export of tractors, pumps and vehicles; (Anonymous, 2012).

Agricultural Machinery Manufacturing in India

India produces agricultural tractors and power tillers as power source, mould board plough, disc plough, sub-soiler as primary tillage, spring loaded tillers, harrow, leveller, bund former, scraper, rotary tiller as secondary tillage, back hoe with tractor, laser land leveller, graders, scrapers with tractors as earth moving equipment, reapers and harvesters as harvesting equipment, sprayers and dusters as plant protection equipment. Escorts, Eicher, TAFE, International Tractors, Mahindra & Mahindra, etc. are the largest producers of tractors in India (Singh, 2016 & 2017). Along with it, India produces sowing machinery such as post hole digger, paddy planter, seed drill for cotton seed, seed-cum-fertilizer drill, potato planter and multi row vegetables planters, irrigation systems such as sprinkler systems, drip system, irrigation pumps like centrifugal pumps, stationary diesel engine driven centrifugal pumps, engine set, electric pumps and submersible pumps, harvesting machinery such as maize combine, sugar cane combine, mowers, paddy combine, reaper, wheat combine, fruits harvester, onion harvester, potato digger and post harvest machinery like baler, tipping trailer, sugar cane grabber, thresher and maize Sheller. This agricultural machinery will enhance the production as the land in Africa is naturally highly fertile. There are different agro-industries that may be promoted in Africa, which will give value addition for their products such as: i) mechanization of rice production by use of rotavators, transplanters and weeding equipment; ii) investment opportunities exist in seed production, manufacture of sprayers and pesticides, veterinary services, construction of cold storage facilities and refrigerated transport for horticultural and other perishable products; iii) industrial units for manufacturing tractors, pump-sets for irrigation, agro-food products, and agro-chemicals (fertilizers and pesticides).

Role of the Private Sector in Support to Smallholders in Africa

There are two levels of private sector involvement. At the macro level it is crucial that international technical development institutions and national, regional or global players in agricultural machinery industries, should join forces with international finance institutions and donors and with the national governments or the regional bodies to facilitate transformation of African agriculture and its related agro-industry to be more business oriented on the one hand, but to reach out to the majority of smallholders farmers (Snobar *et al.*, 2016). It is a matter of fact that small-scale and family farmers are the largest private investors into African agriculture. It is critical to promote such conducive and enabling environments which facilitate the adoption, sustainable use and development of mechanization. In this context, smart PPPs are needed to break the greater partnerships down to local implementation level. Viewing the mechanization sector as a job creation opportunity not a labour displacer, at the local level, such initiatives need to put emphasis on capacity building schemes for enabling inspired young rural dwellers or farmers to become business entrepreneurs for sustainable mechanization services or for services related to it (repair, input supply, marketing, value addition). The development of competitive local, independent private sector entrepreneurs should be the key objective of such PPP initiatives. It would be a catalyst to creating new and more attractive jobs and employment. Where appropriate, the support could be provided through promoting cooperatives or facilitating reforms for the enforcement of legislative and regulatory frameworks for making such efforts possible at the local government levels in the countries concerned. Decentralization of decision-making should be part of entrepreneurship development actions. Farmers shy away from investing in expensive inputs or even in services. On the other hand mechanization service providers need to take an extra risk to provide services to smallholders with their often remote, uneven, smaller fields. To compensate for this to some extent, service providers should seek to diversify into other businesses that are less seasonal, outside the agricultural sector (transport, rural roads maintenance), or in post-harvest processing, so that the long and risky growing season becomes less dominant in their planning. Today, with the increasingly unpredictable cropping seasons and enhanced effects of climatic events, it is not possible to assume that yields and subsequent income will be forthcoming, as required to compensate for the time and money invested into services for land preparation, tillage, planting, weeding, etc.

Opportunities in Farm Mechanization Sector in Africa

Considering the prevailing scenario and the perceived benefits of agricultural mechanization for intensification of African agriculture, efforts required both at policy and industry level. Policies should provide for creative conductive financing mechanism and tools for both buyers and suppliers to overcome the challenges faced by the sector. To increase the availability of mechanization, investment from foreign players can also be encouraged, especially players with similar land holding patterns and consumption requirements, such as India. Consumption requirements in more developed countries are very different from those of India and Africa, owing to the difference in farm holding patterns and availability of farmer assets. Agricultural equipment from India can be adopted in Africa, with minimum customization, as both regions have smaller landholdings and farmers have limited disposable income for utilizing such assets. This would enable the business to save on customization and high inventory costs due to demand gluts in Africa. Similar opportunities also exist in the irrigation sector.

The India-Africa partnership for overall growth of the agriculture sector is moving towards one common goal—food security, and both economies have been flexible in their approach towards achieving the same. Therefore, there exists significant potential for both India and Africa to explore and leverage from various agricultural technologies that have been successful in increasing the productivity of small-scale farming. With Africa’s economic growth gaining momentum, now is the time to evolve and collaborate for the agriculture sector to develop as a whole. More than one-fourth of the world's fertile land is in Africa. However, it has the most undeveloped and unutilized arable land. With the removal of barriers in agricultural development, the agricultural output has the potential to boom into an 800 billion USD industry by 2030 (Anonymous, 2018). The major innovations that can help increase productivity include mechanical innovations such as drones, sensors, GIS-imaging and other farm equipment; biotechnology innovations such as the development new seed varieties; chemical innovations like development of nano-fertilizer, semi-chemical, environment-friendly and more potent fertilizer/pesticides; agronomic innovations, for examples, novel agricultural management practices such as no-till/zero-till agriculture and inter-cropping, and technological innovations such as deployment of ICT in agriculture. To help crop yield and achieve the larger goal of food security, interventions from all value chain stakeholders are required. For instance farm input manufacture needs to develop appropriate tools and technologies to better respond to diverse soil and changing climate types, whereas investments in processing infrastructure are required to reduce post-harvest losses. Future demand projections must also be taken into account owing to rapidly changing patterns.

The African governments should have Policies and Regulations for better mechanization options that is to create conducive environment for successful agricultural mechanization, remove restrictions to choice, leasing or credit programmes for imported machinery as well as locally produced machines, support information for better decision making by farmers, legislation for safe, durable and reliable machinery and equipment (Anonymous, 2017). Increasing land and labour productivity should be adhering too as agricultural productivity is positively correlated with farm power, more land can be cultivated (**Fig. 4**). Conservation agriculture (no-till/reduced-till, permanent organic soil cover, crop rotations), multi-cropping, precision agriculture, controlled traffic farming and permanent raised beds with residue retention are some of the priority area for sustainable agriculture. The way forward and proposed actions should be increasing land productivity, increasing labour productivity and soil fertility through sustainable crop intensification, mechanization innovations to make cropping systems more climate resilient, mechanization to reduce post-harvest losses along the value chain, organizing farmers into groups and networks and enabling private sector mechanization service provision. The Policy priorities should be to enhance mechanization demand, stabilizing mechanization supply, strengthening institutions needed for mechanization development, Private-Public Partnerships for mechanization development, integrate mechanization and good agronomic practices for environmental sustainability and special focus on increasing agricultural mechanization among smallholders.

African governments have encouraged farmers to use agricultural machinery through many development programs and other incentives i.e. intervene to improve supply side (private sector), create an environment which eases the development of businesses including such measures as easing import restrictions, and creating a level playing field for foreign businesses. Any subsidized programme operated by the Govt. should have a pre-defined period of operation after which it should be privatized. Introduce training and education programmes for commercial development as well as technician training. Introduce smart subsidies for mechanization inputs that are in line with sustainable mechanization and concepts such as 'Save and Grow' and 'Climate-Smart Agriculture'. Develop precision agriculture applications as an integrated tool within the sustainable agricultural intensification concept. Work on global agreements for good practices in the procurement and supply of agricultural mechanization inputs.

All-India Agricultural Machinery Manufacturers' Association (AMMA-India)

There are about 250 medium to large scale units, 2,500 small scale industries, 15,000 tiny industries and more than 1,000,000 village

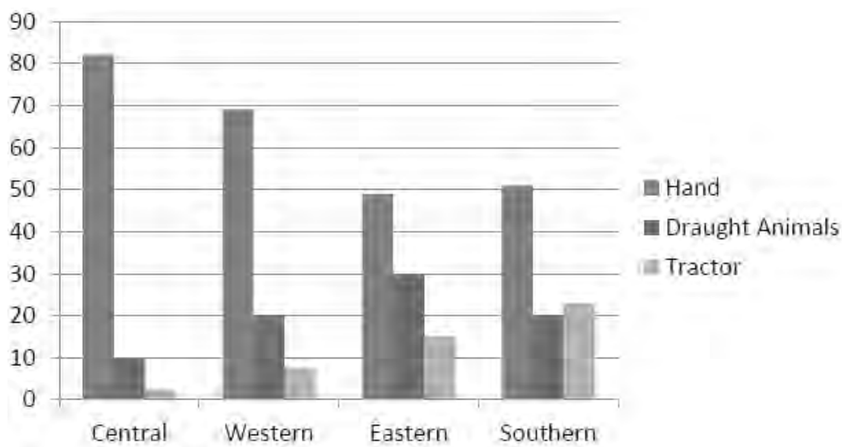


Fig. 4 Use of different sources of power in agriculture in Africa (%)
Source: Josef and Brian (2014)

level artisans in India. Most of them are under un-organized sector except the tractor industries. There was no ways to pass on Govt. benefit schemes to these industries. The All-India Agricultural Machinery Manufacturers' Association (AMMA-India) was established in the year 2010 on January 17 at the behest of Department of Agriculture and Cooperation (Mechanization and Technology Division), Ministry of Agriculture, Govt. of India. This represents the machinery manufacturers of agriculture and allied sectors. The main objectives of association are: i) augmenting and intensifying agricultural mechanization related activities in different agro-climatic zones; ii) promoting scientific development and technological up-gradation of need based agricultural machines and power sources; iii) providing technological coordination, management and advisory back-up to the members of AMMA-India; and iv) providing effective liaison with Government organizations, NGOs and agencies sponsoring national and international fairs/meets and to establish institutional relations for implementation of appropriate policies and initiatives to promote growth of agricultural mechanization. Presently 641 agricultural machinery manufacturers including tractor, power tiller and combine harvester industries are the members of this association. Association is working very closely with central as well as state Governments and UN-ESCAP-CSAM for implementations of various schemes for the benefit of users/ farmers and manufacturers. The association has created an AMMA-India Export Promotion Task Force (AMMAIndiaEPTF) with the Objective to promote AMMA-India members' agricultural machinery outside India and to facilitate the export of the members' machinery & technologies all over the world. AMMA-India ETPF participated in the overseas exhibitions particularly in African countries that were organized with various Indian associations and ministries i.e. i) AMMA-India participated in Agritech Africa—Nairobi, Kenya—4-16th June 2017; ii) AMMA-India participated in Namaskar Africa 2017 at Accra, Ghana on from 16th to 17th August 2017; iii) AMMA-India participated in Future Energy, Lagos, Nigeria 6-8 November 2017; iv) AMMA-India participated in Addis Agrofood 5th Agriculture, Agricultural Machineries, Food, Food Technologies and Packaging Exhibition; 08-11 December 2017 Addis Ababa, Ethiopia. Beside, these members have been participating in many other exhibitions on individual levels and exporting agricultural machinery through distribution centres and dealership network in many African countries. For more details one may visit www.ammaindia.in and may write to email: ammaindia10@gmail.com.

REFERENCES

Akramov, K., and M. Malek. 2012. Analyzing Profitability of Maize, Rice, and Soybean Production in Ghana: Results of PAM and DAE Analysis, International Food Policy Research Institute, Ghana Strategy Support Program Working Paper No. 0028.

Anonymous. 2011. African nations offering land for free to Indian farmers," The Economic Times website, http://economictimes.indiatimes.com/news/economy/agriculture/African-nations-offering-land-for-free-to-Indian-farmers/articleshow/6293149.cms, accessed 23 January 2018).

Anonymous. 2012. Background Note, 2012: 71-72: emphasis mine

Anonymous. 2012a. Agribusiness Indicators: Ghana. The world Bank: ARD-Agriculture and Rural Development. Report Number 68163-GH.

Anonymous. 2015. Transforming Agriculture through Mechanization: A knowledge paper on Indian Farm Equipment Sector. FICCI, New Delhi.

Anonymous. 2017. Consultative Meeting on a Mechanization Strategy: New Models for Sustainable Agricultural Mechanization in sub-Saharan Africa. 30 November to December 3, Nairobi, Kenya

Anonymous. 2017a. https://www.indoasiancommodities.com/2017/05/30/thirteen-african-countries-seal-agriculture-industrialisation-deal-india/. Visited January 23, 2018.

Anonymous. 2018. http://www.africaindia.org/index.php?option=com_content&view=category&layout=blog&id=34&Itemid=29. Visited January 23, 2018

FICCI. 2016. India-Africa partnership in agriculture Current and future prospects

Kienzle, J., and B. G. Sims. 2014. Agricultural mechanization strategies for sustainable intensification: concepts and cases from Sub-Sahara Africa. Club of Bologna 25th Annual Meeting of the Club of Bologna. November 15-16. Bologna—EIMA International 2014

Suresh, K. 2012. Food Security and India's Vision of Agriculture Development in Africa. Africa Review. May.

Ngeleza, G. K., R. Owusua, K. Jimah and S. Kolavalli. 2011. Cropping practices and labor requirements in field operations for major crops in Ghana: What needs to be mechanized? International Food Policy Research Institute Discussion Paper No. 1074, Washington D.C.

(Continued on page 53)

Chinese Agricultural Machinery Enterprises in Africa

by
Youji Li
Deputy Secretary- General
China Association of Agricultural Machinery Manufacturers (CAAMM)
CHINA

Africa covers an area of 30.2 million square kilometers, including 60 countries and regions, with a population of about 1.2 billion. Agriculture occupies an important position as economic pillar of most countries (**Fig. 1**). At present, the developing level of agricultural production is still not high in general and agricultural mechanization rate is very low.

In Guinea, there are 6.2 million hectares of arable land, while only 10% of them be cultivated, one of the main causes is lack of agricultural machinery. Zimbabwe, which used to be a granary in africa, has experienced serious difficulties in food supply due to lack of water and inadequate investment in agricultural machinery (**Fig. 2**).

Africa is rich in crop species and all kinds of farm machinery & implements has been needed. In recent years, with the gradual stabilization of political conditions and economic development in africa, the governments have begun to emphasize agricultural production and promoting agricultural mechanization (**Fig. 3**).

Ministry of Agriculture in Zimbabwe set up an agricultural technology demonstration center to undertake the distribution and management of agricultural machinery assisted by China. Similarly, Ministry of Agriculture in Guinea set up a training center for agricultural machinery services to run the management of new agricultural products trials, training and the coordination of agricultural machinery parts and components.

After many years of hard working, agricultural machinery products from China have already obtained many end-users and market-share in various African countries, while facing the strong advanced technology of western countries products and tough price competition from some developing countries.

Above of all, agricultural machinery products have always been the main products of Chinese government's aid to Africa (**Fig. 4**). China has successively assisted wheeled tractors, walking tractors, corn seeders, suspended sprayer, disc harrow, disc plow, water pump, feed mill, rice mill, rice trans planter, diesel engine and trailers. Aids are unpaid, continuous and have been welcomed by local governments and peasants.

Some huge Chinese enterprises, like YTO and Lovol, have been operating in African market for many years, accumulated rich experience and loyal user groups. As early as 1992, YTO began to export products to Africa as one of the earliest Chinese enterprises to African market, and its sales area continued to expand rapidly to other continents. YTO started from 2010 to promote agricultural mechanization programs in Ethiopia, covering all aspects of products, upgrading of existing tractor assembly lines and building of after-sales service network, signing contracts with amount over 100 million U.S. dollars, which made YTO the leading tractor brand there.

In 2017, 150 hp and 220 hp powershift tractor from YTO showed and

Fig. 1 Young African Farmers Harvesting

Fig. 2 Dry Land in Africa

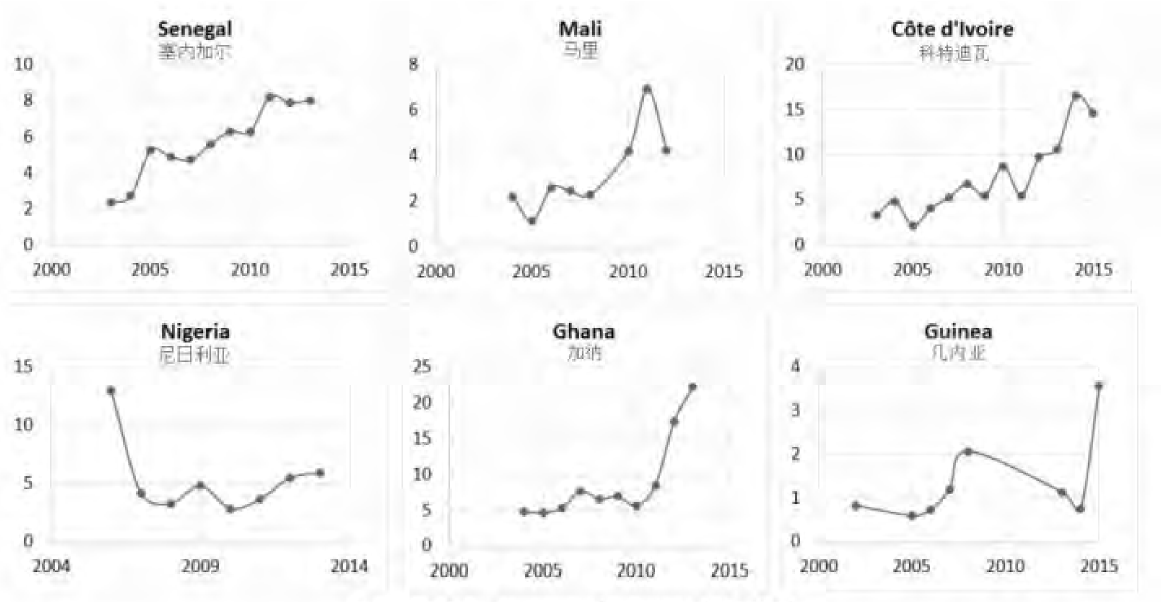


Fig. 3 Net imports of tractors (USD/ha)

sold promptly in Nampo Agricultural Machinery Fair, the largest one in South Africa and even the whole continent, which is the milestone of the first power-shift tractor of China with completely independent intellectual property had achieved a breakthrough in major agricultural machinery markets of the world (**Fig. 5**).

China domestic farm machinery market has been entering the glacial period since 2016, especially in tractor market, and sales volume has dropped significantly. However, the export market has performed well. Tractor exports in 2017 are featured by "increasing amount & quantities decline", and the export structure continues to optimize. Statistics shows that from January to October 2017, China has exported totally around 120,000 units of tractor all over the world including more than 18,000 to Africa. Concerning to walking tractors, exported 23,000 units to Africa, rice trans-planters around 11,000 units, self-propelled rice harvester with 9,200 units, as well as 6,700 units of crawler harvester.

Meanwhile, some Chinese agricultural enterprises establish farms, agricultural demonstration centers by their equipment which sets a good example. For instance, implements of Debont enter African market successfully through its demonstration farms.

Many agricultural experts dispatched by Chinese government to Africa as well as more and more projects such as construction of seaports and hydropower stations introduce familiar farm machinery products to African markets.

As a bilateral cooperation, Chinese government organized African youth and officials to come to China for training, also increased agricultural machinery such as processing of agricultural products during training courses and study tours (**Fig. 6**).

After years of assistance and management, agricultural machinery products of China have become more and more popular in Africa, which is advantage of agricultural enterprises to access. Small agricultural land, uneven arable land, poor infrastructure, maintenance difficulties, and farmers prefer simple

Fig. 4 China-Africa Agricultural Cooperation with "Belt and Road"

Fig. 5 YTO Product on SA Exhibition

Fig. 6 Agricultural Technical Exchange

and cheap products, while Chinese agricultural machinery can just meet their needs.

At present, there are still many difficulties in agricultural machinery development of African countries, the governments are lacking planning and management service system for agricultural development and promotion of agricultural machinery. Due to inadequate financial resources and corresponding financial support policies, agricultural mechanization develops slowly depending on market, despite desire of the government for rapid improvement. Although the agricultural machinery market in Africa is still in start-up period, the vast user base and strong demand for mechanization will bring a prosperous future.

Chinese government has fully supported African countries in developing their own agricultural mechanization during the past years, also supported entry of Chinese agricultural machinery enterprises into Africa, they must learn more about market to operate with a better performance.

Concerning to government agricultural assistance and agricultural machinery enterprises access to Africa, demonstration of the project, product matching selection and adaptation issues must be done in advance. Secondly, mechanization should be implemented step by step, from easy to difficult and then get key breakthrough. Although the gap of agricultural machinery in Africa is very large; however the conditions right now still cannot fulfill complete mechanization of agricultural production. If it is to concentrate on increasing market share of tractors and farm machinery, it will be better for brand promotion and after-sales service.

Fig. 7 Service Training in Africa

More attention should be paid to after-sales service. The shortage of agricultural machinery technicians in Africa, lack of general education of the end-user, local maintenance difficulties, which need to provide more comprehensive services than in China (**Fig. 7**).

In general, there are huge and solid demands for agricultural machinery in Africa. It is a common desire of Chinese agricultural machinery enterprises to make the people all over Africa use high-quality agricultural machinery, advanced farming techniques and finally to achieve agricultural mechanization.

■■

Current Status and Potentials for the Use of Agricultural Machines in Rice Production in Madagascar

by
Koichi Shoji
Associate Professor
Dept. of Agricultural Engineering and Socio-Economics
Graduate School of Agricultural Science
Kobe University, Kobe
JAPAN
shojik@kobe-u.ac.jp

Akihiko Utsunomiya
Project Manager
Overseas Business Promotion Division
Agricultural Operations Business
YANMAR Co., Ltd., Osaka
JAPAN
akihiko_utsunomiya@yanmar.com

Abstract

Madagascar is a major rice-producing country in Africa and its production is mainly from Central Highland. Area around Lake Alaotra in the north-east of the highland occupies about 40% of production, where relatively large-scale (ca. 3 ha) farmers operate Chinese two-wheel tractors for tillage and transportation. In other areas, tillage is done with traditional methods such as angady (shovel) or oxen-drawn plow. Hand weeders, sickles and threshing drums are commonly used. Traditional blacksmiths in Itasy region continue supplying reliable tools, and various artisan fabricating small implements are found almost everywhere. Rice milling has been done with Engelberg machines, but they are now being replaced by Chinese husker-polishers and yield better quality of grains than before. Retail shops handle motorized machines and supply spare parts, but in most cases maintenance workshops are separately operated. The two-wheel tractors need annual heavy maintenance and have a short machine life, and therefore, more durable and reliable tractors are requested. There is a room for introducing machines other than two-wheel tractors such as reapers near Lake Alaotra. In other areas, simple farm implements made by local artisans such as pedal threshers are partly disseminated as a step of mechanization, but currently the possibility is low for introducing motorized machines.

Introduction

Madagascar is located in the Indian Sea to the east of the African Continent, and its agriculture is historically characterized as a major rice producer of Africa, carrying over 1.3 million ha of paddy fields producing 3.6 million ton paddy (2013, FAOSTAT). In particular, the Central Highlands, over 800 m above the sea level, is cooler and drier than the coastal areas and suitable for the majority of the rice grown in wet season from November to April. Most of the rice-producing areas rely on natural supply of water along small valleys (**Fig. 1a**) or uplands, where the source of farm power is limited to human or animal to cultivate small fields in limited area. There are, on the other hand, irrigated areas where flat fields have been developed and some machines introduced around Lake Alaotra (**Fig. 1b**), where 40% of rice in the country is produced. Population is 23.6 million, of which 65%

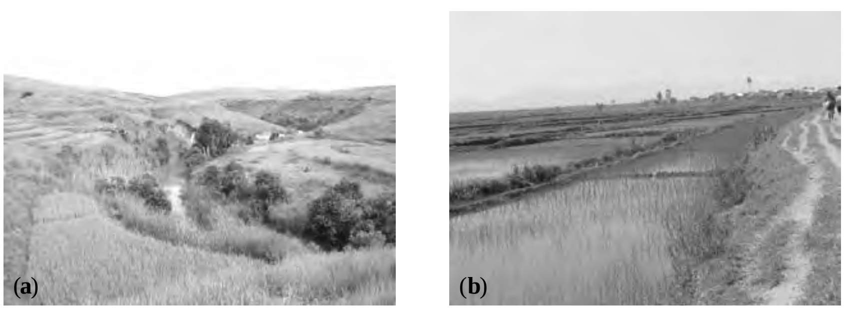


Fig. 1 Typical paddy fields in Madagascar: (**a**) terraces in a deforested valley (Saka, Itasy), (**b**) medium- to large-scale fields along the lake side (Bejofo, Alaotra-Mangoro)

live in rural area (2014, FAOSTAT).

This article is aimed at describing typical situations and discussing future potentials for the use of agricultural machines for rice production in Madagascar, based mainly on the interviews and discussions with locals in the Central Highlands rather than taking a holistic approach.

Farm Tools and Farm Work for Rice Cultivation

There are varieties of soil tillage methods and some of them are hypothesized to have been influenced by the cultures across the Indian Sea (Tanaka, 1989). A traditional manual shovel "angady" is used for multipurposes of tillage such as deep inversion, pulverization and leveling (**Fig. 2a**). In this example, a man tilled about 100 m^2 per day with over 30 cm depth. Common cattle "zebu" functions as a trample tillage tool to incorporate residue into the soil (Tanaka, 1989). Moldboard plow (**Fig. 2b**) pulled by the cattle or two-wheel tractor is an alternative to these, and is used nation-wide. In this factory, the simplest model was about 30 USD.

The rice is started to grow either by broadcasting seeds or by transplanting the seedlings randomly or in straight rows. Where the straight-row transplanting method is adopted, single-row hand weeders are widely used (6 to 20 USD), but in many cases they are made from used steel oil barrels due to limited access to raw materials.

The rice plants are harvested with sickles (**Fig. 4a**). They are not necessarily harvested at full maturity to avoid grain loss associated with predation by birds and with manipulations by the farmer. They are transported out of the field and immediately threshed either by smashing onto a barrel (**Fig. 4b**) or a stone, or by running vehicles over the harvested plants. Because of these primitive threshing operations, easy-detaching varieties of rice have been preferred among farmers. The detached grains are dried on the ground usually packed with dung of the cattle. Over- or under- drying associated with weather condition or thick layer of the paddy is common, and partial deterioration of the grain during the storage is occasionally observed due to high moisture content.

Fig. 2 Tillage tools: (**a**) traditional "angady", (**b**) European style moldboard plows.

Fig. 3 Mechanical weeding in a transplanted field in straight rows

Two-wheel Tractors

In Madagascar, two-wheel tractor locally called "Kyubota" is one of the fewest agricultural machines equipped with engines. Most of them are imported from China, and in 2004 and 2005, rapid increase in the import was recorded in accordance with international competitive biddings through the Malagasy government for the distribution with

Fig. 4 Harvest and post-harvest of rice: (**a**) a sickle for harvesting, (**b**) used oil barrel for threshing, (**c**) sun-drying of paddy in the backyard of a farmhouse

subsidies. Such actions are said to have been to cope with the increase in the theft of the cattle that severely affected the farm work at that time, but the imports thereafter can be regarded on regular commercial basis.

Surrounding of Lake Alaotra (200 km north-east from Antananarivo) is one of the largest rice-producing areas where a large portion of the imported two-wheel tractors has been distributed. Farmers commute from towns to the paddy fields with implements and other utilities behind the tractor on the trailer, and in many cases with farm workers and even school children. The tractor is nowadays an indispensable property not only for farming but also for daily life in the region (**Fig. 6**). According to locals, the minimum size of the farmland per famer capable of purchasing a tractor of their own was hypothesized at about 3 ha, whereas average farm size of 2.9 ha and the median of 1.8 ha were calculated for one of the irrigation districts in the region.

The retail price of a new Chinese two-wheel tractors in Ambatondrazaka was from 1,270 (10 HP) to 1,640 USD (18 HP), of which a model of 1,460 USD (14 HP) was sold the most. According to the owners of the tractors, typical annual cost for the maintenance was about 300 USD, where especially the engine needed to be heavily cared such as cylinder liner, piston rings, or/and oil seals every year. The tractors are therefore usually bought new every 5 years on the average—one of the authors encountered a nine year old tractor, but the sound of the engine was obviously lack of compression. As a result, ca. 600 USD per year are needed for the fixed and the maintenance costs alone, which is far too expensive for small-scale farmers when compared to a typical tillage contractor fee of 51 USD/ha. Despite such contradiction, the ownership of the two-wheel tractor is yet appreciated because of its multi-functions, especially that the farmers cannot stop commuting to the paddy fields without it once they recognize its convenience.

Blacksmiths and Artisans

Tractor- or animal-drawn implements and other small-scale machines are locally made, as it is easily imagined from the last section that even average-size rice farmers near Lake Alaotra are only afford to purchase the least expensive imported two-wheel tractors. Soil-engaging tools in particular need to be hardened through heat processing to increase the strength and to decrease the wear, and this material handling is taken care by blacksmiths (forgerons). On the other hand, artisans directly respond to farmers' needs and create farm implements such as weeder, thresher, or trailer.

Blacksmiths, capable of heat processing and related works, are concentrated in Itasy Region next to the west of Antananarivo. Their history started before the French colonization, and they have functioned as reliable manufacturers of agricultural tools. They are specialists in steel material and are capable of hot forging (hammering, **Fig. 7a**), quenching (hardening), tempering, annealing (softening) and casting. One of the largest factories was in charge of fabrication and assembly of moldboard plows—forging of shares (**Fig. 7b**) to welding of gauge wheels (**Fig. 7c**), and accepted nation-wide orders. The technique was applied to fabricate a share cutter of metals that included forged gears for amplification of the cutting force applied to the bar (**Fig. 7d**). There were also smaller-scale factories specialized in specific parts such as plow beams (**Fig. 7e**) or plow bolts (**Fig. 7f**).

There are various types of artisans. One of the simplest artisans owned only a small welding machine and worked in the backyard of the house to fabricate hand weeders ordered on personal basis (**Fig. 8a**). Another artisan owned only a portable welding machine with generator and repaired irrigation facilities and vehicles under accident in the field (**Fig. 8b**). Cage wheels, paddlers, and trailers (**Fig. 8c**) were their main products in the area disseminated with the two-wheel tractors. In general, machine tools are very scarce, and even a drill bit is difficult to reach. One created his own-made lathe machine from junks (**Fig. 8d**), and other used a welding rod to make a hole on a steel plate. Standardized parts such as bolts or bearings are also scarce, and artisans often have to excavate those

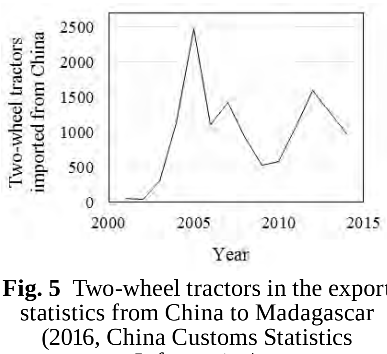


Fig. 5 Two-wheel tractors in the export statistics from China to Madagascar (2016, China Customs Statistics Information)

Fig. 6 Two-wheel tractors for plowing in the field and transportation in the city

one by one from second-hand parts shops in the market, which usually results in inconsistent quality of their products.

In Vakinankaratra Region (ca. 170 km south from Antananarivo) where virtually no tractor has been introduced, there were some artisans fabricating pedal threshers (40 to 110 USD). One produced 20 units per year only by himself (**Fig. 8e**), and other produced 90 units with another three co-workers to cope with the orders from all over the country. The latter explained that the thresher technology has arrived in mid-80s and that he was the only one who survived being capable of copying the whole structure (**Fig. 8f**).

Rice Millers

Rice millers do not only mill (whiten) the paddy for domestic consumption of farmers, but also function as a processor of paddy collected either from farmers or brokers into milled rice for consumers. Therefore, farmers would have difficulties in marketing their own products if they did not exit. Because the investment is needed for the equipment and so as cash stock to be ready for the payment to the farmers, rice millers are relatively wealthy in the municipality and sensitive to technology that contributes to their business.

Typical equipment of a miller is shown in **Fig. 9**, which consisted of separator, husker and polisher from China, and of bucket elevators locally acquired. The husker contained vibrating separator of paddy and brown rice, which would probably occupy a large portion of

Fig. 7 (**a**)-(**f**) Blacksmiths and their works (Mangatany, Itasy), (**g**) their specialized products sold in the market (Ambatondrazaka, Alaotra-Mangoro)

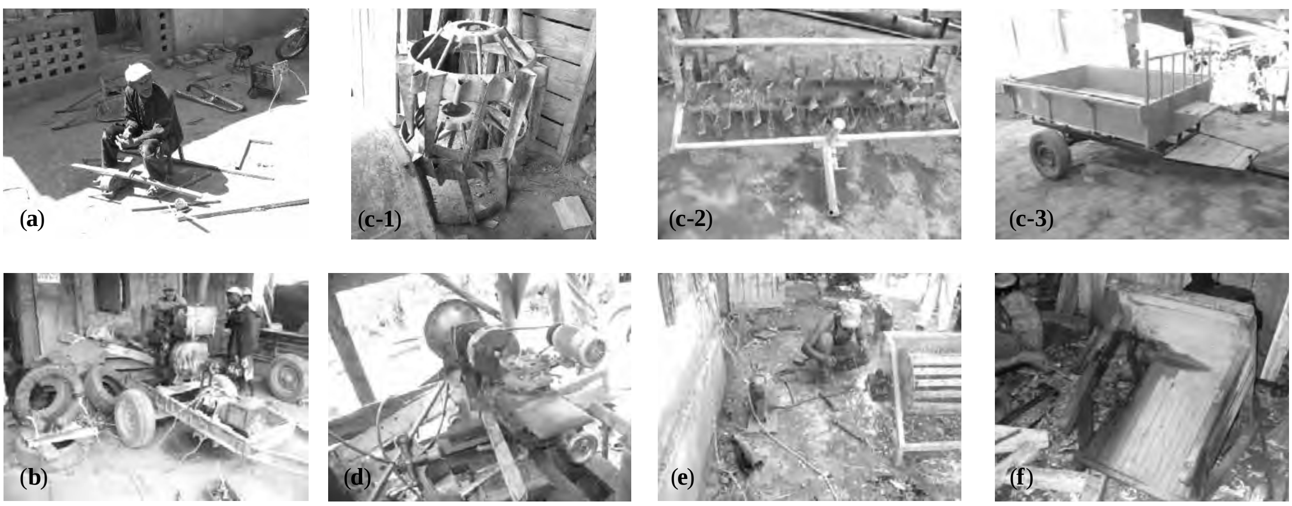


Fig. 8 Various artisans and their works: (**a**) weeder maker (Miarinarivo, Itasy), (**b**) portable welding machine (Ambaiboho, Alaotra-Mangoro), (**c**) implements for two-wheel tractors (Ambatondrazaka, Alaotra-Mangoro), (**d**) lathe machine made by the artisan (Analavory, Itasy), (**e**) artisan fabricating a pedal thresher (Ambohibary, Vakinankaratra), (**f**) frame of pedal thresher being overhauled after 17 years of use (Betafo, Vakinakaratra)

Fig. 9 Typical equipment of a miller and their husked brown rice (Antsirabe, Vakinankaratra)

Fig. 10 Various styles of running a rice mill: (**a**) rice miller owning two one-path husker-polishers, (**b**) brick factory next to the miller (a) (Bejofo, Alaotra-Mangoro), (**c**) rice miller owning an Engelberg milling machine only (Antsirabe, Vakinankaratra).

the initial cost, and therefore the ratio of broken kernel seemed to be less than other methods of milling. Their business was based mostly on purchase and selling of paddy and milled rice (**Table 1**), and if milling ratio of 0.7 is assumed, their surplus is calculated at 0.018 USD/kg (milled rice basis) i.e. 9,100-12,200 USD/year without variable and fixed costs. The bran was sold at 0.14-0.18 USD/kg as livestock feed.

A miller near Lake Alaotra was built next to a brick factory and provided the husk as fuel (**Figs. 10a** and **b**). The equipment consisted only of two one-path husker-polishers (rubber rollers and a metal screw in one) without elevators. The workers poured twice to the first machine for nearly complete husking, then to the second one for polishing. In this system, the initial cost for the two machines may be low (ca. 1,100 USD each without motor at a retail shop in Ambatondrazaka), but they made a proper choice of technology. Pure husk without bran was obtained as the fuel, and the major rice variety they handled "Dista" (red rice) needed soft polishing so as not to lose the value of redness and aroma. They charged 0.015 USD/kg for regular milling fee and 0.018 USD/kg if the bran was taken away by the customers. The throughput was about 11 ton/day, which was higher than the first example, as there was no separator of the brown rice and the paddy as a bottle neck of the process. On the other hand, a portion of the brown rice was broken after the second husking and considerable portion after the polishing, yet they did not care about it as the variety is usually eaten as porridge.

There was a miller sticking to maintain an old one-path Engelberg milling machine acquired in 1995 (**Fig. 10c**). The owner's explanation was that the income was not much from the milling fee (0.015 USD/kg) but mainly from the selling of the mixture of the bran and the crushed husk as instant livestock feed. The farmers near the miller combined livestock, vegetable and rice productions, and it is likely that such by-products can be traded at a higher price than in rice-monoculture regions.

Table 1 Outlook of the rice miller in Fig. 9

Initial cost of equipment	20,000 USD
Throughput	700 kg/h
	504-622 ton/year
Operating time	8 h/day
	3-4 month/year
Operators during season	4
Milling fee (> 1 ton only)	0.012 USD/kg
Purchase price (paddy)	0.26 USD/kg
Selling price (milled rice)	0.40 USD/kg

Retail Shops

Around the Lake Alaotra, there are some agricultural utility shops. One in Ambatondrazaka sold two-wheel tractors (50/year), rice milling machines (5-10/year), fertilizer and motorbikes mainly from China. They provided spare parts but no maintenance service. Payment was basically done with cash and charged 10% annual interest for installment. Another shop handling similar merchandise sold about 200 two-wheel tractors a year, where they were equipped with their own maintenance workshop. According to Ministry of Agriculture, there are about 10 import traders handling such Chinese tractors. There was one shop handling no Chinese products, such as Japanese motorbikes, European or American four-wheel tractors (mainly for cash crop plantations or for constructions), and construction machines for rent or contractor operations. Along the lakeside roads, there were several small shops that sold only Chinese diesel engines and their main spare parts (piston ring, cylinder liner, valve, gasket, oil seal, etc.) so that farmers could readily reach.

In Antananarivo, there were some dealers handling larger machines. One construction equipment dealer sold five 65 HP- four-wheel tractors from India per year for transportation. An automobile dealer sold ten to fifteen 80 HP- four-wheel tractors from Brazil per year for plantation and transportation. A Japanese automobile and equipment dealer sold 16 two-wheel tractors per year from Thailand at 2,900 USD, and imported two 34 HP- four-wheel tractors to be sold at 10,900 USD. These dealers provide spare parts but do not own their workshop, as the maintenance is usually done by mechanics hired at plantations and construction companies.

In general, it is difficult to know how many four-wheel tractors are imported, as import tax is zero for agricultural machines (10% for spare parts) and custom statistics does not contain specific information. Yet, total amount of import of ca. 700,000 USD is disclosed for four-wheel tractors in 2014, of which about a half was estimated to be of second-hand, according to the dealers.

Discussion

Table 2 shows a rough calculation to figure out a farmer's inclination to owning a two-wheel tractor near Lake Alaotra. It shows that, if 3 ha-land ownership is assumed (as locals mentioned as a threshold), the farmer may start to consider purchasing one, as the price (1,270-1,640 USD) is familiar i.e. slightly lower than the annual gross income and is less than double the profit to recover the investment in two years. Farmers over this tentative threshold of 3 ha are only 26% on household basis, but occupy over 60% of the land (**Fig. 11**). This explains our observation that most part of the area around the Lake is cultivated with two-wheel tractors, as the rest 40% of the land is easily assumed to be handled by contractor operation by large-scale farmers or others.

There are some possibilities for the introduction of machines other than two-wheel tractors in the above region. For example, if one reaper is introduced to cover a minimum of 1 ha/day for 40 days of harvesting period, it can roughly substitute 1,800 USD of the labor, assuming a typical harvesting labor cost at 45 USD/ha in the region. If the retail price of the reaper is about a double the amount to recover the investment in two years, farmers' attentions can be easily drawn. A similar discussion can be applied to powered threshers to accelerate the harvesting to maintain the quality of the grain. Rice transplanter, on the other hand, is still way to go, as a labor cost of 80 USD/ha is a threshold in our experiences in other countries, whereas that we interviewed in the region was 49 USD/ha.

To confirm the above prospect, comments were obtained from representative farmers of an irrigation union after a ceremony over snack and drink (**Fig. 12**). All of them quickly responded that reapers should be available at affordable price, as the delay in harvest directly leads to grain loss upon handling and to deterioration of the grain quality. This is partly because limited number of reapers were once available under the Second Kennedy Round (2KR) scheme and most of the members already knew the usefulness of the machine. Pow-

Table 2 Sample calculations of cost and income for a 3 ha- farmer not owning a two-wheel tractor

	USD	Notes
Tillage + puddling (contractor)	153	
Seeds	78	40 kg/ha, 0.66 USD/kg
Transplanting labor	147	1.23 USD/day, 40 man-day/ha
Weeding labor	147	As above
Fertilizer	197	100 kg/ha, 0.66 USD/kg
Harvesting labor	135	45 USD/ha incl. threshing
Irrigation union	63	100 kg paddy/ha, 0.21 USD/kg
Milling for domestic consumption	11	120 kg rice/person, milling ratio 0.7 → 860 kg paddy / 5 person, 0.013 USD/kg for milling
Variable cost	931	
Gross income	1898	3.3 ton/ha, 860 kg paddy for family, 0.21 USD/kg

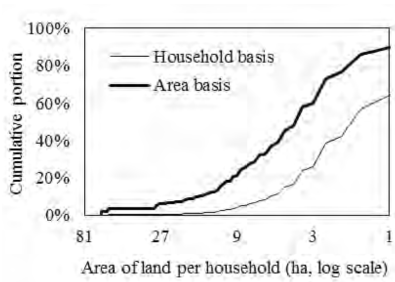


Fig. 11 Frequency distribution of farm land in PC23 district near Lake Alaotra (Source data as of 2013 from the curtesy of Dr. K. Yoshii)

ered weeder was supported by the half the members, as the other half used herbicide as a regular routine. Rice transplanter came up at the end as a kind of joke. Some members did not exactly seem to know the mechanized transplanting system, but one of them declared that he could manage the mat seedlings, who can be one of the potential users of transplanters hopefully in the near future. However, the strongest and the most notable request was the availability of more durable and reliable two-wheel tractors even at a higher initial cost, as all of the members were definitely bothered by short machine life (therefore significant fixed cost) and heavy maintenance cost every year, as already discussed in the section Two-wheel tractors.

In other regions such as Vakinankaratra, in contrast, farmers owning the land on the average around 1 ha are unlikely to introduce any motorized machine at this moment. **Table 3** summarizes typical cost for rice production interviewed from three small-scale farmers (0.8, 0.8, 0.45 ha of rice fields for 4, 6, 4 family members, respectively) near Antsirabe, from which 172 USD/ha is calculated. This amount corresponds to 1-2 month salary of typical employees in the region, and especially if one of the members in the farmer (land owner) family receives pension, this amount is easily paid and one labor is still reserved.

Fig. 12 Initiation ceremony of repair work of an irrigation channel (PC23 district near Lake Alaotra)

One of the reasons for the above slow motivation toward mechanization can be attributed to low price of paddy bought at the farm (< 0.26 USD/kg in Vakinankaratra and 0.21 USD/kg near Lake Alaotra). This is however natural, since only about 18% of the rice produced in the country is estimated to be distributed outside rural area, as calculated from percentage of rural population (65%), total rice supply (2.35 million ton milled rice) and import of rice (0.39 million ton milled rice) (2013, FAOSTAT). In the example of small-scale farmers in **Table 3**, there is an excess in the product in each family and is calculated to be 1,550, 1,210, or 200 kg of paddy, assuming paddy grain yield of 2.8 ton/ha, personal annual consumption of 120 kg milled rice, and milling ratio of 0.7. It is readily understood that the smaller the farm size, sharply less the external distribution of the rice. Where domestic (family and neighbors) consumption of the rice prevails, it is likely that farmers pay little attention to the quality, especially moisture content and maturity, of rice grain for marketing, and therefore the price may continue stagnating. In our observation, retail price at local market was as low as 0.44 USD/kg milled rice, which still reflected proper margin in the food chain. Yet, the price was about 0.65-0.80 USD/kg in the supermarket where they have introduced a separator of broken kernels and a packing machine, which implies potentials in higher price for the better quality rice. Although this discussion looks like a chicken-and-egg dilemma, technical elements to enhance the grain quality such as harvesting aid tools and improved milling system are ongoing dissemination. We hope one more step of growth in grain yield and cultivated area, though some measures for which are already undertaken by governmental and international corporation programs, to increase the proportion of market distribution of rice for steady virtuous cycle that includes gradual use of agricultural machines for further productivity.

Possibilities of introducing motorized agricultural machines other than already pointed out here may be low; however, simple farm implements made by local artisans should be taken into account as an initial step, even outside the Lake Alaotra area. One of the customers of the pedal thresher (**Fig. 8e**) in a less intensively cultivated region (Ambohibary, Vakinankaratra) mentioned that it could handle with two workers a task to be done by as many as five workers, and emphasized that, again, it is a simple matter of comparison of the cost of labor versus that of the machine. To respond to such demand of small-scale farmers, improved implements are being re-

Table 3 Typical rice production cost in Antsirabe, Vakinankaratra

	USD/ha	Notes
Animal tillage	58	
Seeds	0	Seeds domestically taken
Transplanting	43	1.09 USD/day, 40 man-day/ha
Weeding	36	If done by family member, then 0
Chemical fertilizer	0	Organic fertilizer only
harvesting	17	1.09 USD/day, 16 man-day/ha
Threshing	17	1.09 USD/day, 16 man-day/ha
Total	172	

leased from a JICA (Japan International Cooperation Agency) project through several local counterparts, such as pedal or bicycle thresher, winnower, hand weeder, and hand seeder.

Acknowledgements

Investigations in this article were supported by "Improvement of Rice Productivity in the Central Highlands (PAPRiz)", JICA, 2009-2015, and by "JETRO's Project for Dispatching an Expert on the Agri-Business Sector in Eastern African Countries (Madagascar and Tanzania) in FY2014", JETRO (Japan External Trade Organization), 2014.

REFERENCES

China Customs Statistics Information. http://www.chinacustomsstat.com/customsstat/

FAOSTAT. Food and agriculture data. http://www.fao.org/faostat

Tanaka, K. Rice and rice culture in Madagascar. The Southeast Asian Studies 26(4), 367-393, 1989.

■■

(Continued from page 42)

Surendra, S. 2015. Agricultural Mechanization Status on Indian Farms. Souvenir. Agricultural Machinery Manufacturers' Meet (AMMM)—2015. Held at Hotel Le Meridien, Coimbatore during July 17-18.

Surendra, S. 2016. Agricultural Machinery Industry in India. Agricultural Mechanization in Asia Africa & Latin America (AMA). 47(2): 26-35.

Surendra, S. 2017. Agricultural Machinery Manufacturing - Sector in India and Potential for African & Asian Countries. Paper presented at Feed the Future India Triangular Training (FTF ITT) International Training Programme on Farm Mechanization for Small farmers for Extension Practitioners of African and Asian Countries during April 11-25.

Snobar, B. A., B. G. Sims, J. Kienzle and J. Mpagalile. 2016. Agricultural Mechanization in Africa. Presented at 26th Members' meeting of the Club of Bologna. EIMA International—Bologna, Italy during November 12-13, 2016.

■■

Rice Cultivation and Agricultural Machinery in Madagascar

by
Nobuyuki Kabaki
Ex-JICA Expert
JAPAN

Rice Cultivation in Madagascar

Madagascar is an island country located about 400 km off-shore from Mozambique in the east- Africa with an area of 580,000 km^2 (58 million ha) and a population of 22 million. Geography of Madagascar is characterized with water-shedding mountains in the central highland area reaching an altitude of 2,800 m. The terrain is a steep slope reaching the east coast from the central highland with the distance of 50 to 100 km, and a gradual slope of 200 to 250 km to the west coast. Although seven agro-climatic zones were defined based on regional weather condition, they were summarized to five (north, west, central, east and south) in this report, to serve the convenience of understanding (**Fig. 1**).

Production of Rice

Rice is a staple food in Madagascar and the annual per capita rice consumption is about 120 kg, which is extremely high in African countries, and the total production is the second largest after Nigeria among the sub-Saharan countries. The cultivation area is 1.3 to 1.6 million with 1 million ha of paddy rice and 300 to 600 thousand ha of upland rice which fluctuates depending on the variation of rainfall. Total production is somewhere between 4.0 and 4.5 million tons, which doubled in these 50 years. However, despite of this increase in production, the supply does not catch up with the demand due to high population growth rate (2.5 to 2.8% per year). Some 150 to 300 thousand tons of rice is imported from other countries every year.

Weather Condition

The temperature is suitable for rice cultivation all year round in the coastal areas with more than 20°C, but that of the central highland exhibits below 15°C reflecting the high altitude, which hinders rice cultivation. The rainfall is generally monsoon type which is clearly divided between the rainy season from November to April and the dry season from May to October, but on the east coast there is rain all year round due to the influence of the seasonal wind. Annual rainfall is 1,500 to 2,500 mm, but in the south-west there are semi-arid climates with areas less than 500 mm. Solar radiation is higher in rainy season than dry season reaching 15 to 20 MJ/m^2 day which is as high as the

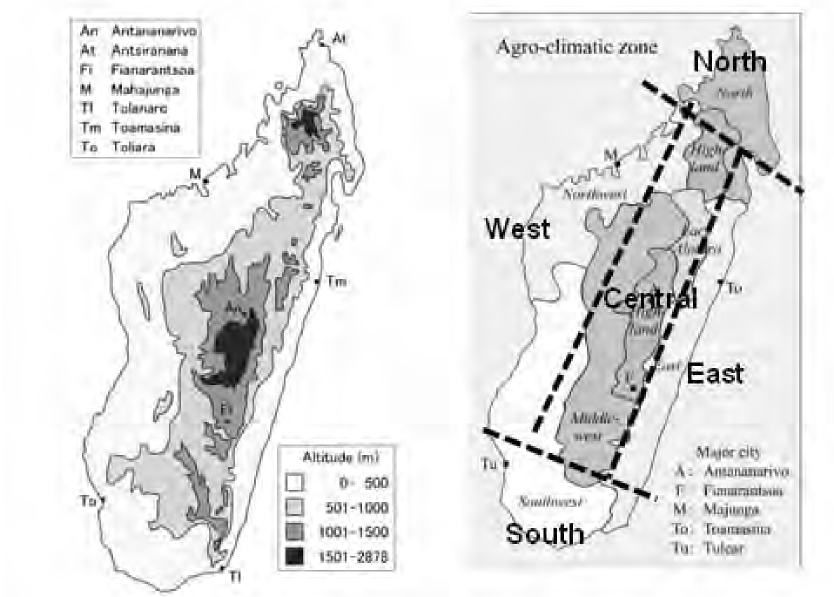


Fig. 1 Geography and agro-climatic zone of Madagascar

dry season of Asian countries and is advantageous for rice cultivation.

Regional Production

Regional rice cultivation area is the largest in central and accounts for about 40%, followed by east (20%), west (20%), north (15%) and south (5%). Seasons of cultivation are diverse reflecting the influence of regional weather and irrigation conditions. Generally, rainy season cropping starts with transplanting in October to December after the acquisition of enough rainfall and terminates with harvest in April to May after entering dry season. Dry season cropping is conducted in the places where irrigation is possible transplanting in August to September and harvesting in December to January. On the other hand, flood plains in west transplant in May after the water level goes down in dry season and harvest from August to September.

Policy of the Government

More than 80% of the people are engaged in agriculture and 92% are living with less than 2 dollars per a day. The government recognizes that agriculture, especially rice productivity, is the most important factor for the eradication of poverty. For this reason, "Madagascar Action Plan (MAP)" was promulgated in 2006 to double the amount of rice production (3.4 million tons to 7 million tons) in the five-year plan of 2007-12. "National Irrigation and Basin Project (BVPI)" was formulated in the same year to integrate irrigation, afforestation and watershed management for the development of the paddy field of 1 million ha. France, the World Bank, the African Development Bank, FIDA, and Japan are collaborating with the government in the implementation of the project. Although the progress of the project was greatly influenced by the political change (coup-d'etat) in 2009, the basic stance of the Madagascar government has not changed, and a new project "Agriculture, Livestock and Fishery Sector Program (PSAEP : 2013-25)" is on-going to enhance agricultural production. In March 2016, Department of Rice Development and Promotion (DPDR) was established in the Ministry of Agriculture and Livestock to prioritize rice production.

Rice Cultivation Technology

Rice cultivation in Madagascar is roughly divided into three types, upland rice cultivation, traditional rice cultivation and improved rice cultivation. Upland rice cultivation is rapidly enlarging on the slope in central and north due to the increase of population and scarcity of undeveloped paddy field. Traditional rice cultivation was introduced from Asian countries with the history of more than 1,000 years. Improved rice cultivation was introduced in the mid 1980's by the International Rice Research Institute (IRRI) as the aftermath of the green revolution.

Three Types of Rice Cultivation

Upland rice cultivation

According to the recommended manual of the Ministry of Agriculture and Livestock, it is conducted on the slope with the gradient of less than 12% to prevent soil erosion. Plowing is done at a depth of 20-25 cm along the contour line in at least 20 days before sowing with the application of 3-6 ton/ha of compost and 250 kg/ha of dolomite. Seeds are sown into the hole spaced 20 × 20 cm at the rate of 4-6 seeds/hole with the depth of 3 cm. Chemical fertilizer (NPK 11-22-16) is applied at the rate of 200 kg/ha. However, these agricultural materials are rarely used and frequent droughts hinder the growth, which result into the low yield of 1 to 2 ton/ha.

Traditional rice cultivation

Seeds of traditional photosensitive varieties are densely sown on water-bed nursery at the rate of 20 to 30kg/100 m^2 at the beginning of rainy season (September to October). Old seedlings with 40 to 60 days in the nursery are transplanted by random planting with high density sometimes reaching 50 hills/m^2. Rice is grown without fertilizer under deep water condition. Harvest is conducted after entering dry season (April to May). Growth period (the number of days from seeding until harvest) is 160 to 180 days, and the yield is about 2 to 3 ton/ha.

Improved rice cultivation

Non-photosensitive varieties with growth period of 120 to 150 days are sown on water-bed nursery at the rate of 10 to 15 kg/100 m^2, and young seedlings with 20 to 25 days in the nursery are transplanted in row with 20 to 25 cm intervals. High yielding varieties, shallow irrigation, fertilizer application and thorough weeding with paddy weeder promote the growth of rice resulting into the increased yield of 4 to 6 ton/ha. From the 1990s, rice cultivation with SRI (System of Rice Intensification) which was invented by a French missionary, has been spread as an improved rice cultivation in which high yield of 8 to 10 ton/ha can be obtained by transplanting very young seedlings with less than 10 days, elaborate fertilization management and intermittent irrigation. It is currently spreading around the world as a rice cultivation technology originated in Madagascar.

At the present time in Madagascar, the area for traditional rice cultivation is 80%, followed by upland rice cultivation with more than 10%, improved rice cultivation by less than 10%, and SRI by 0.2% (**Fig. 2**). In view of regional difference, central highlands adopt the highest rate improved rice cultivation and SRI, which implies more intensive than other areas.

Variety

Varieties of Indica, Japonica and Javanica are used reflecting various introduction processes such as traditional, introduced (IR, ITA number etc.) and improved varieties bred at the National Agricultural Research Institute (FOFIFA). Distinctive ones are red rice cultivated in the central and east, Makalioka 34 introduced at French colonial era as a high quality long grain variety, Chomrong dhan from Nepal as a tolerant variety to rice blast in mountainous area with the altitude of more than 1,500 m. High-yielding improved varieties such as Mailaka, FOFIFA160 and Mahadikatra were released from FOFIFA and are spreading mainly in central.

Land Preparation

Tillage is conducted around one month before transplanting after entering rainy season with oxen-driven plow or manual plowing with "angady" (narrow shovel; unique tool in Madagascal). When irrigation water comes in or rainwater becomes sufficient, the field is inundated followed by pulverization and puddling. In these operations of land preparation, machines (tillers, tractors) are used in some large-scale paddy areas, but most of them are done by cattle or human power.

Fertilizer Application

Although compost or farmyard manure from traditional cattle breeding is occasionally applied in central, the overall amount is very small. Chemical fertilizers are rarely used. On the other hand, the straw is brought out from fields as the animal feed at harvesting period. As a consequence, soil fertility is lower in areas where the history of rice cultivation is longer. Nutritional disorder of rice is frequently observed such as deficiency of phosphorus, potassium and zinc along with iron toxicity due to soil anaerobic condition.

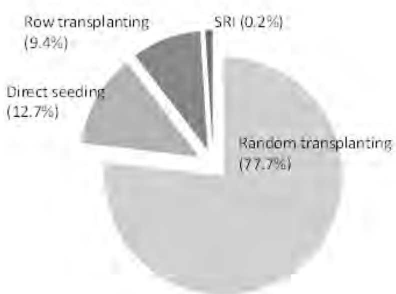


Fig. 2 Percentage of the area with different method of crop establishment (2007)

Irrigation

Large scale irrigation facilities with several thousand to 10 thousand hectares were constructed in 1970-1980 around the western coastal area and the central eastern Lac Alaotra with the support of France and the World Bank. Presently, these have been aged due to sedimentation and it is impossible to cover the initial area. On the other hand, small scale irrigation facilities with several tens to several hundreds of hectares in the mountainous area of the central highlands are maintained in comparatively good condition with the efforts of the local residents.

Pest Control

Rice blast is the biggest problem in central with the altitude of more than 1,000 m. Whereas traditional varieties are generally sensitive, some of the introduced (improved) varieties are relatively resistant. Helminthosporium leaf spot in the unfertile water-logged area of east, and rice yellow mold virus (RYMV) under tropical weather on west are occurring as the notable diseases. In the case of insect damage, the outbreak of the grasshopper flying from the southern part of Madagascar is the biggest problem. Stem bowlers and Hispa similis are frequently observed all over in Madagascar. Weed control is mainly conducted with paddy weeder and hand weeding except herbicide (2,4D) application in large-scaled farming in central.

Natural Disaster

Changes of global environment affect rice cultivation in Madagascar causing irregular rainfall resulting into the delay of rainy season cropping and drought after transplanting. Flooding occurs February to March caused by cyclones (typhoons) seriously damaging rice production. Cold temperature at the reproductive stage of rice induces sterility in the areas with high altitudes of more than 1,200 m.

Harvest and Processing

Harvest is conducted with a sickle at the ground level and grains are generally threshed by beating the rice bundle to stones or wooden trunks. In a large scale irrigation scheme, rice is threshed by running a herd of cattle or a power tiller on the heap of harvested rice. Grains are processed with drying on the roads and gardens followed by cleaning by wind dropping from the head. Milling is conducted with Engelberg miller or husker-polisher that produces white rice from paddy at one path.

Activities on Agricultural Machinery of JICA Technical Cooperation Project PAPRiz

JICA technical cooperation project "Improvement of Rice Productivity in the Central Highlands (PAPRiz)" was implemented for six and half years (2009-2015). The project aimed to enhance rice production in collaboration with the Ministry of Agriculture and Livestock adopting comprehensive approach such as (1) development of technical packages, (2) improvement of seed production system, (3) development of agricultural machinery, (4) cooperation among stakeholders, and (5) extension of technology. Currently, the activities are continued under the new project (PAPRiz2: 2015-2020). Activities on agricultural machinery was conducted at Training Center of Agricultural Machinery (CFAMA) inviting experts from Indonesian Center for Agricultural Engineering Research and Development (ICAERD). Development of agricultural Machinery (**Fig. 3**) and improvement of post-harvest technologies (**Fig. 4**) were conducted in collaboration with local artisans and farmers.

Thresher

Post-harvest loss of rice in Madagascar is considerably low compared to those in Asian countries due to low threshability of varieties. On the other hand, farmers are obliged to spend hard labor for threshing with human power. Introduction of thresher is most effective and beneficial not only to save the labor but also to enhance the quality of rice. The first model was developed following the Japanese model which consisted of the combined use of wood and metal for frame and transmission respectively. The second model was developed with all-metal materials considering the difficulty of the acquisition of raw wood materials, which also reduced the cost of production. The third model was developed to be compact, light and inexpensive. Transportation to the field became easier due to reduced weight and the price was reduced to be half of the previous model with adoption of cheap and available materials.

Winnower

Cleaning of paddy (removal of straw, empty grain and alien materials) is usually conducted by dropping harvested materials from overhead, in which the light contaminated materials move out by wind and filled grains drop straightly. The operation needs wind and is quite time-consuming. Winnower generates wind with fans and separates the materials with the gravity. The first model (prototype) was developed following the Japanese model which was made of wood. Considering the difficulty of the acquisition of raw wood materials and time with labor for manufacturing, the second model was developed with all-metal materials, which also reduced the cost of production. Large hopper and pedal transmission were equipped to enhance the capacity and the function of cleaning.

Paddy Weeder

The project developed and improved rotary-type paddy weeders which were used in Japan and Asian countries for the promotion of efficient weed control in paddy fields. Basic structure of the paddy weeder consisted of the frame with the shape of bottom of ship and rotary claws to uproots weeds pushing in the field. Pentagonal float was attached behind rotary claws to avoid submergence into soil for the operation in soft soil and 2 tiers claws were utilized to facilitate weeding on hard soil. The width was also modified in accordance with condition of the cultivation of rice. The width of 15 cm was adopted for row spacing of 20 cm, and 10 cm for that of 15 cm. Double row weeder which controlled the weeds in 2 rows simultaneously was manufactured for the large scale operation. Developed

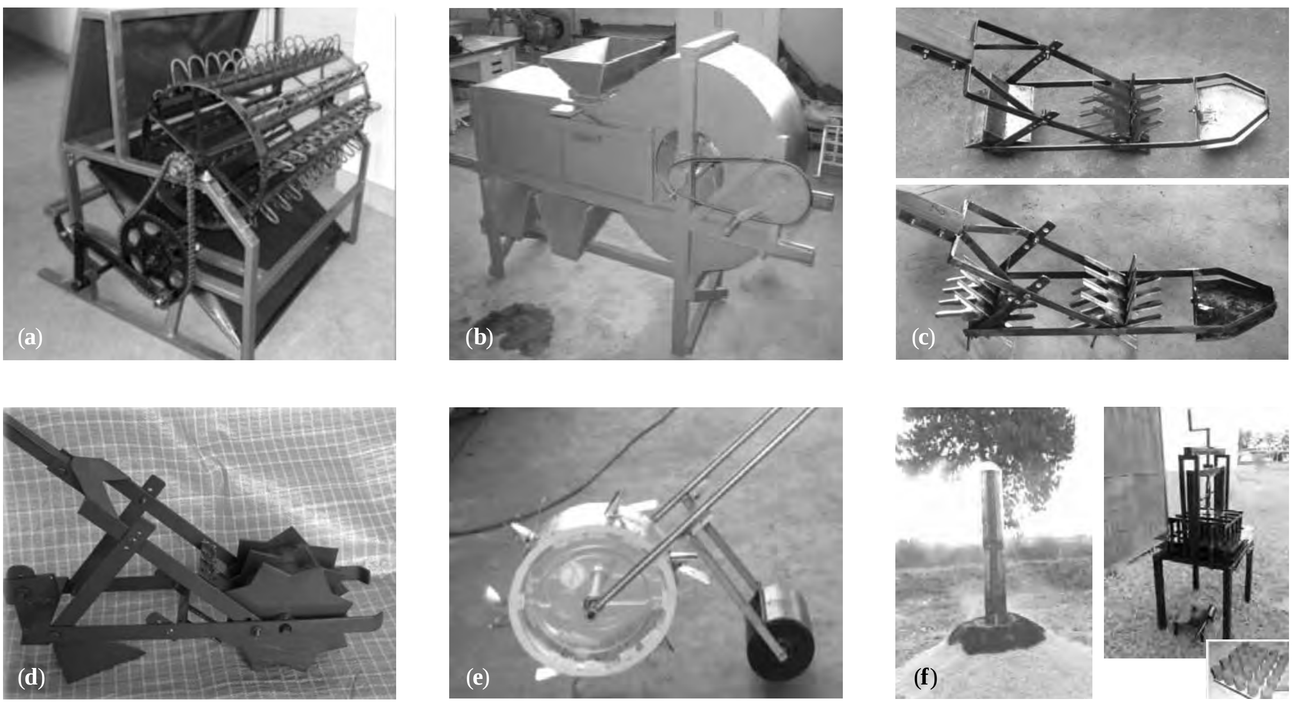


Fig. 3 Agricultural machinery developed in the project
(**a**) Thresher, (**b**) Winnower, (**c**) Paddy weeder, (**d**) Upland rice weeder, (**e**) Upland rice seeder, (**f**) RHCF-Pelletizer

weeders were tested in the farmers' field and improved following the opinions of farmers and extension workers.

Upland Rice Weeder

Weed control plays crucial role in upland rice production and much labor and time are devoted for hand weeding. Development of weeder was conducted improving the defects of the local prototype. The main point of improvement was the adoption of PVC (polyvinyl chloride) pipe instead of iron drum to reduce the weight and to avoid the adherence of wet soil. The cost of operation was estimated in comparison with angady (local hoe) weeding, which elucidated the superiority of the weeder with the field capacity being five times greater than that with angady.

Upland Rice Seeder

The project aimed to develop cheap and efficient seeder to enhance the productivity of upland rice. Considering the prevalent hill (dot) seeding of upland rice in Madagascar, the seeder was designated to be rotative hill seeder. Seeds of upland rice were dropped in bulk (4 to 10 grains) through the drophole which was opened with compressed spring upon landing. With the setting of the common starting point of the seeder, square planting of upland rice was realized, which enabled cross-cut weeding by the weeder. Utilization in the dry direct seeding of rice in paddy fields was recommended to reduce the labor for seeding.

Rice Husk Charcoal Furnace (RHCF) and Pelletizer

Huge amounts of rice husk (some 800,000 ton out of 4,000,000 ton of paddy) are produced every year as a by-product of rice cultivation in Madagascar. The project aimed to promote production of rice husk charcoal which could be used for fuel or soil conditioner. Rice husk charcoal furnace (RHCF) was fabricated with iron and with a chimney pipe attached to square furnace. The pelletizer produced pellets pushing out the mixture of rice husk charcoal, water and coagulator through holes. Charcoal pellet was by no means inferior to gas, wood char-

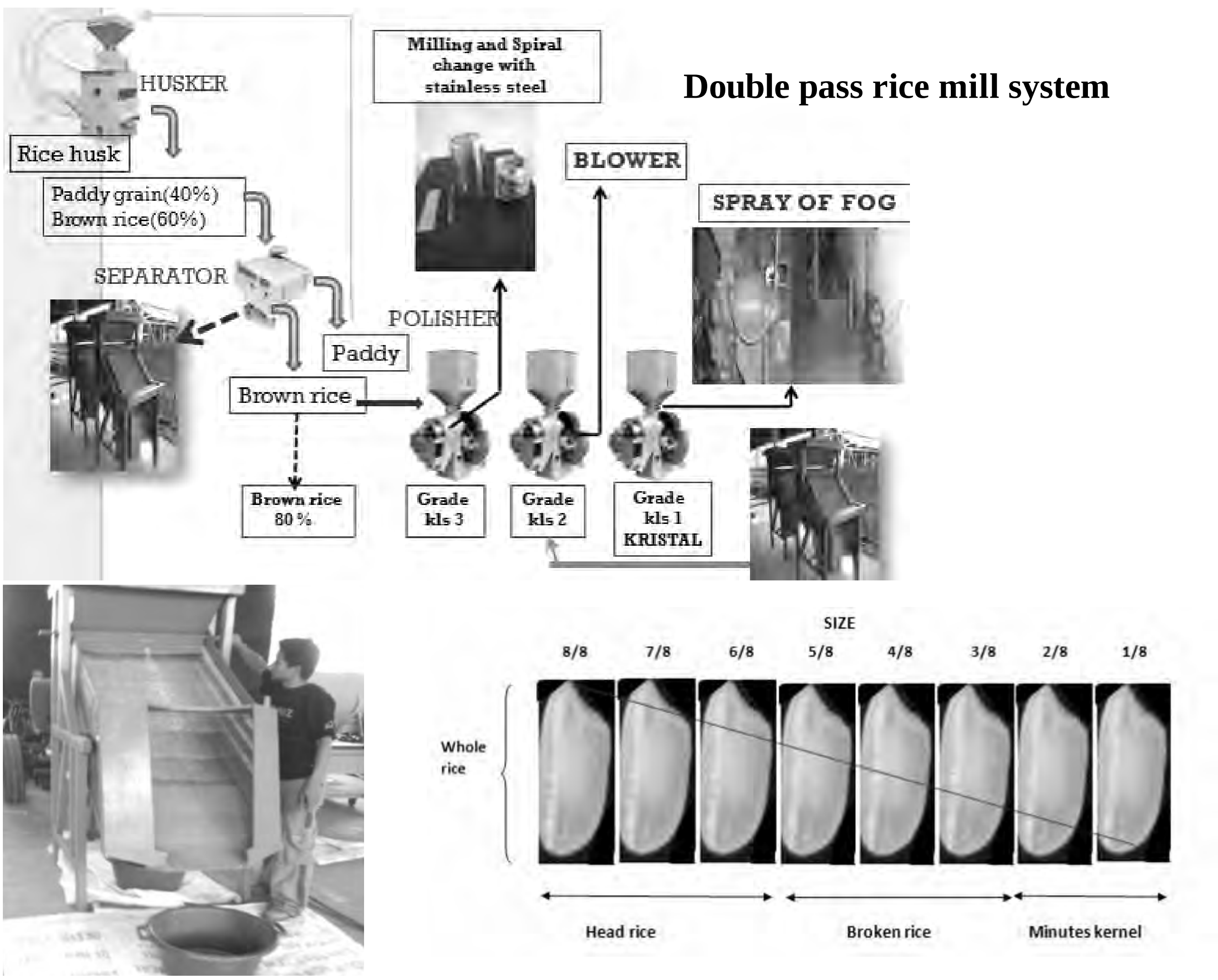


Fig. 4 Trials to enhance quality of rice

coal and wood in energy efficiency and cost. It might be used also for maintenance of moisture in soil in planting of vegetables and trees and for absorption of impurity in drinking water.

Estimation and Reduction of Post-harvest Loss

Rice is the staple food and farmers are eager to increase productivity in Madagascar. On the other hand, they seem to be rather indifferent to the postharvest loss. The project investigated actual situation of post harvest loss in each step from harvest until storage in the model sites in central highlands. Average total loss was some 13% with 0.3% at harvest, 3.4% at the transportation of rice from field, 2.3% at threshing, 1.8% at drying, 2.5% at milling, and 3% at storage. Post harvest loss would be halved adopting the improved treatments such as harvest with sharp sickles without delay, threshing in the field without transportation, use of pedal thresher located on a plastic sheet, drying on the sheet to avoid loss and over-dryness, milling with double pass rice mill system which produces brown rice from paddy followed by the production of white rice from brown rice, and storage in bag in well-ventilated place.

Enhancement of the Quality of Rice

It is inevitable to establish the quality-control system of rice if the export to other countries is to be planned in the future. The project tried to enhance the quality of rice with the development of some equipment.

Separation of broken rice with white rice separator

Percentage of the content of broken rice is the most important factor to determine the quality of white rice. The project conducted the trial manufacture of white rice separator. It consisted of 3 parts such as the frame to support the body, the slider for separation of rice and the hopper to accept rice. Rice was separated into head and broken rice by dropping on the screen from the hopper. Efficiency of separation was determined by combination of screens, angle of inclination, flow rate and times of replication.

Enhancement of double pass rice mill system

Broken rice is commonly observed at the markets in Madagascar, the cause of which may be derived from the adoption of Engelberg system in which white rice is directly produced from paddy. For the improvement of the situation, double pass rice mill system was assembled. The system was composed of a vibrating cleaner to remove impurities, a husker to produce to brown rice from paddy, a separator to separate paddy and brown rice, and two polishers to produce white rice from brown rice. It played big role not only to raise efficiency but also to enhance the quality of rice reducing the rate of broken rice to 10% from 50% in Engelberg system.

Introduction of the standard of the quality of white rice

The project introduced the Indonesian standard of the quality of white rice as a reference to enhance the quality of rice in Madagascar. Paddy was sampled and dehulled by husker to obtain brown rice, which was converted to white rice with polisher. Milling grade was determined with weighing the weight of head rice, broken rice and minute kernel after separating with a grader. Rate of impurities such as red grain, yellow grain, chalkiness grain and paddy was investigated eliminating each type by naked eye and calculated by weight basis. The data were put into a formula of a decision table and categorized into the quality level of 1 to 5.

Perspective

In viewpoint of land use in Madagascar, agricultural land including rice cultivation is only about 6% of national area of 58 million ha with huge unused area, which implies the large potential for production expansion of rice. CARD (Coalition for African Rice Development) reckons Madagascar to be a granary for Sub-Saharan African countries and the government also prioritizes rice production with a long-term scheme. Consequently, there is a possibility that the production of rice in Madagascar will be dramatically increased in future due to investment in infrastructure such as irrigation and transportation and innovation of technology. Utilization of agricultural machinery is one of its core elements, and development and utilization of agricultural machinery conforming to the natural and social conditions of Madagascar are expected.

Acknowledgements

The author appreciate Dr. Joko Pitoyo, Mr. Pattahuddin, Mr. Andri Gunante, Mr. Marsudi and Mr. Suismono (Indonesian Center for Agricultural Engineering Research and Development: ICAERD) for the development of agricultural machinery / training of local artisans and Dr. Koichi Shoji (Kobe University, Japan) for evaluation/guidance on project activities.

REFERENCES

Kabaki, N., K. Yoshii, K. Arai and R. Habara. 2014. For Rice Productivity Improvement in the Republic of Madagascar (in Japanese). International Cooperation of Agriculture and Forestry. Vol.37(4) 27-33

Kabaki, N. 2017. Rice Cultivation and Weed Control in Madagascar (in Japaneser). JAPR Journal Vol.51 (2) 9-15

■■

Outlook on Agricultural Mechanization in Tanzania Regarding Improvement of Rice Industry

by

Koji Yamaguchi
Senior Researcher
Non-profit Organization
IFPaT - International Farmers Participation
Technical Net-work
JAPAN

Anna Mwangamilo
Agro Engineer
Agricultural Mechanization Division
Ministry of Agriculture
TANZANIA

Introduction

Tanzania has been increasing its rice productivity prominently among rice-producing countries in East Africa. The country has high potential for rice production, blessed with rainfall and water supply from the mountainous areas. Under such circumstances, small rice-growing farmers in the country have been making great efforts not only for the quantitative increase of rice production but also for the improvement of the rice quality.

Many of small rice farmers in the country are likely to utilize "custom rice mills" (often called "village rice mills") for milling of their produced paddy into white rice, not only for their home consumption but also for selling it. Such practice will result in more profit for them than selling in paddy form. When farmers sell paddy, as practiced widely in the rice growing area elsewhere, the price is unanimously low, since the quality of paddy (rice) is not clear both for sellers (the farmers) and for buyers. Then, the paddy buyers are likely to estimate the quality to be lower, with the aim to protect their business.

However, when harvested paddy is milled into white rice, the rice quality becomes visible to anybody, and the better quality one can be given recognition with higher price. Then, the farmers will be enthusiastic about improving the quality of rice. Therefore, after selling of white rice (milled rice) in place of paddy selling, the farmers become more sensitive on the quality. As a result, they are more likely to become enthusiastic about improving all farm operations, such as seed selection, fertilizer application, pest control, water management, timely reaping, drying and so on, with the aim of improving the quality of rice. Farmers may pay more attention to percentage of filled grains, the ratio of broken rice, damaged grains, etc. in the white rice produced from their own paddy, since these practices directly relate to their income. Based on the evaluation of their own rice quality, the farmers will feedback the findings into the next growing season. It is worthwhile to note that post-harvest operations play an important role for securing rice quality as well as farm operations in the field.

In this paper, the authors would like to emphasize that, together with utilization of milling machines, selling of white rice by the farmers will improve both productivity and qual-

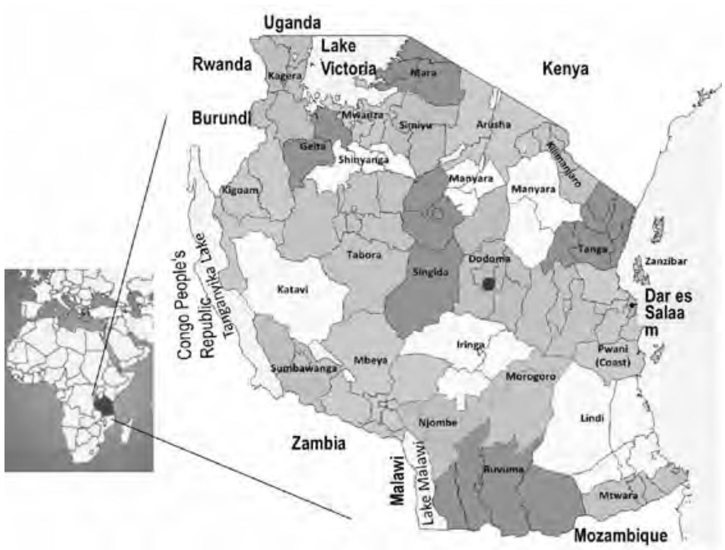


Fig. 1 Map of Tanzania

ity of rice in the country.

General Information

Tanzania is the largest country in East Africa, consisting of the mainland and Zanzibar (a semi-autonomous region). Total land area of the country has about 945,000 km^2, bordering on Kenya, Uganda, Rwanda, Burundi, Democratic Republic of the Congo, Zambia, Malawi, and Mozambique (**Fig. 1**).

In the year 2017, the population was estimated to be 51,557,000 and the population growth is expected to continue in future. Tanzania's GDP is $12 billion ($316 per capita, 2005), which is less than the average value of $424 for LDC (Least Developed Country). The agricultural sector occupies an important part in the economic activity, which accounts for approximately 45% of GDP.

Tanzanian agriculture remains subsistence farming, despite the large untapped land resource of 44 million ha suitable for agriculture. Small-holder farming (ranging from 0.2 to 2.0 ha) is dominant covering 85% of total cultivated land. The major limitation on farm operation is that the most of it is made by family labor, heavily relying upon simple hand tools. Given generally abundant land resource, efforts are being made both expanding the area for farming and intensifying the use of existing cultivated area. They may be achieved through:

- Promotion of mechanization including post-harvest processing,
- Adoption of other improved technology such as seed, fertilizer and agro-chemicals, and
- Accessibility to markets.

Tanzania launched a policy to double the rice production in the decade from 2008 to 2018, which is shown in **Table 1**. In line with this, it is being promoted with the plan to increase rice growing area and unit yield. Not only improving agricultural infrastructure and cultivation technology but also effective utilization and promotions of farm machinery are demanded. In the background, the agricultural sector is the driving engine of the economy. In 2008, the sector accounted for about 26% of the GDP and 22% of foreign exchange earnings. The sector provides 95% of the national food requirements and livelihood to more than 70% of the Tanzania population.

Farm machinery enhances the human capacity, leading to intensification and increased productivity, in such ways as: timely land preparation and planting, weed control, post-harvest handling including timely reaping and improved accessibility to markets. Timely farm operations have become crucial in recent years because the rainy season tends to be shorter in many parts of the country. This tendency puts pressure on farmers to accomplish their field operations in the shortest possible time in order to capture the short growing period. This leads to the need of adopting higher levels of mechanization such as wider use of draught animals, power tillers, tractors, combine harvesters, etc. These have higher field capacity which enables farmers to avoid labor peak constraints in farm operations thus making them to cope up with the short growing season (**Fig. 2**).

Situation on Rice Industry

As mentioned above, the performance of the overall Tanzanian economy has been partly driven by the performance of the agriculture sector due to its large share in the national economy. Its growth is essential in meeting the development goals of the Tanzanian Vision 2025. In meeting these challenges, the Government launched the Agricultural Sector Development Strategy (ASDS) in October 2001 as an instrument for stimulating growth and reducing poverty. The ASDS recognizes that the subsistence-dominated farming must be transformed into profitable agricultural production and the abundant land resource should allow increase in production through expansion of cultivated land. In order to accomplish this, farm machinery has a key role to play.

In 2006, the government started implementing the Agricultural Sector Development Program (ASDP) as an operational response to the ASDS that was focusing on increasing agricultural productivity, profitability and farm incomes.

Fig. 2 Tractor with a 3-disc plow in Lower Moshi irrigation scheme, Kilimanjaro region, Dec. 2016

Table 1 Expected increased paddy production

Year	Upland Rice			Rainfed Lowland Rice			Irrigated Rice			Total		
	Product (1,000t)	Area (1,000ha)	Yield (t/ha)	Product (1,000t)	Area (1,000ha)	Yield (t/ha)	Product (1,000t)	Area (1,000ha)	Yield (t/ha)	Product (1,000t)	Area (1,000ha)	Yield (t/ha)
2008	9	17	0.5	464	464	1.0	426	200	2.1	899	681	1.3
2013	21	21	1.0	561	374	1.5	870	290	3.0	1,452	685	2.1
2018	50	31	1.6	548	274	2.0	1,356	390	3.5	1,963	695	2.8

National policies and strategies on agriculture in the country address the need to increase crop production to meet the food security objective in achieving self-sufficiency in staple food production, including rice. Thus, the proposed National Rice Development Strategy (NRDS) was in line with both national policies and international commitments that Tanzania has ratified aims in improving the livelihood of the majority rural communities through enhancing household food security and incomes.

The existing potentials for rice production in the country include: rainfed-upland and lowlands, and irrigated lowlands eco-systems; range of small, medium and large scale producers; comparative advantage of rice over other food crops for income generation and enhancing household food security; availability of some improved rice production technology and dissemination channels, and availability of some programs for increasing production and productivity of cereals including rice.

As mentioned above in General Information, Tanzania is a leading country for producing rice in the East Africa. The recent production of rice in the East Africa is shown in **Table 2**. It shows that Tanzanian rice production is remarkably higher than that of neighboring countries. This trend is expected to continue more in the future.

Current Status of Farm Machinery

The Tanzania Agricultural Mechanization Strategy (TAMS) is the framework for guiding the development process of the mechanization sub-sector, in contributing to national development aspirations of poverty reduction and economic growth. These are spelt out in ASDS and other national policies, and strategies that are encapsulated in the National Strategy for Growth and Reduction of Poverty (NSGRP, 2005).

TAMS is being implemented under the framework of the ASDP. Execution of TAMS interventions at district level will principally be the responsibility of the Local Government Authorities while interventions at field level are undertaken by the communities and councils. It is their anticipation that the key stakeholders of this strategy will collaborate with the government in its implementation to achieve the desired results.

The level of mechanization in the country has remained low with a hand hoe dominating in the farming systems. Use of animal traction and mechanical power is limited. It is estimated that currently (2006) there were over 14 million hand hoes in use, about 590,000 animal drawn plows, 1,300,000 oxen and 82,000 donkeys (**Fig. 3**).

Beside this, there are only about 7,200 tractors that are operational and other 6,000 are broken down although repairable. The number of tractors has been increasing at an average of 200 to 300 annually. Tractors are more extensively used in Morogoro, Arusha, Kilimanjaro, Manyara, Dodoma, Shinyanga, Iringa, Mbeya, Mwanza and Tanga regions. Such high number of tractors in these regions is mainly associated with direct interventions by the government, former state-owned large farms such as NAFCO (National Agriculture and Food Corporation, which were already privatized).

On the other hand, the use of power tillers may be an alternative to alleviating the power shortage in farming. In the year 2000-2002, the government introduced 230 power tillers. Extensive demonstrations were conducted in the country in order to expose the technology to farmers. The performance of power tillers has been satisfactory and the demand is increasing especially in rice growing areas. Private sector has taken up the initiative of introduction and about 100 power tillers are being sold annually. Currently, the exact number of existing power tillers is not clear, but the use is going to spread in many rice growing areas. The reason is that it is inexpensive and relatively easy to purchase repair parts. Since its structure is simpler than that of tractors, the maintenance work can be made in a small scale village repair shop or even by a farmer himself (**Figs. 4** and **5**).

Furthermore, as paddy fields are mostly divided into small plots by bunds, power tillers can be used there easier than tractors. By use of power tillers, direct puddling (the way to do plowing and puddling simultaneously) can be carried out successfully under the flooded condition. If tractors are used for the purpose, they will bog down frequently. In addition to this, power tillers can be used throughout a year, other than for farm operation,

Table 2 Paddy supply per capita in Tanzania and in the neighboring countries

	Tanzania	Kenya	Uganda	Rwanda	Burundi
Production (1,000t)	2,300	114	223	80	70
Population (1,000)	53,000	46,000	39,000	11,610	11,170
Paddy supply, kg/capita	43	2	6	7	6

Source: FAOSTAT (Average of paddy production in 5 years from 2010 to 2014)
Global Note (Estimated population in 2014)

Fig. 3 Plowing by a 2-pair of oxen on rainfed lowland areas in Mwanza region, Dec. 2016

for the purpose of transport of cargo and men (**Fig. 6**).

During authors' survey in 2017, farmers who were using power tillers expressed valuable opinions as follows:

- Durability of Chinese machine is inferior to that of Thailand machine (Siam-Kubota).
- Although the Kubota brand one is much stronger, still Chinese ones are preferable, since the price of the machines is much cheaper.
- Further, repair parts of Chinese machine are readily available and the price is cheap.

Such a statement shows the importance of the availability of the machine and its spare parts specifically that of repair parts procurement. If the machines were utilized to the full extent throughout a year for contract-hiring operations or for transportation services, then this point will become vitally important factor. According to the farmers, inexpensive power tiller made in China can earn its cost within three years.

Fig. 4 Machinery repair shop in Mkindo Village, Morogoro region, Aug. 2017

In all likelihood, the authors consider the use of power tillers will increase further in future especially in the irrigated rice farming areas. That is because of the fact that, at present, farm operation cost by use of power tiller and that of manual labor are almost the same (or the former being slightly cheaper than the latter). Operation cost per ha of plowing and puddling is about US$315. Even if the costs are same on both cases, the working efficiency by use of machine is much higher, whence farmers can manage farming schedule more smoothly. In order to facilitate the use of a power tiller, it is necessary to ensure the speedy repair parts supply system in rice farming areas (**Fig. 7**).

As mentioned above, the private sectors (machinery suppliers) are encouraged to provide after- sale-services such as supply of repair parts and maintenance services. However, they have not yet established a sufficient supply/service system, since it is not only shortage of parts but also the machines being used in remote areas in the country. Thus the machinery suppliers have not yet responding satisfactory for the farmers' needs. It is a serious problem for farmers, especially in busy farming season.

Role of Farm Machinery in Rice Industry

Here let's think about agricultural mechanization in rice production. In general, roles of farm machinery are classified broadly into two groups from the view point of crop (rice) growth. The first one is machinery use for assisting rice growing such as land preparation (plowing, puddling, leveling, making nursery bed and bunds, etc.), weeding, pest control and irrigation. These operations are to maximize rice growth. It can be said that these works are for assisting natural growth of the crop as pre-harvest farming operations. It should be noted that even without using machinery, or even without human operation, the crop grows of itself.

The other one is farm operations like reaping paddy, threshing, cleaning (winnowing), transporting, husking, whitening, separating operations, etc. so-called post-harvest operation. These are not related to the natural rice growth, they are totally artificial works solely serving to human needs. These are farm operations for artificial use of crops. Without human operation, any and all the post-harvest process will not go at all. Since it is nothing to do with natural growth of crop, human act (handling methods or types of machinery used) becomes decisive factor. This is the basic differences in usage of farm machinery between two phases.

A combine harvester is one of the post-harvest machines. Against this, there may be other opinions that a combine harvester works in the field, therefore it should be clas-

Fig. 5 Chinese power tiller being repaired in Mkindo Vllage, Morogoro region, Aug, 2017

Fig. 6 A Chinese power tiller with a chair working direct puddling, Mbeya region, Jan. 2016

Fig. 7 Farm machinery supplier (Siam-Kubota and others) in Mbeya, Jan. 2016

sified into 'field machine' or 'pre-harvest machine'. We disagree to this. The harvesting operations are intentional works of human beings. Originally, plants like rice naturally drop seeds to the ground when they are ripen. Harvesting operation try to stop this. Therefore, as described above, when farm machinery is classified into two groups, i.e. those for pre-harvest operations and for post-harvest ones, the function of the machine should be considered with reference to the crop growth character (**Fig. 8**).

As mentioned above, pre-harvest operations like land preparations are basically works to assist maximizing crop growth, so it directly affects crop productivity. Therefore, where increased rice production is aimed at, field farm machinery plays particularly important role, for executing timely and efficient farm operations and expanding the rice growing areas.

Post-harvest Operations in Rice Industry

About farm machinery-related situation in Tanzania, most of the argument concentrates on the numbers and utilization of tractors, power tillers, etc. (as part of pre-harvest operations). Of course they are indispensable consideration for mechanization level of the country. However, the role of rice mills in the rice production areas is also important consideration since it is closely related with initiatives of many small farmers to increase the production and to improve the quality of white rice.

According to the TAMS, this is a part of mechanization plans under the ASDP, "agro-processing has a tremendous potential for increasing income (value addition and improved shelf life) and access to food security through the establishment of small-scale agro-processing businesses and rural agro-based industries". And then the TAMS pointed out the importance of post-harvest treatment, and set out of the following objectives.

i) Promote agro-processing and value addition technologies that contribute to the sustainable livelihoods of rural population as well as facilitate the emerging small commercial farmers in the country.
ii) Strengthen capacity of post-harvest and rural based agro industries.
iii) Enhance access to and use of improved post-harvest, rural travel and transport, processing, storage and marketing technologies.
iv) Facilitate private sector investment in medium scale processing of agricultural commodities

Above objectives are not only the rice industry field but also it refers to agricultural products in general. Therefore, here how the role of the rice mills related to increasing rice productivity and improving rice quality, and another thing as high possibility to improve farmer's welfare, to be described in more detail below.

Role of Post-harvest Operations

Basically the types of rice milling business can be divided into two, in terms of the nature of their business. Quite often, large scale mills and small scale ones are distinguished. But what is important is not the scale of milling facility/capacity. What is important is whether the rice mills are operating for commercial transaction of rice or custom operation, i.e. service milling for rice farmers.

The business of the commercial rice mills is that these would buy paddy grains as much as possible during harvesting season from farmers directly and/or through paddy collectors, middlemen, etc. After processing they will sell in white rice while confirming market trends throughout the year, hence their storage facility is much larger than milling equipment facility in order to store paddy grains sufficiently. The duration of paddy storage is depended by the marketing price of white rice. Most of marketed white rice is supplied by them. Their basic nature is that of rice merchant rather than processor.

In contrast with this, the latter one, so-called custom rice mills or village rice mills do basically milling service only for rice farmers. Their profit is the milling charge or custom, collected from farmers according to the quantity of paddy milled or produced white rice. The charge may be paid in cash or in kind (white rice or paddy). In the country where rice production is a small scale operation, the custom rice mills exist many in the rice growing areas. Custom rice mills may buy paddy or white rice sometimes, but it is not their major businesses. Their nature is processor or craftsman, not merchant.

In Tanzania as well, the commercial rice mills existed in major rice growing areas, which were under the government operational system at that time so-called NMC (National Milling Corporation), but all mills were privatized in the early 1990s. Then, they started to make custom milling for farmers. Rice milling equipment that was introduced to NMC was mainly made by

Fig. 8 Indian-made throw-in type multi-purpose thresher with engine, farmers threshing Sorghum, nearby Muungano irrigation scheme in Manyara Region, Aug. 2017

Buhler of Switzerland, and these are still being used although some of them like a whitening machine, etc. have been renewed (**Fig. 9**).

About the 1990s when NMCs were privatized, around the same time many small-scale private rice mills as custom rice mills were rapidly established. As the milling machines in those days, they used so-called an Engelberg type machine. This machine has been used for crushing maize prior to make grinding into flour by a hammer mill. The machine crushes maize grains roughly at the same time removing a tip cap and outer skin of maize as a primary milling process. Although the machine is used for the crushing grains, it can also be used rice husking and whitening with some adjustments, nonetheless, since the structure and pressure (friction) adjustments are simple, it produced many broken rice.

Since around 2000, so-called SB model rice milling machines were widely introduced. The machine is composed of a rubber roll husker and an air-jet type friction whitener in one unit type. This type of machine was developed originally by Satake Engineering Company in Japan, but most of them being used now in the country are exact copycat structure of Satake models. However, SB models from China being used for rice milling cannot be neglected with the fact that white rice quality including milling recovery from paddy grains has been dramatically improved over those of Engelberg machines (**Fig. 10**).

Fig. 9 Custom rice mill (former NMC) in Morogoro region, Jan. 2017

Farmers Already Take Initiative and Act for Rice Industry

As mentioned, there are many custom rice mills in the rice growing areas; as a result they have to work in competition with each other for securing customers, i.e. rice growing farmers. It is generally recognized that if post-harvest operations, such as reaping, threshing, winnowing, drying, milling process and so on, are properly implemented, quality of produced white rice may be improved, and the milling recovery from paddy may be increased. As a result, white rice to be sold at much higher price. Therefore the extension officers and the donors' personnel have been emphasizing and instructing to the farmers on proper operational methods. However, such instructions have a little effect on farmers, particularly those who are selling paddy grains to the buyers. Why is it so?

Those farmers who sell paddy grains to middlemen etc. they do not have motivation to do proper harvesting operations as instructed by the governmental personnel. Even if farmers may try to sell clean paddy grains; however, it is not reflected in the purchase price. It is difficult to judge the quality of rice grain encased in paddy husk accurately, and hence amount of the milling recovery too. The paddy grains buyers are by no means exploiting farmers' grain prices. Because the quality of paddy grain they buy is unapparent, it is inevitable to protect themselves. As a result, paddy grains sold by farmers cannot get appropriate prices of its value matching to the quality; hence the farmers lose willingness not only to increase production of rice but also to improve the quality (**Figs. 11** and **12**).

On the other hand, where the farmers are making use of aforementioned custom rice mills in rice growing areas, according to the authors' observations in 2017, many farmers are trying to sell in white rice to the buyers and/or a local market directory, and these farmers are making more profit than selling in paddy grains. Since the white rice quality is certainly clear unlike the case of paddy grains, in view of this, the farmers stand in advantageous position for the selling price negotiation even the sales volume of white rice is small. Moreover, the authors would like to emphasize that by selling in white rice, the farmers can

Fig. 10 Engelberg use for rice and maize, in Nakahuga village of Songea Region, Aug. 2017

Fig. 11 Paddy drying yard at a custom rice mil in Lower Moshi irrigation scheme, Jan. 2017

Fig. 12 Paddy bags storage at a custom rice mill. Mwanza region, Dec. 2016

study by themselves how the quality of agricultural products are related with their profit. If white rice quality is bad, it is possible the farmers review/assess the pre- and post-harvest operations by themselves. If different kinds of seed/rice are mixed in selling white rice, weeding works are thoroughly carried out, and if there are many broken rice, the farmers try to improve reaping time, threshing, drying operations, etc. in order to produce good quality of white rice. Therefore, the farmers those who sell white rice will act with motivation to increase production and improve quality of rice as well. Such a change in farmers' motivation makes tremendous effect, far exceeding other factors.

It is also possible that many custom rice mills in rice growing areas will also improve services for securing customers. In fact many custom rice mills have started several services as follows. Some custom rice mills had used only one unit of SB model milling machine, but they have recently introduced a pre-cleaner, de-stoner and sizing machine (like a rotary shifter, to separate broken rice by use of a different meshes of sieves). Moreover some of them offer a drying yard (concrete pavement) with free of charge and warehouse for farmers' paddy bags about a few months to half a year for also free. There is also a tendency to make cheaper milling charge than the other neighboring rice mills. In other words, since the number of the custom rice mills are many in rice growing areas, so the principle of competition works providing with the above services for securing customers. Such services facilitates farmers' utilization of custom mills further that would increase farmers' selling of white rice thus improving rice farmers' economy. All in all, this would encourage extension of rice cultivation (**Figs. 13** and **14**).

Finally, the authors emphasize that the most of farmers, as well as the government personnel, do not understand the difference between a commercial rice mill and a custom rice mill (a village rice mill) clearly. As mentioned earlier, it is not the difference in operational scale or in amount of operation funds but the difference in the basic nature.

A commercial mill makes commercial transactions that is buying paddy and selling white rice, and supplies white rice in the local as well as to foreign rice markets. Its major customers are white rice retailers in urban area. Raw material of white rice, i.e. paddy is collected through paddy collectors, middlemen or directly from the farmers, etc. The nature of transaction is a kind of merchant and the processing is inevitable addition for the commercial transactions. Their major concern is the price of marketed white rice. Since the collected paddy is its own property, the mill would try to produce as much quantity and as good quality of white as possible from this paddy. Therefore, its milling technology is likely to be sophisticated by use of advanced machines mostly.

Contrary to this, a custom rice mill is basically making broadly known as a service milling only on custom basis for small rice farmers. These are located in rice growing rural areas where the rice farmers are customers. The nature is basically a processor, even though sometimes, these would make commercial transactions depending on the scale of milling facility. Paddy being processed is not its own but belong to its customers. Therefore, the major concern is to increase the processing capacity so that more money (milling fee) can be earned. These custom mills are indifferent on the milling recovery or for the quality of produced white rice.

However, in case of the custom rice mills in the areas are large number and competing each other, these would pay attentions for the improvement of the rice quality and milling recovery with the aim to secure more customers. Where there is severe competition among the custom rice mills for their survival, their milling technology and the equipment have been improved quickly, against what has been considered traditionally. Since it brings forth the improvement of white rice quality they produce, white rice produced in village mills may go into commercial rice market, threatening the position of the commercial rice mills. This accelerates technical innovation on the side of commercial mills. Thus, development of village mills contributes overall upgrading

Fig. 13 Custom rice mill at the rice market in Mbeya region, Paddy receiving, pre-cleaner, de-stoner, SB machine (left); Sizing machine divided into 4 length of white rice (right), Jan. 2017

Fig. 14 Small-scale milling plant with paddy separator (Chinese made), Babati, Manyara region, Aug. 2017

rice quality in the nation (**Fig. 15**).

Conclusions

The authors emphasized mainly rice processing of the TAMS under National Rice Development Strategy of Tanzania's agricultural policy and pointed out how Tanzanian rice farmers have been changing from selling of paddy into selling the white rice. This is because the rice farmers are getting more profits by doing so. Moreover it also results in improvement of rice quality as well as rice productivity. Therefore, the custom rice mills' services and technological improvements have been also progressing based upon farmer's need. This happened because it is necessary to secure customers since the number of many custom rice mills in the rice growing areas as described above. By doing so, since farmers learn the merit of improved farming operations, they also become positive in acquiring advanced farming technology in order to improve their welfare at large.

In recent years, combine harvesters are gradually being utilized in the country. Most of combine harvesters now used by the rice farmers are made in China as Kubota brand. The combine harvester is a "dream-like machine" for farmers since harvesting works from reaping, piling (gathering), threshing, cleaning and filling into grain bags that is completed in a moment. Most probably combine harvesters will be widely utilized because of its high performance, very clean grains, less losses and much cheaper operation than for the manual operations by hired laborers. The authors are willing to keep on reporting on the progress of farm machinery situation including a combine harvester in the country. It is anticipated that rice mechanization system will continue to improve steadily in Tanzania as a leading rice growing country in Sub-Saharan Africa.

Fig. 15 Combine harvester from China (Kubota brand) harvesting at Mombo irrigation scheme, Tanga region, Sep. 2017

REFERENCES

MAFC. 2009. National Rice Development Strategy (Final Draft), Dar es Salaam, Tanzania

Lyimo, P. 2006. Tanzania Agricultural Mechanization Strategy (TAMS), Agricultural Mechanization Section, MAFC, Dar es Salaam, Tanzania

Koike, M. 2009. Custom Hire Systems for Agricultural Machines in Southeast Asia, -In a Rural Community in Thailand-. Engineering in Agriculture, Environment and Food

Koga, Y. 2016. For increasing rice production and improving rice quality in Africa, the village rice mills play decisive role. Training Textbook at JICA Tsukuba Center

Suzuki, I. 1991. JICA report on Post-harvest processing, Kilimanjaro Agricultural Development Project (in Japanese)

Mwangamilo, A. 2017. Back to Office Report on Survey in Machinery Operation and Maintenance Conducted in the 14 Irrigation Schemes Under PHRD Project (unpublished). Agricultural Mechanization Division, Ministry of Agriculture, Livestock and Fisheries (Current Ministry of Agriculture)

Yamaguchi, K. 2005. Extremely Low Paddy Moisture Prior to Milling Process (in Japanese). Journal of the Japanese Society of Agricultural Machinery

Yamaguchi, K. *et al*. 2009. Design of Throw-in Type Rice Thresher for Small Scale Farmers. Indian Journal of Science and Technology

■■

Physical Properties of NERICA Compared to Indica and Japonica Types of Rice

by
Edenio Olivares Díaz
Graduate School of Agricultural Science
Hokkaido University,
Kita-9 Nishi-9 Kita-ku, Sapporo 060-8589
JAPAN

Shuso Kawamura
Graduate School of Agricultural Science
Hokkaido University,
Kita-9 Nishi-9 Kita-ku, Sapporo 060-8589
JAPAN
shuso@bpe.agr.hokudai.ac.jp

Shigenobu Koseki
Graduate School of Agricultural Science
Hokkaido University,
Kita-9 Nishi-9 Kita-ku, Sapporo 060-8589
JAPAN

Abstract

In Africa, rice production has been increasing due to the contribution of NERICA rice. However, information on physical properties of NERICA is required for designing efficient equipment for its production and expansion. Consequently, the physical properties of NERICA were compared to the Indica and Japonica types of rice. The NERICA and Indica types indicated similarity in dimensions of rough rice and in physical properties of milled rice. This result suggested that technology used for processing Indica rice could be transferred and inserted in countries where NERICA production has been expanding.

Keywords: NERICA rice, Japonica rice, Indica rice, Moisture content, Thickness fraction, Physical properties

Introduction

Rice production in Sub-Saharan Africa has been increasing in recent decades due to the contribution of New Rice for Africa "NERICA" rice (Tollens *et al.*, 2013). NERICA combines the high yields of the Asian parent (*Oryza sativa L.*) with the ability to grow in difficult environments of the African parent (*Oryza glaberrima Steud.*). This is the main reason for its widespread adoption among African rice producers (Fukuta *et al.*, 2012). However, the deficiency of implements for rice farming and the high percentage of losses in the postharvest process are the biggest constraints to the rapid expansion of NERICA. Therefore, more detailed information is still required in order to overcome these limitations (Wiredu *et al.*, 2014).

Both moisture content and thickness have been reported to affect the physical properties of rice. Moisture content principally affects rice's dimensions, volume, bulk density, and the coefficient of friction (Kunze *et al.*, 2004; Bhattacharya, 2011b). Meanwhile, thickness influences drying, processing, and quality (Wadsworth *et al.*, 1982), the head rice yield and degree of milling (Sun and Siebenmorgen, 1993), and the physical properties of rough and brown rice (Edenio *et al.*, 2015).

Consequently, in this study, the physical properties of the NERICA type were compared to the Indica and Japonica types of rice considering different levels of moisture content of rough rice and different thickness fractions of milled rice.

Materials and Methods

Rice Samples

Five fresh-harvested rice varieties produced in 2014 were used to examine the effect of moisture content on physical properties of rough rice: NERICA varieties *NERICA-1* and *NERICA-4*; Indica varieties *IR-28*, *IR-50*; and Japonica variety *Yumepirika*.

Seven varieties of rice produced in 2013 were used to examine the effect of thickness fraction on the physical properties of milled rice: NERICA variety *NERICA-4*; Indica varieties *IR-28*, *IR-50* and IR-64; and Japonica varieties *Nanatsub-*

oshi, *Yumepirika* and *Oborozuki*.

NERICA and Indica varieties were produced in the Japan International Cooperation Agency (JICA) Tsukuba International Centre, Ibaraki Prefecture, Japan. Japonica varieties were produced at the Hokkaido University Farm, Sapporo, Hokkaido, Japan.

Rice Sample Preparation

Each of the fresh-harvested rice samples was dried to at least five moisture content levels, with moisture content decreasing by gradations of approximately 3%, using a laboratory grain test dryer (Shizuoka Seiki Co., Ltd, Japan). Meanwhile, each of the milled rice samples was divided into 3 thickness fractions using a laboratory thickness grader (SATAKE Engineering Co., Ltd, Japan).

Methods for Determining Physical Properties

Dimensional characteristics

Slenderness (ratio of kernel length to kernel width) Sl, was calculated using Equation 1 (Mohsenin, 1986). The volume of kernel Kv was calculated using Equation 2 (Jain and Bal, 1997). Both were determined as a function of length L, width W, and thickness T.

$$Sl = L / W \quad (1)$$

$$Kv = 1 / 4 \, [(\pi / 6) \, L \, (W + T)^2] \quad (2)$$

Length L, width W, and thickness T, of the kernel, were determined by image-analysis software Grain Dimension version 1.6 (Shizuoka Seiki Co., Ltd, Japan).

Mass characteristics

Thousand-kernel weight TKW was determined by weighing 1,000 randomly drawn regular rice kernels in an electronic balance (Sartorius Lab Holding GmbH, Germany) and expressed in g (Bhattacharya, 2011a).

Bulk density BD was determined using a grain volume-weight tester (Brauer type, Kiya Engineering, Tokyo, Japan) and expressed as g/L (Bhattacharya, 2011a).

Grain fluidity GF was determined using a grain fluidity tester and expressed as g/s (Kawamura, 2015).

Frictional characteristics

Static angle of repose θs was determined using a Perspex box (Bhattacharya, 2011a).

The static coefficient of friction was determined using an inclined plane (Bart-Plange and Baryeh, 2003). Rubber material used on the belt conveyor at a grain elevator in Japan was used as the test surface.

Moisture content

Moisture content was determined by the Japanese Society of Agricultural Machinery and Food Engineers (JSAM) standard method: about 10 g of whole grain rice was placed in a forced-air oven at 135°C for 24 h and computed on a wet basis.

Composition analysis

Components of milled rice (sound whole, broken, chalky, damaged, and discoloured kernels) were divided by human observation and expressed as a percentage of the weight (Japan Rice Millers Association, 1997).

Statistical analyses

Two-way analysis of variance (ANOVA) and Tukey's test with 99% of confidence were carried out to determine any significant differences among the means of physical properties by moisture content level among varieties and among moisture content levels within each variety.

One-way ANOVA and Tukey's test with 99% of confidence were carried out to determine any significant differences among the means of physical properties among thickness fractions within each variety.

Results

Effects of Moisture Content on Physical Properties of Rough Rice

In general, dimensional, mass,

Table 1 Average value of dimensions of rough kernel by level of moisture content

Variety	Moisture content %, w.b., 135°C n = 3	Length mm n = 200	Width mm n = 200	Thickness mm n = 200	Slenderness -[a] n = 200	Volume mm^3 n = 200
NERICA-1	10.3	8.70 b	2.98 c	2.06 c	2.92 a	29.2 c
	13.4	8.73 b	3.03 b	2.10 b	2.88 ab	30.2 b
	16.6	8.78 b	3.05 b	2.12 ab	2.88 b	30.9 b
	19.6	8.86 a	3.10 a	2.15 a	2.86 b	32.1 a
NERICA-4	10.2	8.98 d	2.93 b	2.08 c	3.07 b	29.6 d
	13.1	9.22 c	2.95 b	2.11 bc	3.13 a	31.0 c
	16.7	9.42 b	2.97 b	2.14 ab	3.18 a	32.3 b
	19.4	9.57 a	3.02 a	2.16 a	3.17 a	33.7 a
IR-28	10.4	9.42 b	2.80 b	2.08 c	3.37 a	29.4 c
	13.3	9.45 b	2.88 a	2.14 b	3.29 b	31.3 b
	16.4	9.52 ab	2.91 a	2.17 ab	3.28 b	32.2 a
	19.6	9.57 a	2.92 a	2.19 a	3.29 b	32.7 a
IR-50	10.5	8.64 b	2.49 d	1.90 d	3.49 a	21.9 d
	13.1	8.67 b	2.55 c	1.94 c	3.41 b	22.9 c
	16.3	8.75 a	2.60 b	1.98 b	3.38 bc	24.1 b
	19.3	8.78 a	2.65 a	2.02 a	3.31 c	25.1 a
Yumepirika	10.2	7.36 b	3.42 c	2.37 c	2.15 a	32.3 b
	13.4	7.45 ab	3.46 c	2.39 bc	2.16 a	33.3 b
	16.2	7.50 a	3.52 ab	2.41 b	2.14 a	34.7 a
	19.6	7.55 a	3.55 a	2.45 a	2.13 a	35.6 a

For each test, the mean followed by the same letter in the column within each type of rice do not differ statistically at 1% probability through the two-way ANOVA and Tukey's simple main effect. [a] – = non-dimensional and frictional characteristics decreased as moisture content decreased. Two-way ANOVA reported that such characteristics were highly affected by moisture content.

The NERICA varieties were closer in length, width, and thickness to Indica varieties (**Table 1**), and thus showed similar kernel volume. Two-way ANOVA did not report significant differences in volume among *NERICA-1*, *NERICA-4*, and *IR-28*. Moreover, *NERICA-4* shrank much more in length than it did in width with every decrease in moisture content level. As a result, its slenderness decreased as moisture content decreased (**Table 1**).

NERICA-4 also indicated the highest thousand-kernel weight and bulk density (**Figs. 1** and **2**). Additionally, two-way ANOVA did not report a significant difference between *IR-28* and *Yumepirika* in thousand-kernel weight (**Fig. 1**), and between *NERICA-1* and *Yumepirika* varieties in bulk density (**Fig. 2**).

The NERICA varieties showed the highest static angle of repose and static coefficient of friction (**Figs. 3** and **4**). Moreover, two-way ANOVA did not report significant difference among *IR-28*, *IR-50*, and *Yumepirika* in the static angle of repose (**Fig. 3**), and among varieties in static coefficient of friction (**Fig. 4**).

Effect of Thickness Fraction on Physical Properties of Milled Rice

In thickness distribution, the NERICA variety was closer to the Indica varieties. Japonica varieties indicated the thickest kernels and showed the biggest differences in thickness (0.10 mm each) between thickness fractions. By contrast, Indica and NERICA varieties indicated thinner kernels and showed smaller differences in thickness (0.05 mm each) between thickness fractions (**Fig. 5**).

Composition Analysis

In general, the highest thickness fraction within each variety contained a higher percentage of sound whole kernels and a lower percentage of broken, chalky, discoloured and damaged kernels, and hence contained higher quality samples. The quality of the NERICA variety was similar to the Indica varieties. Meanwhile, the Japonica type showed the highest quality, and also showed the smaller difference in the

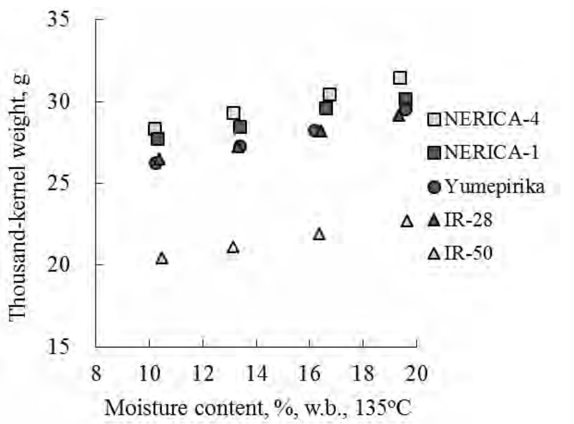


Fig. 1 Dependency of thousand-kernel weight of rough rice on moisture content

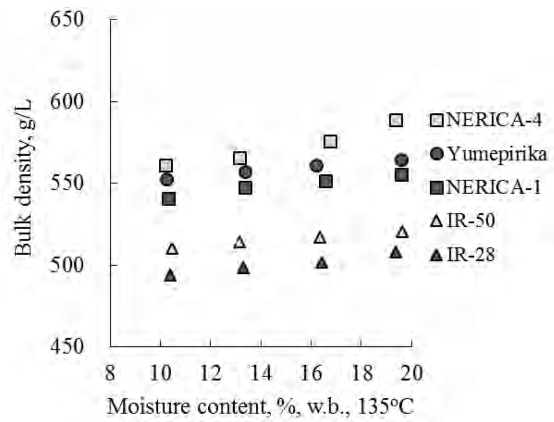


Fig. 2 Dependency of bulk density of rough rice on moisture content

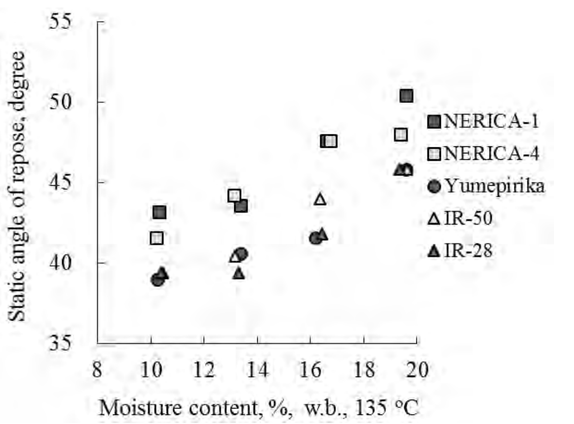


Fig. 3 Dependency of static angle of repose of rough rice on moisture content

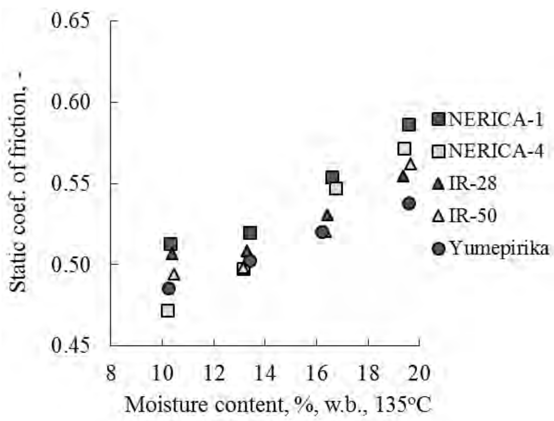


Fig. 4 Dependency of static coefficient of friction of rough rice on moisture content

percentage of sound whole kernel among varieties and thickness fractions (**Fig. 6**).

Dimensional, Mass, Frictional Characteristics of Milled Rice

In general, dimensional, mass, and frictional characteristics increased as thickness increased. One-way ANOVA reported that such characteristics were highly affected by kernel thickness.

The NERICA variety was closer in length, width, and thickness to Indica varieties. The two types of rice thus showed similar slenderness and volume of kernel of milled rice (**Table 2**). Moreover, the behavior shown by thickness distribution was caused by the similarity in kernel dimensions among NERICA and Indica varieties. Consequently, NERICA and Indica varieties were classified as long and medium classes of grain, as their average length was within the range of 6.6-7.5 mm, and their slenderness within the range of 2.1-3.0. The Japonica type was classified as short and round, as its length was 5.5 mm or less and its slenderness was less than 2.0 (Bhattacharya 2011b).

The NERICA variety was closer in weight, density, and fluidity to Indica varieties. However, Japonica varieties were heavier, denser, and flowed faster in volume (**Figs. 7** and **8**). Additionally, one-way ANOVA reported a significant difference in thousand-kernel weight among thickness fractions within each variety (**Fig. 7**). Meanwhile, in grain

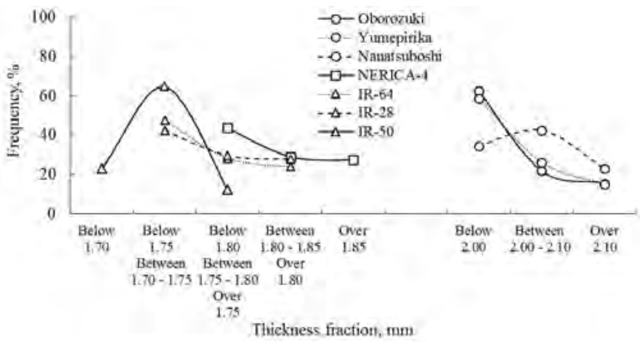


Fig. 5 Frequency distribution of milled rice by thickness fraction

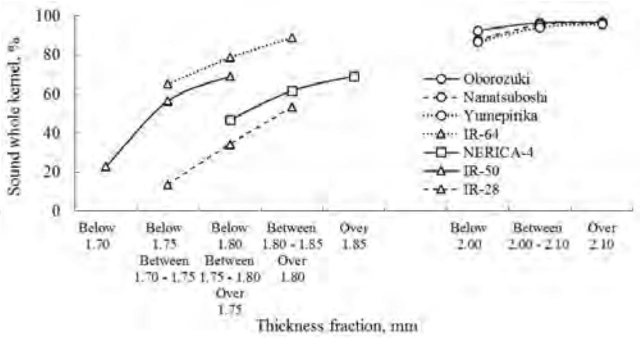


Fig. 6 Sound whole kernel of milled rice by thickness fraction

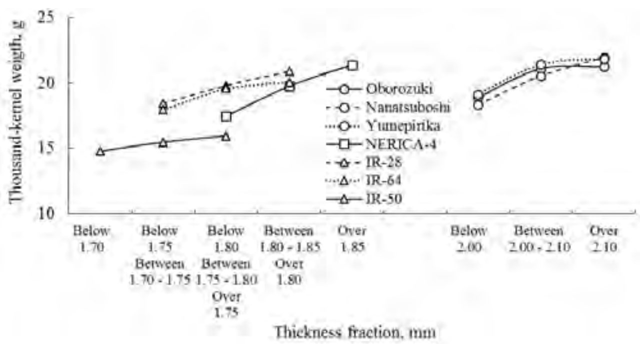


Fig. 7 Thousand-kernel weight of milled rice by thickness fraction

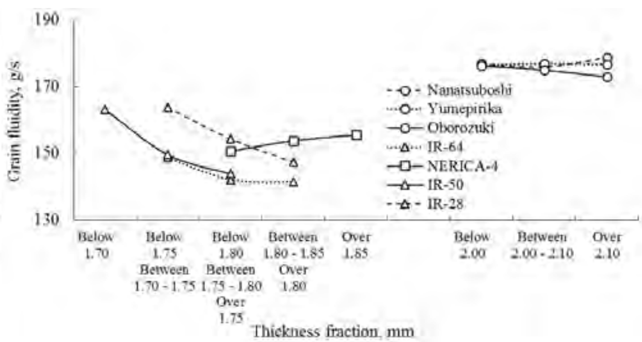


Fig. 8 Fluidity of milled rice by thickness fraction

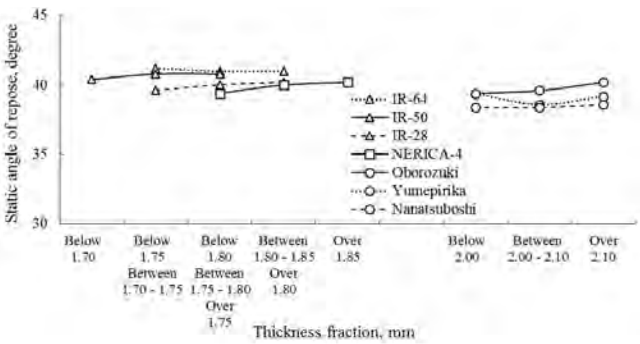


Fig. 9 Static angle of repose of milled rice by thickness fraction

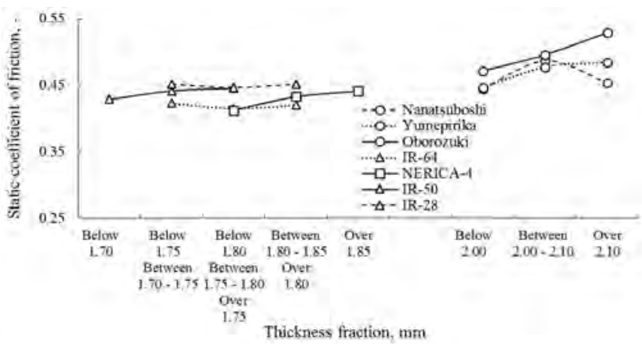


Fig. 10 Static coefficient of friction of milled rice by thickness fraction

fluidity, significant differences were reported among thickness fractions within each Indica variety (**Fig. 8**).

In angle of repose and coefficient of friction, the NERICA variety was closer to Indica varieties. However, Japonica varieties indicated the lower angle of repose and higher coefficient of friction (**Fig. 9** and **10**). Moreover, one-way ANOVA did not report a significant difference in static angle of repose among thickness fractions within each variety (**Fig. 9**). Meanwhile, in static coefficient of friction, significant differences were reported among thickness fractions within each Japonica variety (**Fig. 10**).

Discussion

Rough rice kernel of NERICA varieties apparently had a lower void space between the outer husk and the inner caryopsis compared to other varieties, and hence was heavier in mass despite not being higher in kernel volume. Moreover, rough rice of NERICA varieties indicated higher bulk density because the proportion of empty space in a bulk was lower due to their slenderness. However, the behaviour of the slenderness of NERICA varieties during drying affected the degree of packing of the kernel in bulk; they thus stood higher when piled and needed a greater force to initiate movement on a rubber surface.

Milled rice of the NERICA variety showed similar physical properties to those of the Indica type. Consequently, both types flowed in volume, stood when piled, and needed force to initiate movement on a rubber surface in the same way.

Information obtained in this study could be useful for technology development. Dimensional properties can be used for designing cleaning process, pneumatic conveying systems, fluidized bed dryers, and aeration systems in the drying process (Sablani and Ramaswamy, 2003). Mass characteristics can be useful for determining the diameter of tube conveyors: pneumatic and chute (Bucklin *et al*., 2007). Frictional characteristics can be useful for determining the horsepower required to drive belt conveyors (Wimberly, 1983), and the design of hopper at the bottom of a bin (Kunze *et al*., 2004).

Furthermore, because the NERICA and Indica types indicated similarity in kernel dimensions of rough rice and in dimensional, mass and frictional characteristics of milled rice, the technology used in the post-harvest processing of Indica varieties could be transferred and inserted in those countries where NERICA production has been expanding. Consequently, postharvest losses would be reduced and rice quality improved.

Table 2 Average value of milled kernel dimensions by thickness fraction

Variety	Thickness fraction mm	Length mm n = 200	Width mm n = 200	Thickness mm n = 200	Slenderness -[a] n = 200	Volume mm^3 n = 200
NERICA-4	Below 1.80	6.16 c	2.34 c	1.74 c	2.64 b	13.5 c
	Between 1.80-1.85	6.33 b	2.37 b	1.82 b	2.68 b	14.6 b
	Over 1.85	6.60 a	2.40 a	1.95 a	2.75 a	16.4 a
IR-28	Below 1.75	6.45 c	2.37 a	1.76 c	2.73 b	14.4 c
	Between 1.75-1.80	6.56 b	2.38 a	1.78 b	2.77 ab	14.8 b
	Over 1.80	6.68 a	2.40 a	1.93 a	2.79 a	16.3 a
IR-50	Below 1.70	6.22 c	2.07 c	1.67 c	3.00 a	11.4 c
	Between 1.70-1.75	6.38 b	2.10 b	1.73 b	3.04 a	12.3 b
	Over 1.75	6.44 a	2.12 a	1.77 a	3.04 a	12.8 a
IR-64	Below 1.75	6.74 c	2.16 a	1.72 c	3.13 b	13.3 b
	Between 1.75-1.80	6.91 b	2.17 a	1.76 b	3.19 a	13.9 c
	Over 1.80	7.03 a	2.18 a	1.83 a	3.23 a	14.8 a
Nanatsu-boshi	Below 2.00	4.68 c	2.83 c	1.95 c	1.66 a	14.0 c
	Between 2.00-2.10	4.80 b	2.89 b	2.10 b	1.66 a	15.7 b
	Over 2.10	4.99 a	3.00 a	2.32 a	1.66 a	18.6 a
Yumepirika	Below 2.00	4.92 b	2.96 c	1.95 c	1.67 a	15.0 c
	Between 2.00-2.10	4.99 a	3.00 a	2.01 b	1.67 a	16.5 b
	Over 2.10	5.04 a	3.06 b	2.12 a	1.66 a	17.8 a
Oborozuki	Below 2.00	4.91 c	2.86 c	1.98 b	1.72 a	15.1 c
	Between 2.00-2.10	5.09 b	3.01 b	2.02 b	1.71 a	17.1 b
	Over 2.10	5.21 a	3.07 a	2.12 a	1.70 a	18.7 a

For each test, the mean followed by the same letter in the column within each type of rice do not differ statistically at 1% probability through the one-way ANOVA and Tukey's simple main effect. [a] – = non-dimensional

Conclusions

Physical properties of rice were highly affected by moisture content and thickness. The NERICA and Indica varieties reported similar kernel dimensions of rough rice and dimensional, mass and frictional characteristics of milled rice. Information obtained in this study could be helpful in designing equipment required to improve the efficiency of postharvest processes and in developing a technology-transfer strategy. Consequently, such information could help to relieve the constraints to NERICA expansion, increase its production and improve the quality of the grain.

Acknowledgement

This study was supported by JICA Tsukuba International Centre, Japan, which helped us to collect both NERICA and Indica rice varieties.

REFERENCES

Bart-Plange, A. and E. A. Baryeh. 2003. The physical properties of Category B cocoa beans. Journal of Food Engineering, 60(3):219-227.

Bhattacharya, K. R. 2011a. Appendix A.1: Physical properties. In Bhattacharya, K. R. (Ed.), Rice Quality. A guide to rice properties and analysis (pp. 531-536). Cambridge, UK: Woodhead publishing limited.

Bhattacharya, K. R. 2011b. Physical properties of rice. In Bhattacharya, K. R. (Ed.), Rice Quality. A guide to rice properties and analysis (pp. 26-60). Cambridge, UK: Woodhead publishing limited.

Bucklin, R., S. Thompson, A. Abdel-Hadi and M. Montross. 2007. Grain Storage System Design. In Kutz, M. (Ed.), Handbook of farm, dairy and food machinery (pp. 113-165). New York: William Andrew Publishing.

Edenio, O. D., S. Kawamura and S. Koseki. 2015. Physical properties of rough and brown rice of Japonica , Indica and NERICA types. CIGR Journal, (Special issue: 18th World Congress of CIGR), 274-285.

Fukuta, Y., K. Konisho, S. Senoo-Namai, S. Yanagihara, H. Tsunematsu, A. Fukuo and T. Kumashiro. 2012. Genetic characterization of rainfed upland New Rice for Africa (NERICA) varieties. Breeding Science, 62(1):27-37.

Jain, R. K. and S. Bal. 1997. Properties of Pearl Millet. Journal of Agricultural Engineering Research, 66(2):85-91.

Japan Rice Millers Association. 1997. Rice Museum. Text of Quality Evaluation of Rice (In Japanese) (pp. 25-48), Japan: Japan Rice Millers Association and Kett Electric Laboratory

Kawamura, S. 2015. Fluidity of Grain. In Toyoda, K., T. Uchino and Y. Kitamura (Eds.), Agricultural and Food Process Engineering (In Japanese) (pp. 60-61). Tokyo: Buneido Publishing.

Kunze, R., L. Yubin and T. Wratten. 2004. Physical and Mechanical Properties of Rice. In Champagne, E. T. (Ed.), RICE: Chemistry and Technology (Third Edit., pp. 191-221). American Association of Cereal Chemists, Inc.

Mohsenin, N. 1986. PHYSICAL PROPERTIES OF PLANT AND ANIMAL MATERIALS. STRUCTURE, PHYSICAL CHARACTERISTICS AND MECHANICAL PROPERTIES (Third edit.). Pennsylvania, USA: Gordon and Breach Science Publishers.

Sablani, S. S. and H. S. Ramaswamy. 2003. Physical and Thermal Properties of Cereal Grain. In Chakraverty, A., A. S. Mujumdar, G. S. Vijaya Raghavan, and H. S. Ramaswamy (Eds.), Handbook of Postharvest Technology. Cereal, Fruits, Vegetables, Tea and Spices (Second edi., pp. 17-40). New York: Dekker Marcel, Inc.

Sun, H. and T. Siebenmorgen. 1993. Milling Characteristics of Various Rough Rice Kernel Thickness Fractions. Cereal Chemistry, 70(6):727-733.

Tollens, E., M. Demont, M. Sié, A. Diagne, K. Saito and M. C. S. Wopereis. 2013. From WARDA to AfricaRice: an Overview of Rice Research for Development Activities Conducted in Partnership in Africa. In Wopereis M., D. E. Johnson, N. Ahmadi, E. Tollens and A. Jalloh (Eds.), Realizing Africa's Rice Promise (pp. 1-23). Cotonou, Benin: CAB International.

Wadsworth, J. I., J. Matthews and J. J. Spadaro. 1982. Milling Performance and Quality Characteristics of Starbonnet Variety Rice Fractionated by Rough Rice Kernel Thickness. Cereal Chemistry, 59(1):50-54.

Wimberly, J. E. 1983. Technical Handbook for the Paddy Rice Postharvest Industry in Developing Countries. In Wimberly, J. E. (Ed.), International Rice Research Institute. Los Banos, Laguna, Philippines: International Rice Research Institute (IRRI).

Wiredu, A. N., B. O. Asante, E. Martey, A. Diagne and W. Dogbe. 2014. Impact of NERICA Adoption on Incomes of Rice-Producing Households in Northern Ghana. Journal of Sustainable Development, 7(1):167-178.

■■

Current Status and Future Prospects of Agricultural Mechanization in Egypt

by

Said Elshahat Abdallah
Associate Professor
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University
Kafr Elsheikh 33516
EGYPT
saidelshahat@agr.kfs.edu.eg

Wael Mohamed Elmessery
Associate Professor
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University
Kafr Elsheikh 33516
EGYPT

Farm Machinery Industry in Egypt

Contemporary Status Approach

Effects of dividing agricultural lands in 1960s

The outstanding mistakes which have been revealed from dividing the Egyptian agricultural lands in 1960s as a result of the so-called "Agricultural Reform Law" led to difficulties in using agricultural machinery, i.e., after someone has his own connected hectares that could allow him to use a complete mechanization of crops cultivation now it is limited in a few unconnected areas of acres (Bush, 2007), shown in **Table 1**. So the usage of huge machinery would not be applicable neither in cultivation nor irrigation. By 1980s, small size Japanese machinery—which fit the nature of mutilated form that Egyptian agricultural land became on to help farmers in continuation of their work much more easily—helped the increasing interest in using agricultural machinery and encouraged some side industries connected to them. Egyptian Government policy at this time encouraged mechanization in substantial proportions (Levy, 1985).

Overview of Egyptian Machinery Supply

Most developing countries undergoing agricultural mechanization begin by importing machines from abroad (Kerr, 1990). After 1975-76 the government encouraged mechanization because there was a large increase in tractors imports and stimulation of private sector for manufacturing agricultural implements. Between 1968 and 1978, 55% of land preparation was mechanized (Bahgat, 1978). Until 1988 the majority of agricultural machinery was imported except tractor attachments like plows that were belt in local workshops according to Kerr (1994), given in **Table 2**.

Local Manufacture of Farm Machinery

After the revolution in 1952 the lack of local fabricators make the government put a program to sequester many workshops and the usage of these workshops converted from serving farm machinery to

Table 1 Distribution of land ownership before and after agrarian reform laws, 1952-61 (Sallam, 1998)

Feddans	Landowners pre-reform	Landowners post-reform	Holding size pre-reform	Holding size post-reform	Landowners pre-reform, %	Landowners post-reform, %	Area owned pre-reform, %	Area owned post-reform, %
<5	2,642,000	2,919,000	2,122,000	3,172,000	94.3	94.1	35.4	52.1
5-10	79,000	80,000	526,000	516,000	2.8	2.6	8.8	8.5
10-20	47,000	65,000	638,000	648,000	1.7	2.1	10.7	10.6
20-50	22,000	26,000	654,000	818,000	0.8	0.8	10.9	13.5
50-100	6,000	6,000	430,000	430,000	0.2	0.2	7.2	7.1
100-200	3,000	5,000	437,000	500,000	0.1	0.2	7.3	8.2
200+	2,000		1,177,000		0.1		19.7	
Total pre-reform	2,801,000		5,984,000		100		100	
Total post-reform		3,101,000		6,084,000		100		100

other purposes. The main countries that Egypt imported its farm machinery from were USA and West Europe before 1952 and Egypt began to get replace them by Soviet Union and East German farm machinery. Unfortunately their products were not standardized so any shortage in spare parts would make them inoperative that encourage small workshops to make these spare parts. In 1962, NASCO—a public sector automotive manufacturing company—began to assemble a 50 hp Yugoslav tractor and assembly stopped in 1970. As shown in **Table 3**, distribution of tractors according to the sector and size in 1974 was listed. In 1978 production capacity of Ministry of Agriculture agricultural workshops was estimated to be 10-15% of the countries as listed in **Table 4**.

Thus there are 155 ha cultivated and 293 ha cropped land for each operable tractors.

Table 2 Annual sales of selected machines by source, 1988 (estimated)* (Kerr, 1994)

Machine	Imports	Locally manufactured	Total	Public sector	Private sector
Tractors (50-70hp)	3,000	1,500	4,500	3,000	1,500
Threshers	2,600	200	2,800	0	2,800
Plows	1,300	2,000	3,300	1,650	1,650
Trailers	0	2,000	2,000	1,000	1,000
Combines	100	0	100	0	100
Reapers and mowers	500	10	510	0	510

*All figures were estimated by machinery dealers except locally manufactured threshers, which were counted in the workshop survey.

Table 3 Sector distribution and size of tractors in Egypt in 1974 (Bahgat, 1978)

Engine, hp	Private sector and cooperatives	Public sector	Total
35	4,434	997	5,431
36-50	10,507	1,352	11,859
51-70	4,845	4,108	8,953
71-100	146	186	332
Total	199,322[a]	6,643[b]	26,575[c]

[a] of this number about 4000 are in cooperatives.

[b] of this number about 4000 are in land reclamation.

[c] an estimated 60% of total tractors are operable at any one time.

Table 4 Production capacity and unit cost of selected implements from Behera Company (Bahgat, 1978)

Item	Description	Monthly capacity (units)	Unit cost, US$
Thresher	360-450 kg/h – belt drive (tractor or elec. Motor)	50	658
Chisel plow	mounted 7-9 shanks, 20 cm depth	100	259
Chisel plow	trailed 9-11 shanks, 20 cm depth	100	994
Subsoiler	trailed – single shank w/ mole, 65 cm depth	20	588
Ditcher	trailed – 200 cm width, 45 cm depth	20	490
Blade/leveler (small)	trailed – 2 m widths	40	595
Blade/leveler (large)	trailed – 4 m widths	30	1,050
Trailers	4-wheel, 2 × 4 m box 4 t capacity	25	1,540

Present Status

Farm Machinery Industry in Egypt

Nowadays, of course the previous conditions that have been described in the previous section are still continuing and using the small-scale machinery and their attachments is remaining in Nile Valley and the Delta. After devaluation procedures and the great increase in fuel prices, the usage of farm machinery have affected partially but the majority of farmers cannot leave agricultural mechanization because the physical labor is very expensive. Moving to investments outside the Valley and the Delta, i.e., in the Western Desert in Lower Egypt mechanization is necessary because physical labor cannot cover the cultivated areas or for land reclamation but in some farms specialized in producing horticulture crops for exporting, the physical labor is necessary to meet the requirements of the overseas market according to its standards because the handling using farm machinery could cause a mechanical damage. By 1993, the agricultural sector have been completely liberalized (Khalifa and Moussa, 2017), hence the governmental policy in developing farm machinery industry was left to the private sector. Several corporations were established in Lower Egypt such as Tanta Motors Co. (since 1950) and in Al-Bohaira Governorate (**Fig. 1**).

Agricultural Mechanization Stations in Lower and Upper Egypt

Using Google Maps it is available

Fig. 1 A photograph of Tanta Motors Co. for farm machinery industry (Aboufreikha and Elbehery, 2007)

for user to determine several positions of agricultural mechanization stations and also several companies are related to agricultural mechanization in Egypt. By inserting "agricultural mechanization" in Arabic to Google maps fifteen locations of agricultural mechanization stations and facilities related to them were revealed in the Delta and Lower Egypt while one location was in Upper Egypt. From this it is evident that Upper Egypt is neglected by the government and need more care concerning this, **Fig. 2**.

Research Development

Research Funds in 1970-80s

According to Bahgat (1978), Ford Foundation in conjunction with nine universities and the Ministry of Agriculture a year-long survey was undertake from 900 farms in nine provinces and Ford Foundation sponsored a program for developing small machinery. In 1982-84 there was cooperation between Egyptian Ministry of Agriculture and the United States Agency for International Development (USAID) in different subjects like training and machinery management extension (USAID, 1983).

Current Funds

Presently, funds to agricultural machinery research are too little so such programs for graduate students are so limited for further research on machinery appropriate for Egyptian lands natures and conditions.

REFERENCES

Sallam, M. S. 1998. Agrarian reform in Egypt. Paper presented to the Land Reform Conference, Cascavel, Brazil.

Bush, R. 2007. Politics, power and poverty: Twenty years of agricultural reform and market liberalization in Egypt. Third World Quarterly, 28(8): 1599-1615.

Levy, V. 1985. Cropping pattern, mechanization, child labor, and fertility behavior in a farming. Economic Development and Cultural Change, 33(4): 777-791.

Kerr, John M. 1994. Institutional barriers to policy reform in Egypt: The case of the agricultural machinery industry. World Development, 22(2): 877-888.

Kerr, John M. 1990. Economic and institutional determinants of agricultural mechanization in Egypt. Ph. D. Thesis. The Food Research Institute and the Committee on Graduate Studies of Stanford University, USA.

Bahgat, A. 1978. Status of agricultural mechanization in Egypt. International Rice Research Institute, Proceedings of the International Agricultural Machinery Workshop. Los Baños, Philippines.

Khalifa, H. E. and H. A. Moussa. 2017. Soil and agriculture after the Aswan High Dam. In: M. Satoh and S. Aboulroos (Editors). Irrigated Agriculture in Egypt. Springer, Cham.

Aboufreikha, A. and A. Elbehery. 2007. A presentation prepared with a title of: Agriculture Mechanization in Egypt; the present and the future. Available on: http://www.agrievolution.com/Summits/2008/Presentations/Files/Egypt-Ministry_of_Agriculture_and_Land_Reclamation.pdf

USAID. 1983. Egyptian agricultural mechanization project (contract number 263-0031-HHC-01). Activity report number 11, 1 October 1983 – 31 December 1983. Submitted by Louis Berger International, INC., 100 Halstead Street, East Orange, New Jersey, USA. Available on: http://www.pdf.usaid.gov/pdf_docs/PDAAT797.pdf

■■

Fig. 2 Some locations of agricultural mechanization stations and related facilities in Egypt (Source: Google Maps)

Current Situation of Agricultural Tractors and Equipment in Egypt

by

Taher Kadah
Researcher
Agricultural Economics Research Institute
The Agricultural Research Center (ARC)
EGYPT
Taherkadah166@hotmail.com

Rasha Mohammed
Researcher
Agricultural Economics Research Institute
The Agricultural Research Center (ARC)
EGYPT
dr_rosha99@yahoo.com

Rania Khamis Ibrahim
Researcher
Agricultural Engineering research Institute
The Agricultural Research Center (ARC)
EGYPT
Rania.ibrahim22@yahoo.com

Hanafi Radwan
Chief Researchers
Agricultural Engineering research Institute
The Agricultural Research Center (ARC)
EGYPT
ashourhanafi@yahoo.com

Ahmed El behery
Emeritus, Chief Researchers
Agricultural Engineering research Institute
The Agricultural Research Center (ARC)
EGYPT
behery28@yahoo.com

Introduction

The Egyptian Economy is undergoing a process of liberalization and privatization. Agriculture is at the heart of the economy and consequently the liberalization and privatization policies have a significant influence. Farmers now are free to cultivate any crop they wish.

During the last few years, the costs of farm inputs have increased significantly including seeds, fertilizers, chemicals, energy and labor. Crop prices have also increased, but average crop yields have also increased. The increase in input cost partly recovered by the parallel increase in price of produce, but the farmer's gross margins is decreasing. The increase in the cost of both input and output ultimately will be in line with world prices. This means that in few years, Egyptian farmers will have to compete on an equal footing with farmers everywhere; therefore, must use progressively higher levels of technology in order for their land and labor productivity to keep pace with the world around them. The Egyptian Government, through the Ministry of Agriculture and Land Reclamation, is exerting a lot of effort, through and investment, in the agricultural sector to enable farmers to cope with the new policies.

Egyptian economy has traditionally relied heavily on the agricultural sector for food, fiber and other products. The agricultural sector provides the livelihood for about 55% of the inhabitants and employment for about 34% of the total employment and labor force. In addition, agriculture contributes about 20% of the gross domestic product (GDP) and about 20% of the total exports and foreign exchange earnings.

The demand for agricultural products is increasing due to population growth and the need for more export earnings. The country plan is to bring to cultivation a total of 3.4 million acres from the desert area up to the year 2017. This requires more emphasis on agricultural research to identify agricultural-sector constraints and to develop solutions through appropriate technologies especially in the newly cultivated and reclaimed areas. International Donor Agencies are helping the government to implement its policies, by providing technical assistance and funds. Most of these funds directed toward farmers and the private sector.

This report is concerned with mechanization. There is research and practical evidence that specific farm mechanization will enhance agricultural yields, lower production costs, and produce a positive net income for the farmers and national economy. The most factors are:

- Agronomic: Yield improved through tillage and cultivation practices.
- Crop Calendar Optimization: Crop yield improved through timely planting and harvesting.
- Reduced Production Cost: output per worker-hour increased, therefore, reducing on farm production labor cost.
- Harvest Loss Recovery: on-farm crop losses of main and the losses on secondary products reduced through improvement of harvesting technique.
- Current levels of mechanization

Mechanical Operations

Land Preparation

This phase involves the various field operations for preparing the land for cultivation, including seedbed preparation and planting for vegetable and perennial crops. The primary purpose of tillage operation is to produce edaphically conditions that are best suited for germination, seeding development and crop establishment. Soil structure within the seedbed should:

- Provide the necessary soil-seed contact to ensure good germination.
- Allow plant roots to penetrate easily into the soil to a proper depth so they can exploit the available nutrients and water.

Seedbed preparation influenced by numerous factors, the most important of which are tractors power, tillage equipment and seedbed preparation system used.

In Egypt, the soil is prepared for planting two or three time a year that is for winter, summer and Nile crops. Due to the intensive nature of agriculture, the time for soil preparation is very short. After crop harvesting, the soil is prepared directly without any adjustment for soil moisture. For example, to prepare the soil for wheat cultivation, plowing occurs in the wet soils after the rice harvest, in small areas in very dry soils after cotton picking. Under such circumstances seedbed preparation is technically, very difficult operation since the clay soils are too sticky to plough when wet and under dry conditions, large clods produced.

In both these cases, expensive secondary tillage operations needed to produce a proper seedbed. With these physical and environmental conditions, the tillage implements available to farmers are not sufficient for adequate soil preparation.

Normally farmers use the chisel plough for field plowing in two directions, one perpendicular to the other. The maximum attainable depth of the two paths ranges from 15 to 18 cm according to the prevailing soil conditions. On subsequent examination of the seedbed, it is noticeable that almost 20% of soil surface not distributed at all. Large clods are common and they embedded in the soil by the heavy wooden plate or hydraulic field leveler.

In seedbed preparation for all deep root crops and potatoes, farmers normally use the chisel plough at least four to five or even six times, with the field leveler to produce a smooth seedbed.

Recent studies have emphasized the difficulty of producing a good seedbed using these implements. The poor seedbed thus produced has made the use of mechanical planters or seeders impracticable. In such a case, there is a high chance of machine damage and a negative effect on seed germination. Manual planting is the common practice now. The result of both poor seedbed and manual planting is affecting germination rate, poor crop stand, and uneven plant growth, and thus a lower yield.

Planting

Nearly all planting and seeding are done by hand. Tractor rental station with the ARC, has successfully introduced the use of seed drills for wheat planting. Because of this program farmers, are now aware of the merits of using mechanized planting techniques. For potatoes, some farmers are now using semi- and fully automatic planters, but on a very limited scale in old land, but is widely used in new land.

For rice, small areas are planted using the Japanese rice transplanting system. Apart for this, there is no mechanized planting for other crops except on state farms or research projects. The main problem facing the use of mechanical planters and seeders is the current practice of seedbed preparation.

Agricultural Tractors

The 1982-1986 five years mechanization plan estimated the number of tractors to be 10,000. This is an average of 7 tractors for each 1,000 feddan (420 ha) (1 Fedan = 0.42 ha). During the last ten years, the number of tractors has increased significantly. The published figures from the undersecretary of agricultural economics, Ministry of Agriculture, in 2005 indicate that the tractors numbers is 97,600 as shown in **Table 1**.

Tractor annual replacement

In general, farmers keep their tractors as long as possible; the average lifetime could be 15 years. Consequently, as the number of tractors is around 97,600 tractors (2005). This means an annual replacement of 3,000 tractors. Mainly 95% of imported tractors from Romania, Russia and the Czech Republic, but the remaining 5% of the replaced tractors are imported from Western countries. **Table 3** is the estimated numbers of each power range to fulfill the required operations yearly.

Current trends of increasing the prices of Eastern type tractors will encourage farmers to buy Western type tractors.

Tractor manufactures origin

There are at least 11 different tractors brand in the tractor population of tractor: 42% are Romanian (U.T.B), 32% Russian (Belarus), 11% Egyptian local assembly (Nasr), 3.8% Czech Rep (Zetor), 3.8% Western types (Fiat, MF, Kubota, etc.), 1.5% (former Yugoslavian I.M.T and I.M.R) and 5.9% other makes as shown in **Table 2**.

Power range

The total tractor population is 65-70 hp representing 76.6%, while 23.4% are 25-60 hp. A noticeable difference exists among the governorates for this parameter.

Ownership

According to survey studies, 95.7% of tractor population owned by private farmers and hire service operators. Cooperatives own 1.4% while the remaining quantity owned by government agencies.

Tractor population density

On average, there are 11 tractors for each 1,000 feddan (420 ha). The difference between governorates is obvious. In Qena, the rate is 13.6 tractors/1,000 feddan, as compared to 10.6 in Dakahlia. In Fayoum are 8.8 tractors per 1,000 feddan.

The variation between the three governorates also exists between districts within the same governorate and between villages in the same districts.

Available Tillage Implements

Tillage equipment classified into two main categories: primary and secondary tillage equipment.

Primary tillage equipment cut and shatter soil and may bury trash by inversion, mix it into the tilled layer or leave it undisturbed.

Secondary tillage equipment work the soil to a shallower depth, providing additional pulverization, leveling and firming the soil, closing air pockets, killing weeds and helps to conserve moisture.

In Egypt, the distinction between primary and secondary tillage is not known and the tillage implements available to the Egyptian farmers on a very limited scope. The most common plough is a locally produced tractor mounted chisel type, with seven shanks. The plowing width is 2 m. Maximum attained depth in one path is not more than 15 cm.

From a professional point of view, this plough not considered as primary tillage equipment, but rather as a cultivator. Recently in sugar cane areas, farmers have started to use two bottom mould-board ploughs but on a very limited scale. Secondary tillage tools like harrows and motivators are limited use to the majority of the farmers.

The hydraulic field leveler is well designed and is reasonably efficient. It is manufactured in medium size workshops and companies. It has 1.8, 2.4, 3 or 3.6 m operating widths. The last two sizes accommodate laser-leveling requirements.

In summary, the only tillage implements owned by farmers and private sector machinery service operators are:

- Chisel plough (cultivator)
- Rotary cultivators
- Furrow opener
- Field leveler
- Disc harrow

Role of Dealers, Distributors and Local Manufacturers

One of the main functions of dealers and distributors should be to market their goods by demonstration at field days, providing a comprehensive after-sales service, making spare parts available and providing training for end-users. These functions are new for most dealers and distribution as other organizations used to perform these functions on their behalf.

With the implementation of privatization, dealers and distributors will have to undertake these functions in order to establish themselves in the market. The concerned institutions can help in this transitional phase by cooperating

Table 1 Number of tractors

Year	1995	1997	1999	2002	2005
Lower Egypt	62,250	55,578	57,217	60,524	60,266
Upper Egypt	26,840	27,428	29,038	29,527	37,334
Total	89,090	83,006	86,255	89,527	97,600

Source : Central Department of Economic Affairs Sector, MLAR, Egypt

Table 2 Tractors origin

Country	Brand	%
Romanian	Universal	42%
Russia	Belarus	32%
Egypt	Nasr	11%
Czech. Rep	ZETOR	3.80%
Western Type	DEUTZ, Lamborghini, New Holland, John Deere, Kubota, Case IH, SAME	3.80%
Yugoslavian	TMR, IMT	1.50%
Other makes	Foton, YTO, ACT	5.90%
Total		100%

Source: Central Department of Economic Affairs Sector, MLAR, Egypt

Table 3 Yearly tractor replacement

Tractor No.	Power range
2,000	60-70 hp
500	25-45 hp
500	90-150 hp

Source: Professional estimates

with dealers in demonstrations and in disseminating information. One of the key functions of the Principal Bank of Agriculture and Development Credit is to encourage private distributors at the branch level by providing loans for the provision of technical assistance to end users.

The development of local manufactures of farm machinery is a crucial factor if the level of mechanization is to be improved. Local manufacturers can ensure reasonable prices, the availability of spare parts, and the continuous development of the machinery. Although farm machinery is not very complicated, it requires materials of certain specifications and tolerance. Farm machinery manufacturers are well established in Europe and locally. One way to upgrade the industry is for local manufacturers to establish institution that can also provide loans to local manufacturers to upgrade their facilities and construct new production lines. The following are tentative list of manufacturers, companies and dealers functions in Egypt **Table 4**.

Ministry of Agriculture's Role and Support

In the late 1970s, the government of Egypt and MALR took the lead on promoting machinery custom hire service stations in each governorate, the main goal of these stations was to provide machinery services to farmers on actual cost, and introduce new type of equipment. The Ministry of Agriculture and Land Reclamation considered these stations as a pilot activity. The aim behind that was to encourage small contractors on village level to establish similar centers. The Ministry of Agriculture has established about 146 stations and some stations are under construction. Also, the public sector was involved and established ASWAN mechanization Co., NUBARIA engineering Co., and MENIA mechanization Co. In the meantime, QENA mechanization Coop. and General Mechanization Coop. were established and functioned at the same period. The Agricultural Engineering Research Institute being the official national governmental body is responsible for leading and conducting applied research on agricultural engineering. The main emphasis of the involvement is to strengthen and build up the agricultural machinery adoption process, this means to develop, test, and extend suitable technologies which address the most critical bottlenecks and constraints in the farming system.

Training Activities

Concerning Ministry of Agriculture and Land Reclamation strategic plan on capacity building in mechanization field, the ministry has established specialized agriculture machinery training centers fully equipped with advanced teaching materials and equipment. The fol-

Table 4 List of Egyptian Local companies produce Agricultural Equipment

Company Item	Tanta Motors	Mabrouk Inter.	Raga Egypt	Mitto for trading	Abou samra	Etmeed	ElNasr Co.	MM	Diamond	Others
Location	Tanta	Tanta	Bani Sueif	Tanta	Damiatta	Asuet	Cairo	Alex	Sadat City	
Cheisl plow	√	√	√	√		√				√
Disc Harrow	√			√						
Field Leveler	√	√	√	√						√
Bidder & Ditcher	√	√		√						√
Agri. Trailers	√	√	√	√	√	√			√	√
Water Tank trailers	√	√	√	√	√	√			√	√
Chemical sprayers	√		√	√	√				√	√
Chopper Machine	√	√		√						√
Front monnted Loader	√	√								√
Agri. Backhoe	√									
Rice mills										√
Corn Griners	√	√		√						√
Cattel Feed Mixers		√		√						√
Environment Equipment		√				√				
Tractor assamblly							√	√		
Wheat thresher	√	√							√	√
Paddy Rice Threshers	√	√								√
Irrigation Pumps Assembly			√							√
Compost Turner	√	√		√						

Source: Ministry of Agriculture and land Reclamation, Egypt lowing is a tentative list:

- Farm Machinery Training Center, Mamoura, in Alex. Governorate.
- Farm Machinery Training Center, Bilbas, in Sharkia Governorate.
- Rice Mechanization Center, Meet Eldiba, in Kafer El Shaik Governorate.
- Sids Machinery Training Center, Sisd, In Bani Souif Governorate.
- Senbllaween Training Center, in Dakahlia Governorate.

Agricultural Tractors and Equipment

Number of Agricultural Tractors and Equipment at the Level of the Country

Tractors

Statistical data for the period (2007-2015) indicate that the number of tractors increased from about 102 thousand in 2007 to about 133 thousand in 2015, an increase of about 31 thousand, which represents about 30.4% compared to the same in 2007, for many reasons perhaps the most important increase in agricultural newly reclaimed land during the period as shown in **Table 5** and **Fig. 1**.

Irrigation Pumps

As shown **Fig. 2** Statistical data for the period (2007-2015) indicate that the number of irrigation pumps increased from about 687.4 thousand in 2007 to about 957.5 thousand in 2015, an increase of about 270 thousand representing about 39% compared to the same in 2007. This may be due to the development of irrigation methods and desert reclamation during this period.

Threshing Machine

As shown **Fig. 3** Statistical data for the period (2007-2015) indicate that the number of threshing machine increased from about 50 thousand in 2007 to about 71.7 thousand in 2015 with an increase of about 20 thousand and about 41% compared to 2007.

Other machinery and equipment

Statistical data for the period (2007-2015) indicate that the number of machines and other equipment increased from about 174 thousand in 2007 to about 243 thousand in 2015 with an increase of about 69 thousand and about 40% compared to 2007 as shown in **Table 5** and **Fig. 4**.

Agricultural Tractors and Equipment at the Level of Egyptian Region

Tractors

As shown **Fig. 5**, the data for the average period (2011-2015) indicate that the number of agricultural tractors reached about 124 thousand tractors, and the governorates of lower Egypt had the largest share of about 77 thousand tractors, which

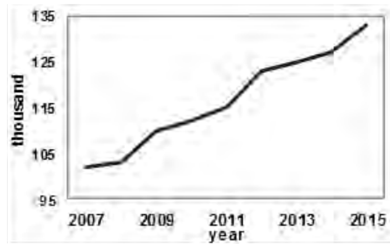


Fig. 1

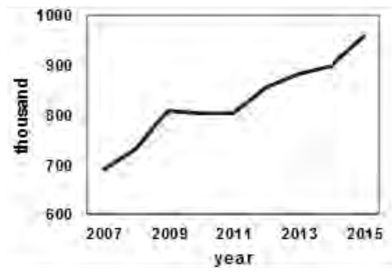


Fig. 2

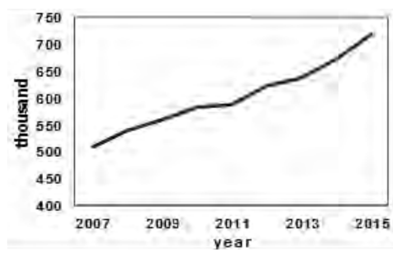


Fig. 3

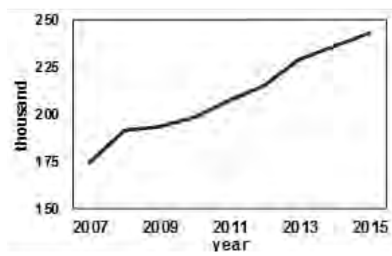


Fig. 4

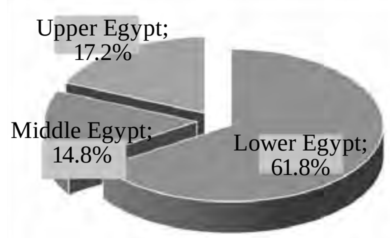


Fig. 5

Table 5 Numbers of agricultural tractors and equipment in the governorates (2006-2015)

Years	Agricultural Tractors	Irrigation Pumps			Threshing Machines	Other Machines & Equipment
		Stationary	Portable	Total		
2006	N.A	N.A	N.A	N.A	N.A	N.A
2007	102,219	107,100	580,398	687,498	50,886	174,118
2008	103,413	114,923	614,197	729,120	53,876	191,140
2009	110,068	140,161	666,122	806,283	55,926	193,861
2010	112,824	144,346	657,685	802,031	58,363	198,277
2011	115,491	149,642	652,725	802,367	58,695	207,651
2012	123,276	173,322	680,684	854,006	62,171	215,731
2013	125,131	165,607	714,846	880,453	63,790	229,882
2014	127,704	174,254	721,732	895,986	67,294	236,447
2015	133,298	175,016	782,518	957,534	71,743	243,847

Source: Central Department of Economic Affairs Sector, MLAR, Egypt
N.A (Not Available).

amounted to about 62% of the total number of tractors, while in the governorates of Middle Egypt on about 19 thousand tractors by an estimated 14.8%, while the governorates of Upper Egypt accounted for about 17% of the total number of tractors.

Irrigation Pumps

The data for the average period (2011-2015) indicate that the number of irrigation pumps reached about 878 thousand machines, and the governorates of lower Egypt the largest share of about 590 thousand irrigation machines by about 67% of the total number of irrigation pumps, while in the governorates of Middle Egypt About 170 thousand machines at a rate estimated at 19.4%, and the governorates of Upper Egypt accounted for about 10% of the total number of irrigation pumps as shown **Fig. 6**.

Threshing Machine

As shown **Fig. 7**, the data for the average period (2011-2015) indicate that the number of threshing machines reached about 65 thousand machines, and the governorates of lower Egypt accounted for the largest share of about 42 thousand machines, which amounted to about 64.4% of the total number of threshing machines. Similarly, in the governorates of Middle Egypt about 10 thousand machines by an estimated 16.2%, while the governorates of Upper Egypt accounted for about 14% of the total number of study machines and ablation.

Agricultural Tractors and Equipment at the Governorates

Tractors

As shown in **Table 6** Data for 2015 indicate that the total number of tractors reached about 133 thousand tractors, of which about 125 thousand tractors representing 94% in the governorates within the valley, where the governorates of Kafr El-Sheikh about 17 thousand tractors representing 12.6%, and Sharkia about 13 thousand tractors representing about 10% of the total. The number of agricultural tractors in Egypt, respectively, the governorates of Dakahlia 13 thousand tractor representing 9.5%, El-Beheira 12 thousand tractor representing 9.2%, El-Gharbia 11 thousand tractor representing 8.5%, Menia 8.1 thousand tractor representing 6.09%, Assiut 8 thousand tractor representing 6.04%, and Menoufia 7.8 thousand tractor representing 5.9% for the same year as shown **Fig. 8**.

Table 6 Numbers of Agricultural Tractors and equipment In The Governorates, 2015

Governorates	Agricultural Tractors	%	Irrigation pumps	%	Threshing Machines	%
Behera	12,262	9.2	144,178	15.06	6,361	9
Gharbia	11,305	8.48	109,304	11.42	5,256	7
Kafr – Elsheikh	16,848	12.64	99,502	10.39	14,839	21
Dakahlia	12,633	9.48	35,349	3.69	5,197	7
Sharkia	13,416	10.06	118,888	12.42	8,643	12
Menoufia	7,857	5.89	56,353	5.89	2,612	4
Menia	8,121	6.09	81,653	8.53	6,258	9
Assuit	8,050	6.04	29,536	3.08	6,666	9
Other governorates	34,401	29.42	254,085	28.56	14,679	22.87
Inside the valley	124,893	93.69	928,848	97	70,511	98
Noubaria	5,220	3.92	19,200	2.01	492	1
Other governorates	3,185	2.45	9,486	1	740	1.04
Outside The Valley	8,405	6.36	28,686	3.01	1,232	1.73
Total	133,298	100	957,534	100	71,743	100

Source: Central Department of Economic Affairs Sector, MLAR, Egypt

The governorates outside the valley contributed to the number of tractors about 8.4 thousand tractors representing about 6%, mean while Nubaria region about 5 thousand tractors representing about 3.9% of the total Republic.

Tractor Population Density

The average five years from 2011 to 2015 estimated the number of tractors 124,980. on average of 8 tractors for each 1,000 feddan (420 ha).

The difference between governorates is obvious. In Qena the rate is

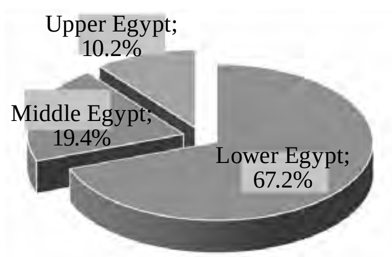


Fig. 6

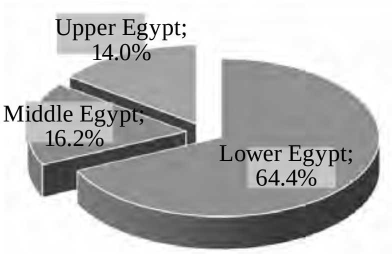


Fig. 7

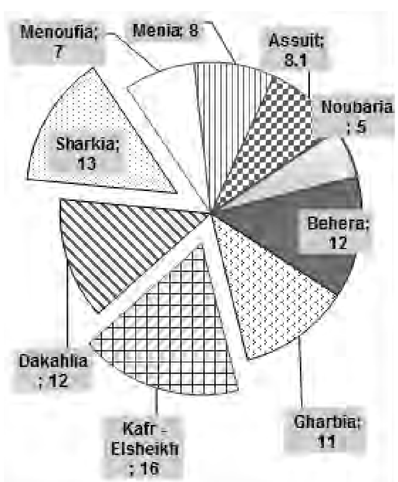


Fig. 8

15 tractors/1,000 feddan, as compared to in Gharbia and Kafr El-Shikh tractors 16 per 1,000 feddan in 2015.

Irrigation Pumps

The data in 2015 indicate that the total number of irrigation pumps reached about 957 thousand machines, of which about 928 thousand pumps representing about 97% in the governorates within the valley. The governorates of Behera about 144 thousand pumps representing 15%, and Sharkiya about 118 thousand pumps representing 12.4% and Al-Gharbia about 119 thousand pumps representing 11.4% of the total number of irrigation pumps in Egypt. The governorates of Kafr El-Sheikh about 99 thousand pumps representing 10.4%, Menia about 81 thousand pumps representing 8.5%, Menoufia about 56 thousand pumps representing 5.9%, El-Dakahlia about 35 thousand pumps representing 3.7% and Assiut about 29 thousand pumps representing 3% respectively as shown **Fig. 9**.

The outside the valley contributed to the number of irrigation pumps with about 28 thousand machines representing about 3%, meanwhile the Nubaria region about 19 thousand machines representing about 2% of the total Republic.

Threshing Machine

Data for the year 2015 indicate that the total number of Threshing machines reached about 72 thousand machines, of which about 71 thousand machines represent about 98% in the governorates within the valley, where the governorates of Kafr El-Sheikh about 15 thousand machines representing 21%, Sharkia about 8 thousand machines representing 12%. The total number of Threshing machines in the Republic, respectively, followed by Assiut about 6 thousand machines representing 9%, Behera about 6 thousand machines representing 9%, Menia about 6 thousand machines representing 9%, Gharbia about 5 thousand machines representing 7%, Dakahlia about 5 thousand machines representing 7% and Menoufia about 2 thousand machines representing 4% respectively as shown **Fig. 10**.

The Governorate outside the valley contributed to the number of threshing machines of about a thousand machines representing about 2% of the total Republic.

Agricultural Tractors and Equipment by Brand

Tractors

The average period (2007-2015) indicates that the most used tractors in Egypt are U.T.B, Nasr, Belarus Brand with about 43, 28, 16 thousand tractors representing about 37%, 23.9% and 13.8% of the total agricultural tractors. Then comes Kubota, Zetor, Fiat, and Yugoslavia Brand by 4.4%, 3.1%, 2.9%, 2.7% of the total as shown **Fig. 11**.

Irrigation Pumps

As shown **Fig. 12**, data for the average period (2007-2015) indicate that the most used irrigation pumps in Egypt are Kirloska, Piter Brand with about 246,92 thousand machines representing about 30%, 11% of the total irrigation pumps. Then comes Deutz, Kubota Brand representing 9.1%, 8.6% of the total.

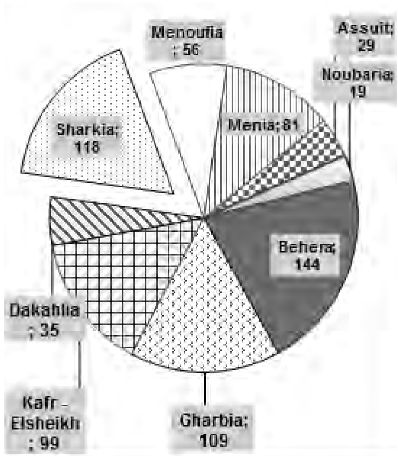


Fig. 9

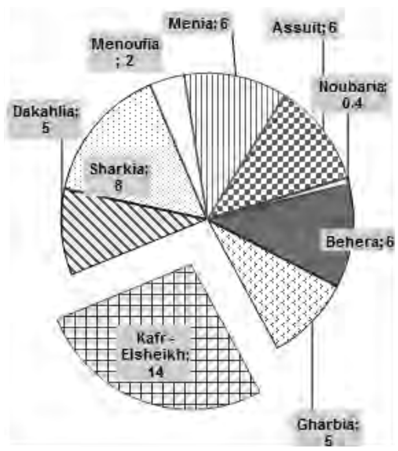


Fig. 10

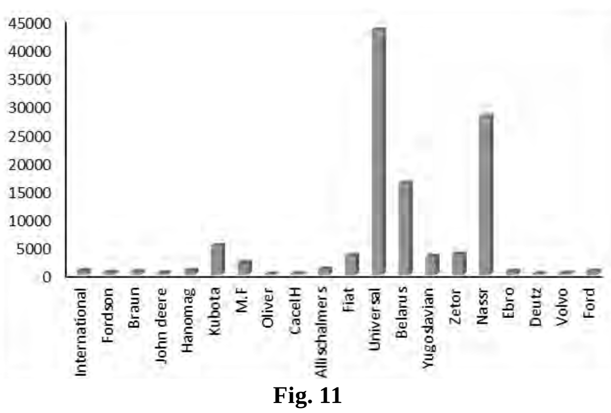


Fig. 11

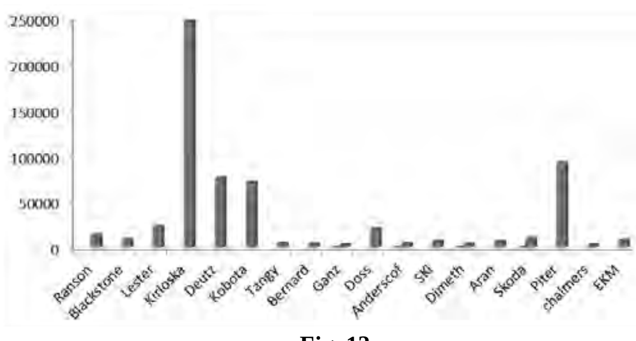


Fig. 12

Threshing Machine

Data for the period (2007-2015) indicate that the most threshing machines local manufactured are 77.4% of the total. Next comes Marshal 3.8%, Danube (Bulgarian) Brand representing 3.6% of the total as shown **Fig. 13**.

Agricultural Tractors and Equipment by Brand Name, According to Geographical Sectors*

Tractors

The data for the period (2011-2015) indicate that the number of agricultural tractors reached about 124 thousand of tractors, and number in the governorates of lower Egypt about 77 thousand tractors, and the most used brands in those provinces Romanian about 27 thousand representing 35% , Nassr Brand about 24 thousand tractors estimated at 31.6% of the average number of tractors in that period accounted for about 67%. The Russian brand is then 7.4% of the average number of tractors in lower Egypt as shown **Fig. 14**.

While the number of tractors in the governorates of Middle Egypt

*Source: Central Department of Economic Affairs Sector, MLAR, Egypt

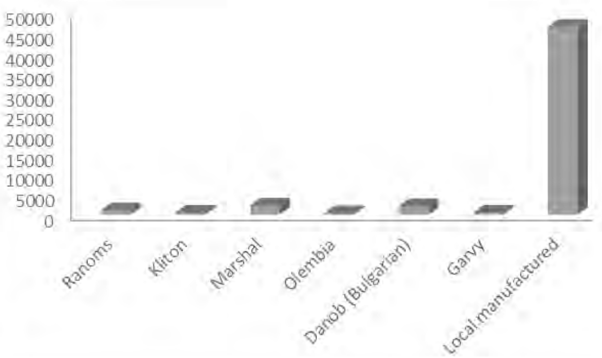


Fig. 13

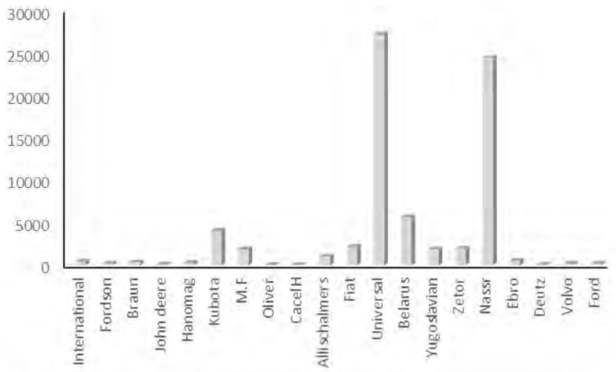


Fig. 14

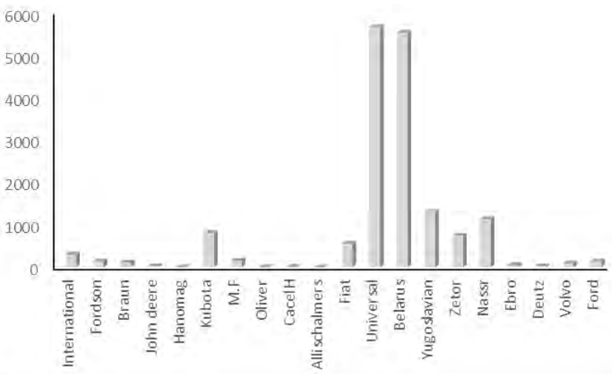


Fig. 15

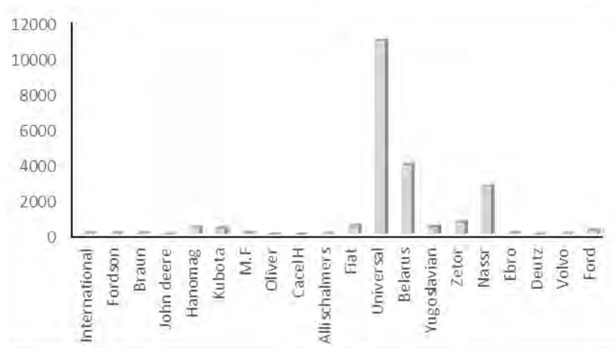


Fig. 16

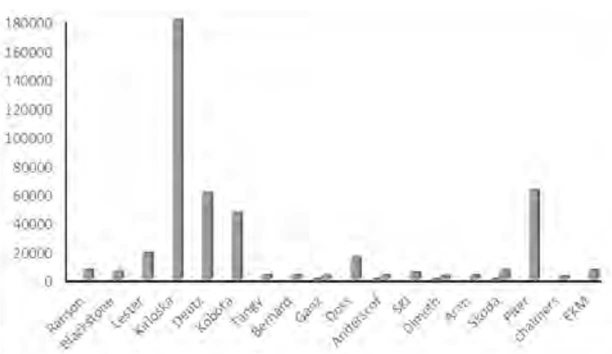


Fig. 17

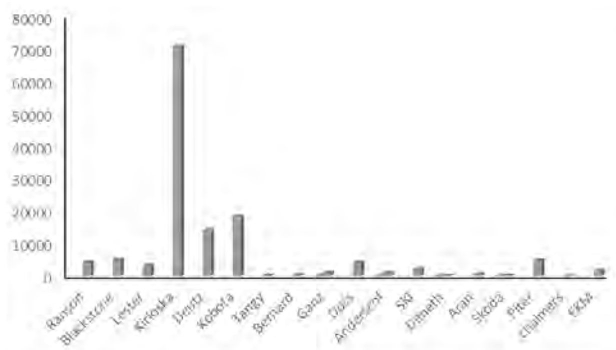


Fig. 18

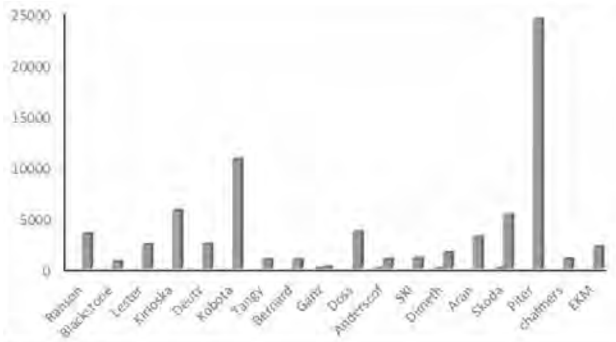


Fig. 19

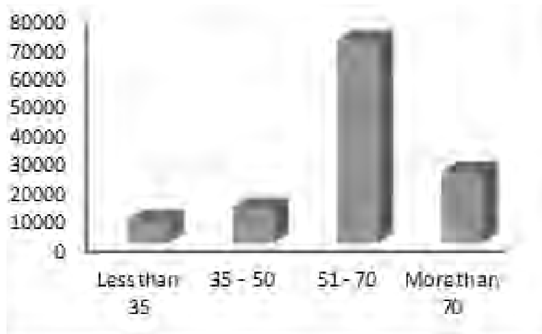


Fig. 20

about 18 thousand tractors, and the most used brands in those provinces, the Romanian 6 thousand representing 30.7% and, Russia about 5 thousand tractors by 29.9% of the average number of tractors in the governorates of Middle Egypt, Nasr by 6.2% of the average as shown **Fig. 15**.

As shown **Fig. 16**, the highest tractor number in governorates in Upper Egypt have acquired about 21,000 tractors, and the most popular brands in these governorates are Romanian, with about 11.4 thousand tractors by 50.4% and 18%, by the average number of tractors in Upper Egypt governorates. Next comes Nasr brand about 12.3% of the average, representing more than 80% of the total number of brands.

Irrigation Pumps

As shown **Fig. 17** The data for the period (2011-2015) indicate that the number of irrigation pumps reached about 878 thousand machines, about 590 thousand in the provinces of lower Egypt, and the most used brands in those provinces Kirloska about 179 thousand representing 30%, Piter about 61 thousand representing 10%, Deutz about 59 thousand representing 10% of machines in lower Egypt.

As shown **Fig. 18**, while the number of irrigation pumps in the governorates of Middle Egypt about 170 thousand during the average of the same period, and the most used brands in those provinces Kirloska about 70 thousand representing 42%, Kubota about 18 thousand representing 11% of the average number of irrigation pumps in the governorates of Middle Egypt.

As shown **Fig. 19**, the governorates of Upper Egypt acquired about 89 thousand irrigation pumps, and the most used brands in these provinces Peter about 24 thousand representing 27.2%, Kubota about 11 thousand representing 12% of the average number of irrigation pumps in the governorates of Upper Egypt.

Tractors in Terms of power and ownership

As shown in **Table 7**, the number of tractors during the period (2007-2015) according to the horsepower less than 35 horsepower, estimated at about 8 thousand tractors representing about 7% of the average number of tractors. While the number of tractors at power 35-50 hp about 12 thousand tractors on average, which is about 10.5% of the average total number of tractors.Tractors of 51-70 hp 71,000 tractors as shown **Fig. 20**, representing about 60.1% of the total number of tractors. The number of tractors more than 70 horsepower: The average number of tractors is about 25,000 tractors representing about 21.6%

Table 7 Numbers of Agricultural Tractors According to Powers, Ownership in the Governorates (2006-2015)

years	Tractor Numbers	Power by Horse				Tractor Ownership		
		Less than 35	35-50	51-70	More than 70	Individuals	Associations	Organizations
2006	N. A	N. A	N. A	N. A	N. A	N. A	N. A	N. A
2007	102,219	4,843	10,639	65,634	21,103	95,491	2,913	3,815
2008	103,413	5,296	10,250	65,153	22,714	98,686	1,892	2,835
2009	110,068	7,115	10,238	69,492	23,223	105,519	1,577	2,972
2010	112,824	6,798	10,466	71,907	23,653	107,781	1,899	3,044
2011	115,491	8,512	11,876	70,737	24,366	110,338	1,849	3,304
2012	123,276	8,651	13,264	75,421	25,940	117,468	2,701	3,107
2013	125,131	9,794	12,843	73,828	28,666	117,678	3,597	3,856
2014	127,704	10,358	14,817	74,635	27,894	123,294	1,548	2,862
2015	133,298	12,421	16,600	74,339	29,938	127,469	1,936	3,893

Source: Central Department of Economic Affairs Sector, MLAR, Egypt; N. A (Not Available)

Fig. 21

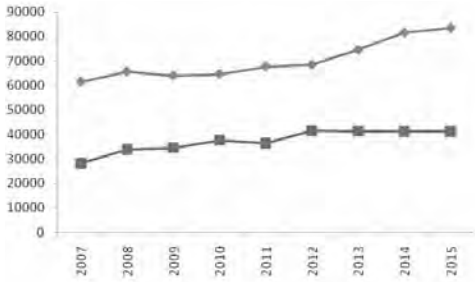


Fig. 22

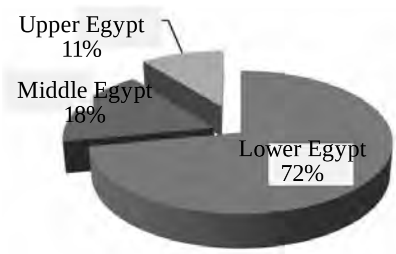


Fig. 23

of the average of tractors. The adult 117 thousand tractors The majority of power is between 51-71 hp, where they account more than 61% of the total power in the agricultural sector, followed by tractors with more than 70 hp, of 21.6% of the average Total tractors.

The number of the tractor ownership, the data for the same period show that they are distributed among the private representing 95%, associations representing 2% and owned representing 3% respectively, indicating that the private sector is dominated by the majority of the tractors working in the agricultural sector as shown in **Fig. 21**.

Pesticides Sprayers

As shown **Fig. 22**, statistical data for the period (2007-2015) indicate that the number of pesticide sprayers in the Egypt increased from about 89,000 in 2007, Including 61,000 knapsack sprayers, 28,000 big sprayer motors to about 125,000 in 2015, of which 84,000 were submachine sprayers, 41,000 large sprayers.

As shown **Fig. 23**, data for the average period (2007-2015) indicate that the number of pesticide sprayers reached about 100 thousand machines, and the governorates of lower Egypt accounted for the largest share of about 71 thousand sprayers, which amounted to about 72% of the average total. While in the governorates of Middle Egypt about 17 thousand sprayers estimated at about 18%, and the governorates of Upper Egypt accounted for about 11% of the total number of pesticide sprayers.

Recommendations

In light of the results that can be reached, the study recommends the following:

- Increasing the number of agricultural tractors in light of the increasing investment opportunities in the agricultural sector in Egypt.
- Increase the opportunity for a variety of brands of agricultural tractors in Egypt.
- Attention to areas of agricultural reclamation and new agricultural projects.

REFERENCES

Central Department of Economic Affairs Sector, MLAR, Egypt.

Agricultural research Center, Ministry of Agriculture and land Reclamation, Egypt.

■■

Present Status and Future Prospects of Agricultural Machinery Industry in Ghana

by

Ahmad Addo
Associate Professor
Dept. of Agricultural and Biosystems Engineering
Kwame Nkrumah University of Science and Technology (KNUST), Kumasi
GHANA

Shadrack Kwadwo Amponsah
Research Scientist (PhD) and Agricultural Engineer
CSIR-Crops Research Institute, Kumasi
GHANA

Introduction

Agriculture plays a noticeable part in the economies of most developing countries in sub- Saharan Africa (SSA) (Dewbre and de Battisti, 2008). In Ghana, it has been the principal sector for the development and growth of the economy for several decades (Buri *et al*., 2011). Ghana Statistical Service (2017) reports that the agricultural sector employs an estimated 44.7% of the population and contributes 14.3% to the country's Gross Domestic Product (GDP). According to Ghana Cocoa Board (2017), cocoa export alone generates about US$2 billion in foreign exchange, contributes approximately 57% of total agricultural export annually and is a major contributor to government revenue (30% of all export revenue) and GDP. Agriculture in Ghana is predominantly on a smallholder basis (less than 2 ha) using rudimentary technology to produce about 80% of the country's total agricultural output, though its activities occupy 56% of the country's total land area of 23,884,245 hectares (MoFA SRID, 2016). Due to the predominantly gentle slope nature of the country's agricultural lands, effective agricultural mechanisation is favoured, especially in the Northern part of the country.

Despite the contribution of agriculture to Ghana's economic development, the sector suffers from some serious challenges. The Ghana News Agency (GNA), 2016 cited in a report, low level of technology, inadequate number of agricultural extension officers, shortage and high cost of labour, prevalence of pests and diseases, high cost of farm inputs, limited credit facilities, land disputes, poor marketing network and facilities, and low prices of farm produce as some of the constraints confronting the agricultural sector. It is therefore not surprising that agricultural productivity in Ghana and the sub-Saharan African region as a whole has been on the decline over the past decades owing to these challenges.

Yields of maize and other staple cereals have typically remained at about 1.7 t/ha, which is about a third of the average achieved in Asia and Latin America (Abdulai *et al*., 2013). Studies by Wood (2013) report significant yield gaps for maize where actual yields are 50% to 80% less than achievable yields. Yields of most crops are still far below their potentials, and the level of modern agricultural mechanisation adoption in agricultural production and processing is still extremely low (Diao, 2010). Ghana depends heavily on imported rice with an estimated US$ 200-400 million worth of rice imports annually, accounting for more than 50% of all rice consumed in the country (USAID, 2009; Angelucci *et al*., 2013; Okine, 2014). Kumar and Kalita (2017) indicated that for most developing countries, between 30% and 50% of agricultural produce is lost due to poor harvest and post-harvest handling, storage and processing methods. Ghana's agricultural production is principally rainfall dependent with only 2% of the total agricultural land currently under various forms of mechanised irrigation (MoFA SRID, 2016). The low productivity could be a direct result of smallholder farmers' unfamiliarity with modern agricultural technologies.

A worrying trend in Ghana and the SSA region is that agriculture is increasingly becoming unattractive to the youth (Naamwintome and Bagson, 2013; Awiah, 2015). The high level of drudgery, coupled with the unavailability of appropriate technology and equipment, especially during production and postproduction operations is a major cause of this situation. It is not uncommon to see majority of Ghanaian youth, who could have been actively involved in agriculture, venturing into other profit-making businesses including illegal small-scale mining popularly known as "galamsey". This has led to labour shortages, causing unnecessary increases in labour cost for agricultural operations in most farming communities (Djokoto and Blackie, 2014). If appropriate measures are not taken, this could seriously threaten Ghana's agricultural sector with the current ageing farmer population. Studies by CARD (2010) identified inadequate appropriate technology as a major problem that may constrain agricultural production in the country. The mechanisation of agricultural operations is an essential step toward increasing production efficiency (Kibaara, 2005). Amponsah *et al*. (2012) reiterated that without effective mechanisation, Ghana's food and agricultural sector will not make the expected economic impact.

History of Agricultural Mechanisation in Ghana

Agricultural mechanisation is the application of agricultural engineering principles and technologies to agriculture, using mechanical systems in food, fibre and fuel processing, and also, in the production, processing, handling and storage of agricultural produce (Adamade and Jackson, 2014). Gifford (1992) reiterated that it embraces the manufacture, distribution, and operation of all types of tools, implement, machines and equipment for agricultural development. Agricultural mechanisation is also aimed at decreasing human drudgery, increasing yields through better timeliness of operations because of the accessibility of more power, bringing more land under cultivation, providing agriculture-led industrialisation and markets for rural economic growth and ultimately improving the standard of living of farmers (FAO and UNIDO, 2008). To solve both seasonal and permanent labour constraints, mechanisation has a long history in Ghana and has in recent times received appreciable support from the government aimed at fostering agricultural intensification. It is important to also note that agriculture is becoming increasingly mechanised throughout the world. As industrialised nations approach complete mechanisation, many developing countries are also making significant shifts toward mechanised farming (McCauley, 2003). According to Abdulai *et al*. (2013), about 40% of farmers in Ghana use some form of mechanisation. Majority of the farmers use only available technology for various agricultural production activities. In most cases, these technologies are not appropriate and efficient.

Mechanisation comprises three main power sources; human, animal, and mechanical. Hand tool technology is the simplest and basic level of agricultural mechanisation which involves the use of simple tools and implements using human muscle as the main power source. Because the human muscle is the main power source in this technology, it limits work rate since intermittent rest periods are required. Thus a farmer on the average can cultivate only a hectare of land. It is therefore not surprising that most farmers are involved in subsistence agriculture leaving large tracts of land uncultivated. FAO and UNIDO (2008) estimated that about 50% of farmers in Ghana use hand tool technologies, 42% use draught animal power and 8% use mechanical power in agriculture. The most common tools used in hand tool technologies are the hoe, machetes and axes for clearing land, weeding, seedbed preparation and harvesting.

The second level of mechanisation is draught animal technology which refers to implements and machines utilizing animal muscle as the main power source. The use of draught animals dates back to 2000 BC in Ethiopia. In South Africa, it started in the fifteenth century, while in most parts of SSA it started at the beginning of the twentieth century. In areas where traction was introduced, it was mainly associated with European settlers, missionaries and different colonial administrations, which promoted the technology in an attempt to expand cash crop production to serve the industrialised world. Animal traction is one of the sources of power in smallholder agriculture in the region, contributing up to 40% of the total power use in some countries such as Botswana (Pawlak *et al*., 2002). Kline *et al*. (1969) cited that the Tanzanian government even reversed an earlier decision of actively encouraging engine-powered mechanisation to one of limited use of tractors in an effort to promote the use of oxen for cultivation.

Animal traction technology, which is widespread in the Upper-East, Upper-West and Northern regions, was introduced in Ghana by the British colonial government in the 1930s. There are also a few places in the Brong Ahafo, Ashanti, Volta, Greater Accra and Eastern regions where animal traction is being gradually introduced (Bobobee, 1999). Animal traction was mainly employed for various tillage operations and transport of farm produce. Animal traction technology was relegated immediately after independence because it was considered to be outdated and inappropriate (Bobobee, 1997). However, after tractorisation attempts failed in the 1960s and early 1970s, ox traction received new attention. Subsequently, new government and NGO projects were launched to support further diffusion of ox traction (Herbst, 1993; Bobobee, 1999). However, some of these projects were not successful. Despite the long history of the technology in the country, animal traction is used on less than 15% of the arable land in Ghana (Madama *et al*., 2008 as cited in Makki *et al*., 2017).

Mechanical power technology is the highest technology level in agricultural mechanisation and embraces all agricultural machinery which obtains its main power from other sources other than muscular power. Tractors were introduced in Africa from the 1940s onwards, in the periods leading to independence of most Sub-Saharan countries and immediately thereafter. They were first used in commercial white settlers' farms, but they spread quickly through tractor hire schemes for small farmers, initially promoted by aid agencies, donor countries and tractor manufacturers before the drive was taken up by government. Policies favouring tractorisation were then initiated. This led to the establishment of large tractorisation scheme in developing countries in the 1960s. After gaining independence, many governments promoted the use of tractors in an effort to increase both food and cash crop production in a drive to be self-sufficient in food, produce raw material for local industries and increase foreign currency reserves (FAO, 2005).

Benin (2015) cited that it is because mechanisation is seen as a way of relieving drudgery that tractor-based mechanisation has historically received popular support among policy makers across Africa and in other developing countries. Different makes of tractors such as Massey Ferguson, John Deere, Ford, Case International, Swaraj, Same and Leyland are used in various parts of the country for both agricultural and non-agricultural purposes. These tractors are usually employed for land preparation operations (Clarke and Bishop, 2002) with majority of them located in Nyankpala, Navrongo, Bawku, Tamale, Techiman, Ejura, Kumawu, Wenchi and the Afram Plains (Taiwo and Kumi, 2015). **Fig. 1** shows the number and the trend of wheel and crawler tractors (excluding garden tractors) available for agriculture in the country from 1961 to 2005 according to FAOSTAT (2016).

Results from the graph clearly summarises the tractorisation situation in Ghana since its introduction in the 1960s. Notwithstanding the unfortunate fact that available number of tractors for agricultural use is on a steady decline, data from 2006 to 2016 is non-existent and thus immediate intervention from the government is needed if agricultural production can make any meaningful economic impact.

Status of the Agricultural Machinery Industry

In recent years, most countries in SSA, including Ghana, have seriously attempted to introduce mechanised agricultural technologies from Asia and other developed countries to help boost the agricultural sector (Rickman *et al*., 2013). Regrettably, these efforts have not really achieved expected results. Besides the fact that these technologies are unaffordable and in most cases unavailable to these resource-poor farmers, they are not well suited to local conditions (CARD, 2010). Moreover, because these machines or technologies sometimes cost a fortune, it is highly uncertain that even some of the larger farms in the tropics could raise that much capital to purchase them. In most cases, they could only be bought by governments. The country's recent policy of advancing mechanisation emphasises the importance of public-private partnerships. A typical example of such government intervention is the provision of tractors at subsidised rates to farmers and entrepreneurs who run 89 Agricultural Mechanisation Service Centres (AMSECs) within 62 districts across the 10 regions of the country. Moreover, markets for mechanisation hire services in Ghana is generally low with usually very little demand due to the lack of awareness among smallholders of the need for mechanised services (Sims *et al*., 2016). It was to this end that the government saw the need for the establishment of the AMSECs. The AMSECs programme was initiated in 2003 and established in 2007 to provide agricultural mechanisation services to farmers who cannot afford to purchase agricultural machinery on their own. (MoFA SRID, 2016).

Despite government's effort to increase farmer adoption of appropriate mechanisation for improved agricultural production and increased national food security through the establishment of Ag-

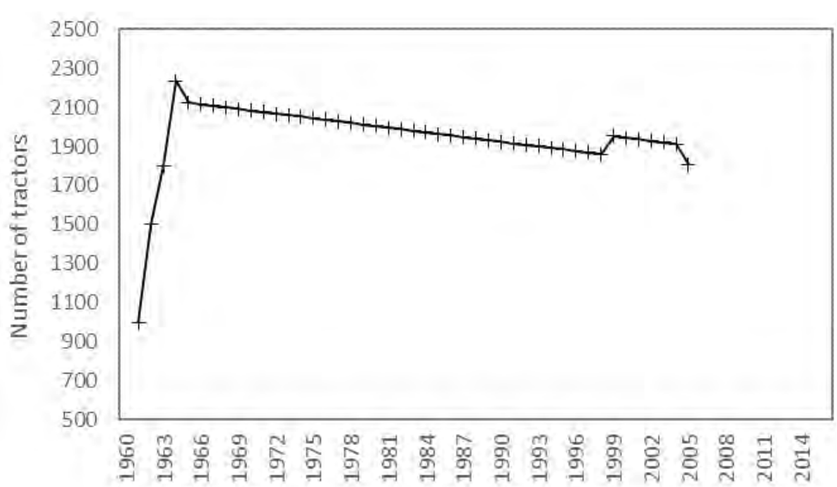


Fig. 1 Tractor usage in Ghana between 1961 and 2005 (FAOSTAT, 2016)

ricultural Mechanisation Service Centres (AMSECs), the intervention is not without challenges. Lack of market for the output of agricultural production stand as a serious disincentive for farmers leading to their inability to expand production. Diao *et al*. (2016) confirms that sufficient market demand for agricultural products is a key driver of intensification. Government systems and mechanisms to purchase agricultural produce from farmers to stock the country's food buffer is non-existent. Farmers are forced to maintain their current subsistence farming practices with no motivation at all to employ available machinery hiring services. Moreover, not only are farm sizes smaller, but distances from these scattered farm holdings to the nearest AMSEC are quite far to permit effective mechanisation. Low utilisation rate of agricultural machinery and implement has threatened the sustainability of most of these AMSECs causing their collapse or total overhaul. It is important to note that a visit to some of the location addresses provided on paper, it is easily realised that the enterprise supposed to provide agricultural mechanisation services to farmers in the catchment area has either shifted focus to other profit making ventures (mostly agriculture unrelated) or relocated to other places where their services is much needed. This situation is as a result of the seasonal nature of agricultural production. Conversely, due to the urgent demand on mechanisation service providers to settle the huge cost for these machinery and implement within a stipulated time period, another problem comes up in the form of frequent breakdowns due to overuse of the machinery. Lack of spare parts continues to significantly reduce the economic life of most agricultural machinery and implement found in some of the AMSECs. The situation has even worsened with the problem of inadequate or lack of trained technicians to undertake repairs and proper maintenance of machinery.

The Agricultural Engineering Services Directorate (AESD), one of the technical units of the Ministry of Food and Agriculture (MoFA), is mandated to ensure the availability of farm power and other engineering technologies with sound and sustainable environmental practices for all categories of farmers, fishermen and agro-processors in Ghana for improved agricultural production and increased productivity. As part of its functions, the AESD facilitates the procurement and distribution of appropriate technology to meet the agricultural machin-

Table 1 Various agricultural machinery in Ghana from 2007 to 2015 (MoFA AESD, 2016)

Year	Machinery type/make	Quantity	Source
2007	Power tillers	100	Japanese Grant Assistance
2008	Shakti power tillers	200	Importation
	John Deere tractors	500	Importation
	Mahindra tractors	232	Importation
	Kubota tractors	78	Japanese Grant Assistance
	Water pumps	16	Japanese Grant Assistance
	Rice mills	20	Japanese Grant Assistance
2009	Farmtrac-60 tractors	200	Importation
	Kukje combine harvester	12	Importation
	Foton combine harvester (D200)	5	Importation
	Foton maize/rice combine harvester	10	Importation
	China run Yuan Gin Ying combine	10	Importation
2010	Thailand combine (KT09 rice harvester)	2	Importation
	Irrigation pumps and accessories	40	Importation
	Rice mills	12	Importation
	Rice threshers	30	Importation
	Rice reapers	30	Importation
	Grain procacoons (50 MT)	100	Importation
	Grain procacoons (20 MT)	150	Importation
	Rice destoner	2	Importation
	Tractor and matching implement	125	Japanese Grant Assistance
2011	Foton DC200 rice harvester	70	Importation
	Foton GE20H rice/maize harvester	50	Importation
	Cabrio compact tractors	50	Importation
	Combine harvester	2	Japanese Grant Assistance
	Rice threshers	35	Japanese Grant Assistance
	Rice reaper	35	Japanese Grant Assistance
	Rice mill	10	Japanese Grant Assistance
	Irrigation pump	40	Japanese Grant Assistance
2012/13	Cabrio tractors and matching implement	100	Importation
2013/14	Tractors and matching implements	70	Japanese Grant Assistance
	Power tiller	43	Japanese Grant Assistance
	Rice thresher	35	Japanese Grant Assistance
	Rice reaper	20	Japanese Grant Assistance
	Rice mill	5	Japanese Grant Assistance
2015	Cabrio tractors (50 hp)	100	Government of Ghana
	Same tractors	77	Japanese Grant Assistance
	Power tillers	49	Japanese Grant Assistance
	Rice threshers	20	Japanese Grant Assistance
	Rice reaper	11	Japanese Grant Assistance
	Rice mill	6	Japanese Grant Assistance

ery needs of the country. **Table 1** provides information (machinery type, quantity and source) on some agricultural machinery and equipment that were procured from other countries to support agricultural production in Ghana between 2007 and 2015.

Under the current hand tool mechanisation associated with Africa's agriculture, it is not surprising that no significant industrial development has happened in the manufacture or even assembly of agricultural machinery. FAO and UNIDO (2008) however reported only a few established farm tool and implement factories mainly in South Africa, Zambia, Kenya and Zimbabwe. Unfortunately, similar efforts in other countries including Ghana have survived competition from the importation of low-cost machinery and equipment from countries in other continents mainly China and India. Almost all the agricultural machinery being used in the country is imported. According to Diao *et al*. (2016), since the capacity to manufacture machinery locally in Africa remains limited, mechanisation will likely continue to depend on imported machinery. CARD (2010) cited high cost of machinery, unsuitability of machinery to local conditions and lack of spare parts as serious limitations to these imported agricultural machinery. There are some private companies and enterprises that deal in the importation and supply of agricultural machinery in Ghana (**Table 2**).

In terms of agricultural machinery adoption, **Fig. 2** illustrates the various rice harvesting and threshing methods employed by sampled farmers in selected locations within the Ashanti, Volta and Northern regions of Ghana according to studies by Amponsah (2017). Combine harvester was the commonly used method for threshing rice and was patronised by 51% of the farmers followed by "bambam" (manual threshing by impact method), constituting about 36% of the farmers. Others include bag beating (11%) and mechanical thresher which accounted for only 2% of the sampled farmers. The significantly high level of combine use from the survey results was attributed to the activity of private rice out-grower scheme companies located in the Northern and Volta regions. These companies provide agricultural support services, including mechanisation to these smallholder farmers who are members of their out-grower scheme in exchange for paddy under a mutually beneficial contractual agreement (Technoserve and IFAD, 2011; Paglietti and Sabrie, 2012). This suggests that these private partners are doing a good job in the provision of rice mechanisation for improved production and more of such efforts should be encouraged. However, given that combine harvesters may be costly and unaffordable to most farmers, designing appropriate mobile and affordable small threshers and other appropriate agricultural machinery locally could help in reducing postharvest losses during threshing.

Machinery fabricators or manufacturers are important stakeholders in the machinery development process (Sims and Kienzle, 2006). Manufacture of agricultural machinery in Ghana is still scanty with virtually no government-owned

Table 2 Some agricultural machinery importers and suppliers in Ghana (MoFA SRID, 2016)

Company name	Machinery/Implement type
Kay Gee Enterprises	Irrigation pumps
Senaky Enterprise	MF tractors, implements
Chemico Limited	Spraying machines
RST Co. Ltd.	Rice mills, threshers, reapers, combined harvesters, power tillers, pumps
Japan Motors	Agricultural machinery, fishing equipment
Destiny Azumah Farms & Trading Ent.	Corn mills
Alex Nkrumah Enterprise	MF, Ford, Mahindra tractor spare parts
Biga International Technologies	Cabrio tractors
Foundries & Agric. Machinery	Farmtrac tractors, combined harvesters, Shakti power tiller, pumps, implements
Agrimat Limited	Tractors, spare parts, implements, pumps, chemicals
CFAO	New Holland tractors, trucks, combined harvesters, implements,
Dizengoff Gh. Ltd.	Planters, boom sprayers, irrigation systems
Bow's Agricultural machinery Ent.	Corn mills
Mechanical Lloyd Co. Ltd.	Massey Ferguson tractors, implements, Combines harvesters
Ghana Heavy Equipment	Zetor tractors, implements, shellers
Reiss & Co. (Gh) Ltd.	Outboard motors, irrigation pumps
Deng Ltd	Irrigation water pumps
John Deere Agricultural & Equipment Co. Ltd	John Deere tractors, implements
Jubilee Tractor & Assembly Plant	Mahindra tractors, implements, Foton combined harvesters

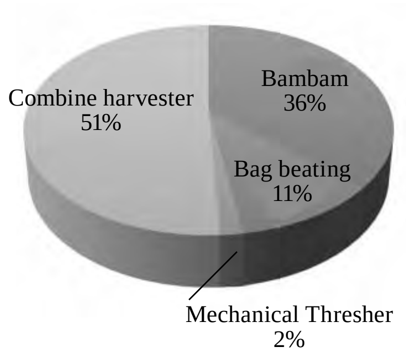


Fig. 2 Level of adoption of various rice threshing methods (Amponsah, 2017)

machinery fabrication workshop in existence. Majority of the privately-owned fabrication workshops however focus largely on the manufacture of agro-processing machinery. In most SSA countries, machinery manufacturing capacity is virtually non-existent (Diao *et al*., 2016). There are also countless number of private-owned metal welding workshops across the breadth and depth of the country, though very few have ventured into agricultural machinery manufacturing. Sims *et al*. (2016) reported that private sector agricultural machinery manufacturing is at an early stage in many countries across sub-Saharan Africa and it is most often troubled by international competition and imports, and held back by less developed distribution networks. **Table 3** presents some agricultural machinery manufacturers and fabrication workshops in the country.

Future Prospects of the Agricultural Machinery Industry in Ghana

Generally, markets for mechanisation hire services in sub-Saharan Africa are in their infancy with usually low demand due to the lack of awareness among smallholders of the need for mechanised services (Sims *et al*., 2016). It is therefore reasonable to argue that promoting mechanisation when demand is insufficient tends to be socially sub-optimal and can have adverse equity effects (Diao *et al*., 2016). In the case of Ethiopia and Tanzania however, increased demand for hired services by smaller farmers is often one of the main reasons mentioned by machinery owners to justify their investments in costly machinery.

A critical look at Ghana's agriculture clearly depicts an economy whose potential agricultural mechanisation demand far exceeds the available machinery supply. However, both government and private sector efforts have been woefully inadequate in meeting this demand amidst the country's low agricultural machinery manufacturing capacity. It has been established from studies by Amponsah (2017) in some rice growing areas across Ghana that smallholder farmers are willing to adopt appropriate rice harvesting mechanisation to help reduce drudgery, increase production and overall productivity. This suggests that the manufacture of appropriate harvest and postharvest equipment is already a demand driven issue as it is an essential need among the rice farmers. The studies also revealed that the use of portable mechanised rice production systems was economically rewarding than manual option; offering profit margins of over 200% while breaking even after just two seasons of cultivation. With such renewed conviction by farmers on the need for appropriate agricultural mechanisation, not only does the future of Ghana's agriculture looks promising but the impact of the agricultural machinery industry is expected to be massively appreciated nationwide as in the case of Asia.

Conclusion and Way Forward

Agricultural mechanisation has been identified as the beacon of hope for the country in its pursuit to achieving increased agricultural production for sustainable food security and improved livelihood in line with the Millennium Development Goals (MDGs). Besides previous interventions by the government, mechanisation of agriculture is still low due to the country's low machinery manufacturing capacity. Ghana's inability to establish an effective agricultural machinery industry after all these years could be attributed chiefly to factors such as non-utilisation of academic research related to agricultural machinery, lack of government support for the training of farmers and operators on appropriate use and maintenance of various agricultural machinery and lack of appropriate local channels/networks to create the needed farmer awareness on available agricultural mechanisation options. In addition, there is a dearth of useful information on existing agricultural machinery and levels of utilisation.

Fortunately, Ghana is well favoured if it decides to establish effective agricultural machinery industries to supply locally manufactured demand-driven appropriate

Table 3 Some agricultural machinery manufacturers and fabrication workshops in Ghana

Industry	Ownership	Products/Services
GRATIS Ghana Foundation, Tema, Accra, Kumasi, Sunyani, Takoradi, Tamale, Koforidua	Government	Fabrication of various agro-processing machinery, repairs, capacity building, machine testing and dissemination
Technology Consultancy Center, KNUST, Kumasi	Government (University)	Agro-processing equipment
Bamba Products, Accra	Private	Combine harvesters, threshers, feed mixers, grain silos
Agricultural and Biosystems Engineering Department workshop, KNUST, Kumasi	Government (University)	Mechanical grain dryers, feed mixers, rice threshers, mechanical cassava harvester
Ibrahim Engineering, Suame, Kumasi	Private	Rig for borehole drilling, agro-processing equipment, crop harvesting implement
Zowfa Fabrication Services, Akatsi	Private	Agro-processing equipment

technology and machinery to farmers. This is because the country's current political and economic environment is relatively favourable for investors in that sector as compared to other African countries. Moreover, availability of labour in the form of creative and smart local artisans with appreciable level of technical background is not a problem. The availability of affordable construction materials and machine parts is an added advantage. This is affirmed by the government's recent tax exemption on importation of raw materials, agricultural machinery and spare parts for agricultural purposes.

REFERENCES

Abdulai, S., P. K. Nkegbe and S. A. Donkoh. 2013. Technical efficiency of maize production in Northern Ghana. African J. Agric. Res. 8, 5251-5259.

Adamade, C. A. and B. A. Jackson. 2014. Agricultural mechanization: a strategy for food sufficiency. J. Agric. Sci. 4, 152-156.

Amponsah, S. K. 2017. Technical performance and economic feasibility of some rice harvesting systems for application in sub-Saharan Africa. Dr. Thesis. Kwame Nkrumah University of Science and Technology (KNUST).

Amponsah, S. K., P. Oteng-Darko and F. Kumi. 2012. Potential and constraints of agricultural mechanisation in Ghana –A review. Int. Agric. Eng. J. 21, 38-45.

Angelucci, F., A. Asante-Poku and P. Anaadumba. 2013. Analysis of incentives and disincentives for rice in Ghana: Technical notes series. MAFAP, FAO, Rome.

Awiah, D. M. 2015. Lack of support preventing youth from farming - Report [WWW Document]. Graph. Online. URL http://graphic.com.gh/news/general-news/38115-lack-of-support-preventing-youth-from-farming-report.html (accessed 5.12.15).

Benin, S. 2015. Impact of Ghana's agricultural mechanization services center program. Agric. Econ. 46, 103-117.

Bobobee, E. Y. H. 1997. Animal Traction Utilisaion, Constraints and Research Options in Ghana.

Bobobee, E. Y. H. 1999. Role of draft animal power in Ghanaian agriculture. In: Kaumbutho, P.G., Simalenga, T.E. (Eds.), Conservation Tillage with Animal Traction. Animal Traction Network for Eastern and Southern Africa (ATNESA), Harare, Zimbabwe, pp. 61-66.

Buri, M. M., A. Imoro and S. E. Ahiakpa. 2011. The state of mechanization in Ghana with particular reference to the rice sector. In: Workshop on Boosting Agricultural Mechanization of Rice Cropping Systems in Sub-Saharan Africa, St. Louis, Senegal. June 6-8, 2011. p. 14.

CARD. 2010. Mapping of Poverty Reduction Strategy Papers (PRSPs), Sector Strategies and Policies Related to Rice Development in Ghana.

Clarke, L. J. and C. Bishop. 2002. Farm Power - Present and Future Availability in Developing Countries. In: ASAE Annual International Meeting/CIGR World Congress, Chicago, 30th July 2002.

Dewbre, J. and A. B. de Battisti. 2008. Agricultural Progress in Cameroon, Ghana and Mali.

Diao, X. 2010. Economic Importance of Agriculture for Sustainable Development and Poverty Reduction: Findings from a Case Study of Ghana. In: Global Forum on Agriculture: Policies for Agricultural Development, Poverty Reduction and Food Security Held on 29-30 November, OECD Headquarters, Paris.

Diao, X., J. Silver and H. Takeshima. 2016. Agricultural Mechanization and Agricultural Transformation, IFPRI Discussion Paper 01527.

Djokoto, J. G. and S. Blackie. 2014. Harvesting Technology Adoption among Irrigated Rice Farmers on the Kpong Irrigation Project in Ghana 3, 23-37.

FAO. 2005. Contribution of farm power to smallholder livelihoods in sub-Saharan Africa. In: Sambrook, C.B. (Ed.), Agricultural and Food Engineering Technical Report 2. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, UNIDO. 2008. Agricultural mechanization in Africa – Time for action: planning investment for enhanced agricultural productivity. Rome.

FAOSTAT. 2016. FAO Statistical Yearbook. Food and Agricultural Organisation of the United Nations, Rome, Italy.

Ghana Cocoa Board. 2017. Cocoa [WWW Document]. URL https://www.cocobod.gh/home_section.php?sec=1 (accessed 9.18.17).

Ghana Statistical Service. 2017. Quarterly Gross Domestic Product (QGDP): First Quarter 2017. Accra Ghana.

Gifford, R. C. 1992. Agricultural Engineering in Development: Concepts and principles. Food and Agriculture Organization of the United Nations, Rome, Italy.

GNA. 2016. Ghana government urged to address agriculture sector challenges. Ghana News Agency Gen. news Rep.

Herbst, J. 1993. The Politics of Reform in Ghana, 1982-1991. University of California Press, California.

Kibaara, B. W. 2005. Technical Efficiency in Kenyan's Maize Production; An Application of the Stochastic Frontier Approach. Colorado State University.

Kline, C. K., D. A. G. Green, R. L. Donahue and B. A. Stout. 1969. Agricultural Mechanization in Equatorial Africa, Institute of International Agriculture Research, Report No. 6.

Kumar, D. and P. Kalita. 2017. Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. Foods 6, 8.

Madama, E. A., A. Naazie, T. Adogla-Bessa and L. K. Adjorlolo. 2008. Use of donkeys and cattle as draught animals in the Northern and Upper East and Volta Regions of Ghana. Draught Anim. News 46, 10-13.

Makki, E. K., F. E. Eltayeb and O. A. Badri. 2017. Factors Affecting Draught Animal Technology Adoption in Rural Kordofan. Int. J. Agric. Innov. Res. 5, 2319-1473.

Mccauley, J. F. 2003. P LOWING A HEAD: T HE E FFECTS OF A GRICULTURAL M ECHANIZATION ON. J. Public Int. Aff. 14, 6-27.

MoFA AESD. 2016. Procurement Details of various Agricultural Machinery and Equipment. Accra, Ghana.

MoFA SRID. 2016. Agriculture in Ghana: Facts and figures (2015). Accra Ghana.

Naamwintome, B. A. and E. Bagson. 2013. Youth in agriculture: Prospects and challenges in the Sissala area of Ghana. Net J. Agric. Sci. 1, 60-68.

Okine, C. B. 2014. Ghana to reduce heavy rice imports. Graph. Online.

Paglietti, L. and R. Sabrie. 2012. Outgrower schemes: advantages of different business models for sustainable crop intensification: Ghana case studies. In: FAO Investment Centre: Learning from Investment Practices. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 1-12.

Pawlak, J., G. Pellizzi and M. Fiala. 2002. On the development of agricultural mechanization to ensure a long-term world food supply. Agric. Eng. Int. CIGR J. Sci. Res. Dev. IV.

Rickman, J., J. Moreira, M. Gummert and M. C. S. Wopereis. 2013. Mechanizing Africa's rice sector. In: Wopereis, M. C. S., Johnson, D.E., Ahamdi, N., Tollens, E., Jalloh, A. (Eds.), Realizing Africa's Rice Promise. CAB International, Wallingford, UK, pp. 332-342.

Sims, B., Hilmi, M. and J. Kienzle. 2016. Agricultural mechanization: A key input for sub-Saharan African smallholders, Integrated Crop Management. Food and Agriculture Organization of the United Nations, Rome, Italy.

Sims, B. G. and J. Kienzle. 2006. Farm power and mechanization for small farms in sub-Saharan Africa. Food and Agriculture Organisation of the United Nations, Rome, Italy.

Taiwo, A., F. Kumi. 2015. Status of Agricultural Mechanization in Ghana: A case study of maize producing farmers in Ejura/Sekyedumase District, Ashanti Region. Int. Res. J. Eng. Technol. 2, 36-43.

Technoserve & IFAD. 2011. Outgrower schemes: Enhaning profitability: Technical brief.

USAID. 2009. Global Food Security Response: West Africa Rice Value Chain Analysis, Micro Report No. 161.

Wood, T. N. 2013. Agricultural Development in the Northern Savannah of Ghana. University of Nebraska-Lincoln.

■■

Farm Mechanization in Sudan: Historical Development, Present Status and Future Prospects of Industry, Research and Policies

by

Amir Bakheit Saeed
Professor of Agricultural Engineering
Dept. of Agric. Eng.
Faculty of Agric.
University of Khartoum
SUDAN

General Country Information

Sudan occupies a region that is located in the middle part of the Nile Basin to the south of Egypt. The country is located within the Sudano-Sahelian region in north east Africa, with geographic coordinates: (Lat. 4° and 22° north and longit. 22° and 38° E) and has a special geopolitical location that bridges the Arab World and Sub-Saharan Africa: it facilitates trade and human movement between, and is a melting pot of, African and Arab cultures. Sudan achieved independence in 1956. The country comprises four regions divided into 15 states. Its total area was reduced from 2,500,000 km^2 to 1,882,000 km^2 following the independence of South Sudan in 2011. Together, the two countries contain 63 per cent of the Nile basin and share borders with nine countries.

Sudan is divided into five distinct ecological zones: desert, semi-desert, woodland savannah, flood region and vegetation.

The country is traversed by the Blue and White Niles, which meet in the capital Khartoum to form the main River Nile, which flows north into the Mediterranean Sea. The two Niles and their tributaries have varying degrees of influence on irrigated agriculture and livestock production systems. There are also a large number of seasonal rivers and wadis.

Sudan has constructed five dams which provide water for irrigation, fishing and to generate electricity. Erratic rainfall and recurrent spells of drought emphasize the importance of reliable sources of groundwater. The water bearing rock strata comprise the Nubian Sandstone, the Um Rwaba Series and the basement complex (Abdalla and Karar, 2010). Although Sudan lies within the tropics, the climate ranges from hot and dry to arid desert, with a rainy season between April to November that varies by region.

Soils in Sudan can geographically be divided into four categories: sandy in the northern and west-central areas; clay in the central region; and laterite in the south; with alluvial soils as a fourth, less extensive and widely separated category.

Sudan is endowed with large areas of cultivable land that has different uses, as illustrated in **Table 1**. Arable land constitutes approximately one-third of total area of the country, of which 21 per cent is cultivated with fluctuating productivity—but output remains far below potential performance.

More than 40 per cent of the total area consists of pasture and forests (Stads and ElSiddig, 2010). Subsistence farming and commercial production for local consumption and export are practised. Five main types of farming exist in Sudan (UNEP, 2007):

- Mechanized rain-fed agricultural schemes
- Traditional rain-fed agriculture
- Mechanized irrigation schemes
- Traditional irrigation
- Livestock husbandry/pastoralism

Table 1 Land use in Sudan

Item	Area (000 ha)
Total area	250,429
Land area	237,443
Area under water	12,986
Arable land	84,034
Cultivated land	17,471
Uncultivated land	66,563
Forest and wood land	64,360
Other	49,569

Source: Administration of Statistics and Information (1995)

Fig. 1 illustrates how wheat imports started to increase since 1990s up to 2006 that reflected the change in the population's food consumption patterns. Sorghum production fluctuates because it is mainly grown in traditional and semi-mechanised rain-fed areas. Crop production from traditional rain-fed farming has grown since the early 1990s; it has surpassed the level of semi-mechanized farming, which shrank during the same period. Semi-mechanized system has ceased to be the dominant source of food (sorghum) for Sudan (Institute for Security Studies, 2005). However, the contribution of the irrigated sector has remained relatively stagnant.

Generally speaking, in terms of availability of arable land and different water resources, the country has the potential to become the main food provider for Africa and the Middle East.

To achieve long-lasting agricultural development, the Government announced its "Green Mobilization" programme in 2006 and adoption of the Strategic Five-Year Plan (2007-11). The Agricultural Revival Plan (ARP) aimed to broaden the base of rural development and export earnings, with particular emphasis on reactivation and diversification of non-oil exports. A plan was formed with a view to achieving the following targets:

- Diagnosing the current situation in the agricultural sector.
- Analyzing the crop mix and requirements of food security and export.
- Increasing productivity.
- Promoting agro-based industrialization.
- Implementing policies supporting agricultural development.

However, although agriculture continues to provide the majority of export revenue outside of the oil sector, growth in recent years has been tepid (IFAD, 2009).

The following is a summary of the constraints which are facing the agricultural development (Abbadi and Elhag Ahamed, 2006):

- Reduced competitiveness because of low productivity and high marketing costs, which results in lower prices for farmers.
- Exports of most goods are concentrated in a few foreign markets, which make them vulnerable to disruptions.
- Lack of strategic planning for different agricultural sub-sectors.
- The low priority accorded to the sector, which is reflected in allocation of public expenditure (3% of the total for the country), formal banking credit (11%) and investment (3%).
- Inadequate complementarities and coordination of macroeconomic and sector policies, and persistent neglect of the role that small producers play in achieving food security and poverty alleviation.
- Instability of production that is exposure to natural risks and hazards causes, in addition to price competition from subsidised imported goods.

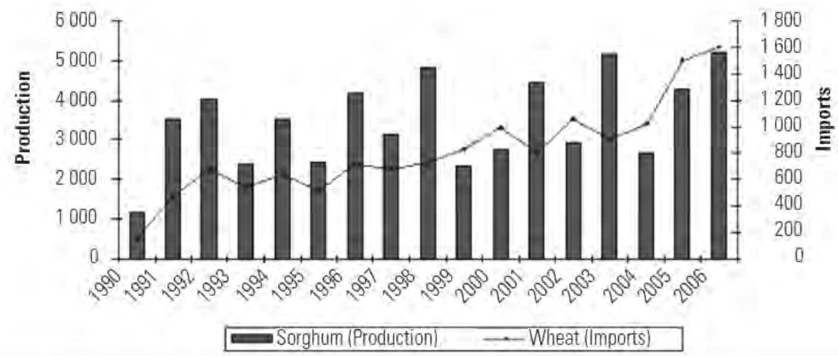


Fig. 1 Sudan – Imports of wheat and production of sorghum, 1990-2006 ('000 tons)
Source: Shukri Ahmed, Getachew Diriba *et al.*, 2007

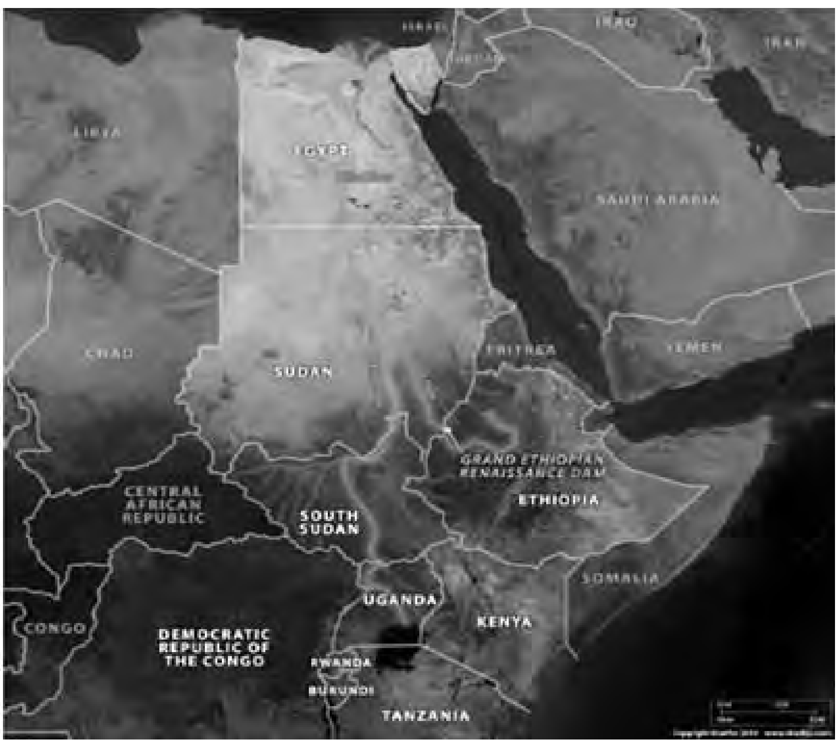


Fig. 2 The River Nile Course

Table 2 Ecological zones of Sudan

Zone	% of Sudan area	Mean annual rainfall (mm)	Wet season	Dry season	Main land use types
Desert	28.9	<75	July-Sep.	Nov.-June	Irrigated agriculture ,grazing along seasonal water courses
Semi-desert	19.6	75-300	Nov.-Jan	March-Sep.	Irrigated agriculture ,dry land farming with water harvesting pastoral
Low-rainfall savannah	27.6	300-800	May-Sep.	Nov.-April	Irrigate agriculture ,rain-fed traditional cultivation ,mechanized farming ,pastoral ,forestry
High-rainfall savannah	13.8	800-1,500	April-Oct.	Dec.-Feb.	Rain –fed traditional cultivation ,mechanized farming ,pastoral, wild life
Flood region	9.8	600-1,000	May-Oct.	Dec.-April	Traditional cultivation ,pastoral ,wild life
Mountain vegetation	0.3	300-1,000	Variable	Variable	Traditional cultivation ,pastoral ,forestry ,horticulture

Source: (Harrison and Jackson 1958)

- The low productivity of animal and crop producers because of inadequate training, and a lack of extension programmes or supportive producers' associations.
- The inefficient use of human resource capacities engaged in agriculture.
- The meager budget allocated to agricultural research (0.04%) of public expenditure.
- Inadequate social and physical infrastructure.
- Weakness of laws governing the lease and use of land.

Irrigation

The variety of agricultural zones in Sudan means that the country is suitable for a wide range of crops (**Fig. 2**). Agriculture depends principally on rainfall and irrigation from major and seasonal rivers.

Sudan is divided into different ecological zones.

Table 2 shows these zones and major agricultural enterprises in each zone are indicated:

Desert & Semi-desert
Low-rainfall savannah zone
High-rainfall savannah
Flood plain
Mountains

Agriculture in Sudan accounts for 97% of the country's water use. The diversion of water to mechanized farms and intensive cultivation by rural farmers is contributing to the spread of arid conditions across Sudan (Barton and Writer 2012). Water is in high demand to meet the needs of rapid population growth and food production, and plans to expand agriculture through irrigation further raises the demand for water. **Table 3** shows Sudan's estimated water requirements in 1957 (Taha, 2010). Despite the oldness of **Table 3** it is intended to serve two purposes: First, to explain that the Sudan's requirements of water even at that time exceeded its share of the Nile waters by 3 milliards m^3. That means 'The 1959 Nile Water Agreement' between Egypt and Sudan was not fair. And the water amount allocated to Sudan would not be enough if the country would have implemented all entries in the table; Second, Sudan would face water deficit if it implemented its policy to extensively increase the area of irrigated land, bearing in mind the frequent drought spells that Sudan has been facing recently.

It is estimated that the country's water requirements for food security and other essentials will be 32 milliards m^3 by 2025. Actually, Sudan is using only 12 milliards m^3 out of its share of 18.5 milliards m^3. Thus an annual amount of about 396 milliards m^3 has been passing to Egypt since 1959 (Salman, 2013). About 80 per cent of irrigated schemes in Sudan were developed in the early 1960s. These were designed on the basis of a constant water calculation now considered defunct: 400 (m^3/feddan) applied at 14-day intervals.

Table 3 Sudan: Total water requirements, 1957

Region	Feddans (1 feddan = 0.42 ha.)	m^3 per feddan	Billion cubic meters
Southern Sudan	500	2,700	1.35
White Nile pumps: Sobat-Geiger	120	3,400	0.41
White Nile pumps: Geiger-Khartoum	210	4,400	0.92
Blue Nile pumps: Roseires-Sennar	250	3,600	0.9
Blue Nile pumps: Sennar-Khartoum	200	4,500	0.9
Kennana gravity area: West	600	4,400	2.64
Kennana gravity area: East	580	3,600	2.09
Kennana gravity area: Southh	40	3,100	0.12
Gezira and Managil	1,800.000	4,500	8.1
Butana	500	4,500	2.25
Northern Sudan pumps	700	5,330	3.73
Total	5,500.000		23.41
Less 10% for transmissions losses			2.34
As at Aswan			21.07

Source: Taha, 2010

Any unused amount of water by Sudan is used by Egypt as a loan not exceeding 1.5 milliards m^3, provided that the utilization of this loan shall cease in November, 1977. However, the loan has not been ceased until today.

Mechanization

This is the key input in any farming system. It aims to achieve the following:

- Increased productivity per unit area due to improved timeliness of farm operations;
- An expansion of the area under cultivation where land is available,
- Accomplishment of tasks that are difficult to perform without mechanical aids;
- Improvement of the quality of work and products;
- A reduction of drudgery in farming activities, thereby making farm work less unattractive.

The term "mechanization" is used to describe tools, implements and machinery applied to improving the productivity of farm labour and of land; it may use either human, animal or motorized power, or a combination of these. In practice, therefore, it involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, through draught animal power to mechanical power technologies.

In Sudan, tradional farming systems are dominated by small-holder peasant farmers which in most cases are based on subsistence farming. The average landholding of farmers is less than 2 hectares. The average number of persons in the family varies greatly but with an average of about five members. These family members constitute the main source of labour, however, it is often the case that not all members are available for farm work all of the time. In particular the younger generations, in order to earn off-farm income and to seek a better life, are increasingly migrating from rural areas to urban centers and elsewhere.

Generally, the yields are very low when compared with other regions in the world. For example, average cereal yields of about 1,000 kg/ha are only about one third of average cereal yields in other countries. Fertilizer use is far less than it is in the rest of the world.

Another problem is the losses that occur during harvest, transport, and storage; losses in both quantity and quality are common of production.

Farm mechanization seems to have become, to a certain extent, the neglected waif of agricultural and rural development. As an essential input, mechanization can transform farm family economies by facilitating increased output. However consideration of mechanization as a vital input is in need of research and development which have been frequently neglected. Several factors contribute to these low levels of production. Some of the reasons for low productivity are technical (low fertilizer use, poor seed, poor crop husbandry, low levels of irrigation, poor storage, etc.); others reasons relate to the prevailing physical and socio-economic environment.

Factors Leading to the Low Level of Agricultural Mechanization

The low levels and lack of growth in the use of mechanization may be attributed to the following:

The first and most crucial element represents demand for agricultural mechanization. Most agricultural systems are based on subsistence farming and the cash incomes of farmers remain relatively low. This is not only due to low production and productivity but also to other factors such as the lack of added value to crops that are sold. Therefore there is very little surplus cash generation in these subsistence farming situations.

One of the consequences of this is that there is a very low potential to invest in inputs apart from seed and fertilizer, particularly agricultural machinery and therefore demand for tools and machinery remains low. This lack of investment in production enhancing technologies has resulted in very low levels of productivity which again leads to a continuing situation of low farm incomes.

The lack of demand for mechanization drives another debilitating element: the supply side. This is represented by the low supply of tools equipment and power sources (limited choice and low sales volumes) which tend to lead to higher costs of agricultural mechanization which in turn lead to higher ownership and running costs. Finally, this high cost of farm machinery use leads back to the low demand in a vicious circle.

These inter-related factors illustrate the structural constraints to the increased use of mechanized methods of farming faced by the country. These also demonstrate the interdependent relationship between the demand and supply sides of agricultural mechanization inputs. However, these also give some indication as to how debilitating factors might be converted to enabling ones.

Nevertheless, these weakening factors provide only a partial explanation of the problems surrounding the development of agricultural mechanization. There are other factors which are also present, that include:

Adequate infrastructure is a very important determinant factor of agricultural mechanization development; the high cost of tractor use; the lack of roads to access rural areas and farms and the scarcity of fuel stations.

All of such factors demonstrate how crucial for the State to develop a strategic plan and how essential it is to take these broader issues into account when planning and programming agricultural mechanization developments.

Lack of Farmer Skills

Although the farmers have a great deal of traditional knowledge and experience accumulated over generations, access to new knowledge remains largely limited. Mostly the level of training for farmers is relatively low and the opportunities for further training are limited.

Another problem is that a large proportion of rural farming populations are illiterate. Where machines are used, the lack of both farmer knowledge and skills leads to misuse and mismanagement of machinery; especially of more sophisticated machines.

The whole of the farm machinery sub-sector, which encompasses manufacturers, importers, distributors, and retailers, faces several constraints which hinder its development. Although low demand is mostly caused by lack of development, these other constraints should nevertheless be taken into account.

Agricultural Machinery Importation and Distribution

There are several ways in which farm machinery is imported and distributed. Some of these ways are more successful and sustainable than others. The following options are in practice:

Specialist private importers of agricultural machinery

These are usually companies which have a franchise to sell and import a selected and commonly limited number of brands. The franchise is given to them by the company manufacturing the machines. These companies are usually located in the capital city, Khartoum and may sometimes have branches in other major cities and towns. Traditionally these have represented one of the major western agricultural machinery manufacturers but more recently, Asian and Latin American manufacturers have moved into these markets.

Occasional private importers

These tend to be general traders with no specialist knowledge or experience of farm machinery. It is usual for these companies to import a batch of machines and once these machines are sold there is no further obligation to provide either spare parts or service for them. The next batch of machines to be sold might come from a different manufacturer. The farmers who purchase from these companies are mostly inexperienced and often do not realize that there may be later problems with spare parts and repair services

Manufacturing and Assembling of Tractors, Farm Tools and Machinery

The manufacturing and assembling industries produce a wide range of tractors, hand tools, farm implements, and processing equipment. Using a wide variation of simple and sophisticated manufacturing facilities (Giad for Tractors & Agricultural Machinery Company is the example). At various times farm tool and machinery manufacturing has also been supported through bilateral and multilateral cooperation. Unfortunately the sustainability of the manufacturing industry has often been problematic, because of erratic raw material supplies, fluctuating demand, issues of quality as well as problems caused by bulk ordering from projects.

Donations of Agricultural Machinery

Quite often the country receives donations of tractors and implements from many foreign countries. Unfortunately most of these, though no doubt well intentioned, programmes have failed to produce the desired results. This is due to a number of reasons, the main ones being a lack of compatibility between products manufactured in donor countries and machines that are already on the market. Very often there has been no dealer or spare parts available to support the operation of the equipment. The machines that have been donated quickly become “orphans” with no support and once the first breakdowns occur the machines cannot be repaired.

Direct Importation

Large farmers and agro-industrial companies often import machinery directly from abroad. This is the case when large orders attract high discounts or when the company or farm has sufficient resources to stock their own spare parts as well as to carry out their own maintenance and repairs. It also occurs when particular specialized machinery is required e.g. sugar cane harvesters (Kenana Sugar Estate and the Sudanese Sugar Company are examples).

Importation of Used Equipment

In some cases the importation of used machinery, particularly tractors, combine harvesters and other specialized machinery offers are given to local and foreign investors as an alternative source of cheaper machinery and offers an additional way to meet demand. However, whether the new owners can benefit from this cheap source of machinery depends upon whether the importer is serious in offering services including the provision of spare parts and repair services. Importation and sale of used machinery occurs mainly where there are technicians who have a relatively high level of skills and knowledge but where the costs of labour are low. As is the case with new machinery, it is often tempting for the public sector to become involved in the importation of used machinery, however, without specialized knowledge of agricultural machinery these schemes usually end up with disastrous consequences.

Maintenance and Repair Services

In general the maintenance and repair of hand tools and animal traction implements is not a problem as it is mostly carried out at a local level by small workshops. The situation has been improved by the standardization of spare parts, facilitating inter-changeability between tools sourced from different manufacturers. However, for motorized farm machinery and equipment many problems still remain, particularly for tractors. This is mostly caused by poor maintenance facilities and a critical lack of spare parts. This situation leads to long down times, and a consequent under-utilization of equipment and eventually to premature write off. Many years ago, emphasis was given to public sector programmers and projects which developed agricultural mechanization maintenance and repair centers. However, these were not very successful and many have since fallen into disuse.

Hire Services

A wide range of operations can be covered by machinery hire services. In addition to crop operations such as soil tillage, planting, and spraying, other hire services such as threshing, shelling, and transport are also offered. Established public sector operated farm machinery hire services in an attempt to include small farmers into growing markets for high-value commodities. Most of these schemes, which were mainly for the provision of tractor hire services, failed. There are some remaining vestiges of them which only continue to exist through the provision of government subsidies, but the remainder have disappeared. There were many reasons for the failure of these schemes but the main ones were small fields with long travel distances, unaffordable hire charges, problems of non-payment, inflexible and inefficient public sector administration, lack of operator and mechanic incentives, breakdowns, and the non-sustainability of the subsidies that were required to keep the service running.

New More Suitable Sources of Farm Machinery

Western technology, which was a very important source of farm machinery in the past, has become increasingly more sophisticated and has become less suitable and affordable by small farmers. However, the newly emergent industrial economies such as India, China and Brazil have stepped in and have provided new sources of farm machinery which is continually coming on to local markets. This machinery is often more suitable for Sudan condition and is considerably cheaper than machinery manufactured in Western Europe or North America.

Need for More Innovative and Energy Efficient Sustainable Mechanization

New ideas on energy efficiency and the use of other energy sources will have to be further developed and adopted that are of particular interest regarding the development and use of solar power. Many technologies have already been developed for drying vegetables and fruits as well as for pumping water and the provision of electrical energy and more precise and energy efficient production technologies such as reduced and no-tillage/direct seeding practices.

Climate Smart/Conservation Agriculture—A New Need for Environmentally Sustainable Mechanization

The use of agricultural machinery has sometimes been criticized for the negative effects it can have on the environment. At the same time it is clear that developing new machines and techniques which are more precise and protective of the environment is the key to climate-smart agriculture. One powerful concept is conservation agriculture which maintains a permanent cover on the soil and uses direct seeding through the vegetative cover. This can only be made possible by the introduction of specialized technologies which is envisaged to tackle emerging environmental problems.

Agricultural Engineering Research Activities

The first Research Station was established in the early fifties of the last century at Tozi in the Central Clay Plains to deal with the rain-fed agriculture, the main activity was directed towards services rather than actual research work. During 1971 to 1976, the 300,000 feddans (100 Feddans = 42 ha) Rahad Irrigation Scheme was established for full mechanization thereafter, agricultural engineering research programmes have been dealing with mechanization and irrigation engineering problems with a view to qualifying the following strategy:

- Tillage experiments (for soil moisture conservation, weed control, soil reclamation and conservation tillage for field crops production in irrigated and rain-fed sectors.
- Improvement of mechanized operations of field crops.
- Evaluation of irrigation systems and water harvesting techniques.
- Evaluation of crop harvesting and crop residue management.
- Development and evaluation of appropriate technologies for crop production in small holdings.
- Development and evaluation of agricultural machinery for mechanized rain-fed and irrigated schemes.

The general objectives of Agricultural Engineering Research Programmes are to test, fabricate, improve and adopt the agricultural tools and modern irrigation systems in order to:

- Solve the problems of hand labour bottleneck.
- Introduce the economical choices to the users at private and public levels.
- Improve cultural operations.
- Reduce the cost of production.

- Improve the quality of product.
- Minimize crop harvesting losses.
- Conserve the natural resources.
- Save the amount of irrigation water and to increase its use efficiency.
- Conserve soil moisture content.
- Transfer the approved technologies to the farmers' fields.
- Train the operators of agricultural tools for high field efficiency with satisfactory performance in methods of land preparation, mechanical sowing of various field crops, irrigation engineering, crop harvesting and crop residue management.

Released Technologies

Due to the continuous effort of agricultural engineering research, certain technologies have been released by the Agricultural Research Corporation:

Most of irrigated and rain-fed schemes in Sudan are lying in the Central Cracking Clay Plains. The soil of these plains is characterized by swelling when wet and shrinking when dry, and then it cracks. The cracking is considered as the natural soil cultivation that helps in aeration and deep water percolation. However, the phenomenon of swelling and shrinking affects the land preparation, by equalizing the effect of land preparation systems and the type of implement to be used. Therefore, the type of land preparation in these Cracking Clay Plains is determined according to the following factors:

- Soil conditions (hard or friable, dry or wet).
- The degree of clearness of the field (infested with or free of noxious weeds).
- The availability of tillage tools.

In various rain-fed and irrigated agricultural schemes in these Plains, experimental studies on different tillage tools and systems have shown positive results from many field crops, particularly strategic crops viz. cotton, sorghum, wheat, groundnuts, sesame and sunflower. Similar results have been obtained from sandy clay soil (locally known as Gadud soil) in the Western region and light and heavy soils in the Central, Northern and Eastern regions of the country (Omer 1995).

Following are some examples of released technologies: (See **Fig. A-C**)

A. Released water harvesting techniques for crops production

(**1**)

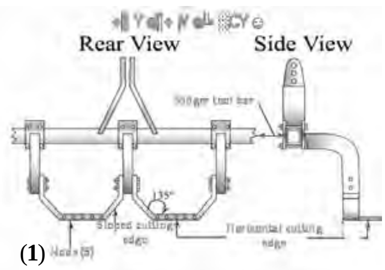
(**2**)


Fig. A (**1**) Scarifier; (**2**) Single-acting disc harrow

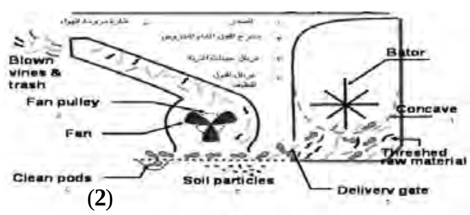
B. Crop sowing released technologies

Fig. B Combined-operations machine for wheat crop establishment in irrigated schemes in working

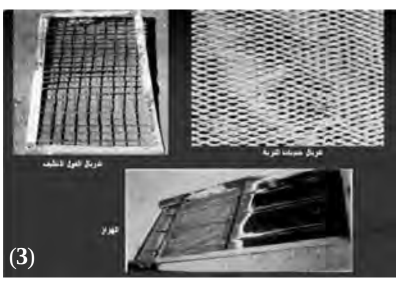
C. Crop harvesting released technologies



(1)



(2)


(3)


(4)

Fig. C. (1) Locally made 2-unit digger for cotton stalks uprooting; **(2)** Longitudinal section showing the modified parts for ground nut threshing; **(3)** The shape of some modified parts, (**4**) General Shape of the simple system for sorghum harvesting in rain-fed areas

D. Released Intermediate Technologies

Fig. D The animal drawn planter

Gaps and Suggestions for Future Research

Research Constraints

Although there is a problem of funding for research work in general, its impact was so great on the Agricultural Engineering Research Programmes. This is because fabrication, modification, adoption of agricultural tools and modern irrigation systems require high funding, in addition to the training of professionals and stakeholders, and transfer of technologies to the farmers' fields.

Future Research Projects

The following research projects cover the continued, the gaps and the required future research work:

- Land preparation of light soils in north and west of Sudan: To determine the optimum and economical system for land preparation, that prevents wind and water erosion, and in turns prevents soil degradation.
- Design and development of combined operations machines for economic use of tractors, to reduce machine requirements and to improve cultural operations timeliness, which leads to crops production increase.
- Conservation and management of soils in the mechanized rain-fed areas.
- Design and development of intermediate technologies for crops land preparation, sowing and weeding: these are very important for the improvement of the existing situation of various field crops production in small holdings.
- Mechanical eradication of noxious weeds in spate irrigation schemes: the soil under spate irrigation is considered as first class soil, therefore, to increase the value of organic products under such soil, it should not be contaminated by chemicals.
- Crops residues treatment: One of the problems that is facing the farmers in irrigated and rain-fed sectors is the crop residue of various field crops. The crop residue affects land preparation operations, and efficiency of fertilizers and insecticides. Also it harbors insects that attack the new grown crops. Moreover, these crops residues require handling methods to facilitate their use as a source of energy or as animal feed stuff. The project aims towards the economical use of crop residue treatment, and to provide the basic information of equipment for crop residue handling.
- Crops harvesting: Crop harvesting represents the big portion of production expenses of most crops. Moreover, it requires much of hand labours, which are not available. This causes failure of most agricultural seasons. Therefore, the findings of methods and choices of crops harvesting are of great importance. This project covers development, adaptation and evaluation of harvesting machines for some crops with special conditions in the Sudan, such as sesame, winter leguminous crops and guar crop in rain-fed sector by using combine harvesters with different harvesting headers.
- Bailing of sorghum stalks residue: the rain-fed areas are characterized by the scarcity of water after the end of the rainy season, which make the availability of livestock in these areas impossible to make use of sorghum crop residue. Therefore, for the use of these residues and the economical transportation to the sites of livestock rearing, mowers and bailers should be introduced for economic evaluation.
- Determination of field crops harvesting losses and minimization of harvesting losses under rain and irrigation.
- Mechanical sowing and harvesting of sesame, groundnut, cotton, sunflower, etc.
- Performance of different methods of inter-row cultivation for weed control in irrigated and rain-fed sectors.
- Hydraulic evaluation of irrigation systems under heavy clay and light soils.
- Water requirement for field crops and evaluation of deficit irrigation strategy under heavy clay and light soils.
- Effect of residual and accumulative effect of tillage system on soil and crop yield in rain-fed areas in addition to the effect of machinery movement on clay soils and compaction.
- Evaluation and management of agricultural machinery in rain-fed areas.
- Evaluation of the optimal use of chemicals such as sulphuric acid in delinting different cotton seed varieties using different blender sizes.
- Evaluation of the accuracy of seed placement with mechanical sowing operation of various field crops under rain and irrigation.
- Catchment approach for enhancing traditional terrace cultivation for higher sorghum production in low rainfall areas.
- Development of adaptation technologies to climate change: Special attention for adaptation is on proper allocation of the efficient rain and irrigation water supply, land and crop development among components of the production system. The development aims at providing appropriate natural resources management tools through influencing of micro and macro systems of runoff farming, surface hydrology of watersheds, groundwater, soil and vegetation cover which contributes to domestic and agricultural water supply, resource conservation and production.
- Drought and desertification measures: Land degradation resulting from natural climax such as drought and miss-management of natural resources has become the

most common phenomena across the arid and semi-arid regions of the Sudan. The degradation is generally known to alter the hydrological balance over land and affect the productive capacity of land. Increased degradation over significantly large region could lead to desertification and desert-like conditions and reduced rainfall as well. This highlights the inherent links between crops, climate and conservation measures, and suggests the need for fully integrated crop-climate-conservation measures modeling approaches to take careful account of hydrology, soils and plants.

REFERENCES

Abbadi, K. A. and A. E. Ahmed. 2006. Brief Overview of Sudan Economy and Future Prospects For Agricultural Development. Khartoum Food Aid Forum, The World Food Programme (WFP).

Abdalla, S. and M. Karar. 2010. Water Policy of Sudan: National and Co-Basin Approach, Ministry of Irrigation and Water Resources, Sudan. Regional Centre on Urban Water Management. Tehran.

Administration of Statistics and Information. 1995. Ministry of Agriculture and Forestry, Sudan.

Barton, A. and G. Writer. 2012. “Water in Crisis – Spotlight on Sudan.” The Water Project. Retrieved 28/03/2013, from http://thewaterproject.org/water-in-crisissudan.asp.

Harrison, M. N. and J. K. Jackson. 1958. Ecological Classification of the Vegetation of the Sudan. Khatoum ,Agriculture Publications Committee.

IFAD. 2009. Republic of Sudan: Country Program Evaluation. Khartoum .2060-SD:136.

Institute for Security Studies. 2005. “Sudan Economy Overview.” Knowledge empowers Africa. Retrieved 22/03/2013 from http://www.issafrica.org/.

Omer, M. A. 1995. Adoptable Water Harvesting Techniques in the Sudan; Symposium of the Role of Scientific and Technological Research in the Sustainable Utilization of Arid and Semi-Arid Area, ARC, Wad Medani, Sudan.

Salman, S. M. A. 2013. The Gezera Scheme: Historical Background and Developments- Promulgated in Arabic. Algrar. Khartoum, Algrar Company.

Salman, S. M. A. 2013. “Sudan has failed to use 350 billion cubic meters of its share of the Nile water.” Sudanile. Retrieved 27/06/2013, from http://www.sudanile.com/index.php?option=com_content&view=article&id=53963:------350--------&catid=42:2008-05-19-17-16-29&Itemid=60.

Shukri Ahmed, *et al*. 2007. FAO/WEP Crop and Food Supply Assessment Mission to Sudan Special Report. Rome, FAO.

Stads, G. and K. ElSiddig. 2010. Recent Developments in Agricultural Research. Rome, FAO.

Taha, F. 2010. The History of the Nile Waters in the Sudan. The River Nile in the post-colonial age. T. Tvedt. London, IB Tauris:179-216.

UNEP. 2007. Sudan: Post-Conflict Environmental Assessment. Nairobi, United Nations Environment Programme.

■■

Modelling Variable Cost of Tractors: A Case Study of Ten Tractor Models in Juba of South Sudan

by

A. N. Gitau
Associate Professor
Department of Environmental and Biosystems Engineering
University of Nairobi
KENYA
gitauan@yahoo.co.uk; ayub.gitau@uonbi.ac.ke

S. N. Wilba
Department of Environmental and Biosystems Engineering
KENYA
samanicola@gmail.com

D. O. Mbuge
Department of Environmental and Biosystems Engineering
KENYA

S. T. Mwangi
Department of Environmental and Biosystems Engineering
KENYA

Abstract

Variable costs contrary to fixed costs increase with machine age. In addition, most of the decisions made by a farm power manager to replace a farm machinery are made based on the variable cost records. Thus, modelling variable costs of a farm tractor is very important because it will enable the farm manager to know the yearly cost of crop production and accumulated costs for operating a tractor, therefore, to make a decision on whether it is profitable to continue operating the machinery or it is better to sell it and replace it with another one.

This study was carried out in Jubek State of South Sudan by use of questionnaires for collecting operation costs data of ten tractor models of tractors which are MF375, Belarus800, JD5503, MF385, JD5510, JD5425, Mahindra8000, Mahindra705DI, Sonalika DI-90, and Sonalika DI-75. Data collected was sought on tractor characteristics and economic costs such as use of tractor each year, fuel consumption cost, lubrication oil cost, oil and fuel filters replacement cost, labour cost and workmanship cost.

Result showed that the cost of tractor repair and maintenance for all tractors studied had the highest percentage share from the total percentage cost followed by cost of fuel, labour (operator) cost, and then cost of lubrication oil.

From the results, it was found that power model gave better cost prediction with higher confidence and less variation than other models.

The derived models indicated that the accumulated variable costs as percentage of initial purchase price (List Price) increased as the accumulated hours of use increased for the ten tractor models studied.

Keywords: South Sudan, Modelling, Tractors, Variable Cost.

Introduction

Agricultural tractor is one of the most important energy and power sources in agricultural mechanization (Gifford and Rijk, 1980). It requires high initial capital investment. Effect of tractor power on agriculture is very huge (Singh, 2006).

The introduction of modern technology during the last century resulted in rapid growth of farm production. Tractors and farm machinery are important samples of this modern technology (Singh, 2000a; Singh, 2000b; Xinan *et al*., 2005).

Tractor costs have great influence on farm business profit. Knowledge of tractor costs for farm operations has a prime importance in making management plans and decisions especially in comparing different tractor types and models thereby assisting in the selection of a more appropriate farm tractor. Costs of owning and operating farm machinery represent 35 to 50% of the costs of agricultural production when the land is excluded (Anderson, 1988).

The repair and maintenance (R&M) cost is an important item in the costs of ownership and operation. R&M cost is a function of machine age and use (Hunt, 2001). In general, the costs other than those for R&M usually decrease with increasing usage, but the reverse is true with respect to R&M costs. The cost of R&M is usually about 10% of the total cost; as the machine age increases the cost increases until it becomes the largest cost item of owning and operating the farm machines (Rotz and Bowers, 1991).

Several studies have been conducted in both developed and developing countries either to develop models to determine the cost during a certain period of time or to get absolute numbers to represent owning and operating certain equipment (Abimbola, 1989; Bowers and Hunt, 1970; Fairbanks *et al*., 1971; Farrow *et al*., 1980; Gliem *et al*., 1989; Gliem *et al*., 1986; Rotz, 1987; Ward *et al*., 1985).

This study dealt with the variable costs which include repair and maintenance, fuel cost, oil and lubrication cost, and labour cost. The cost data of the variable cost parameters were collected then analysed using a SPSS. A model was developed by running a regression analysis on the data by trying the following models of linear, logarithmic, exponential, polynomial and power.

The results of this study could serve as benchmark information to farm managers in the study area regarding optimum use of tractors for minimizing repair and maintenance cost per operating hour and for making replacement policy. Thus it could be used by policy makers, farm managers and other agencies for future planning in the provision of tractor services to the farmers at relatively lower repair and maintenance cost.

The objective of this study was to develop a model for predicting or estimating variable costs of the 10 tractor models available in South Sudan. Specifically, the study involved identification of cost parameters pertinent to variable costs, establish the numerical values of the parameters identified and develop models that would best predict the variable costs.

Materials and Methods

Study Area

Juba city was founded in 1922 by Greek traders who were mostly supplying the British army at the time and it was called Gondokoro. It is a Capital City of the Republic of South Sudan as well as the capital of the former central Equatoria state and the current Jubek state and it is located in central south of the country west of the White Nile River some 140 km south of Bor town at a distance of three-hour drive from the border of Uganda (**Fig. 1**).

Fig. 1 Map of the Study Area

Juba has an estimated area of 22,956 kilometer square. It has an elevation of 550 m above sea level and falls between longitude 31° 34' 16.5036'' E and latitude 4° 51' 33.7068'' N. Juba has an estimated population of 300,000 inhabitants according to the world population review of 2017. The city is also the administrative center of the country. It is a river port and serves as the agricultural commercial center in the area.

Juba has a tropical wet and dry climate, and as it lies near the equator, temperatures are hot year-round. The summer Season starts from November to March, which is also the time of the year with the hottest maximum temperatures, reaching 38°C (100°F) in February. From April to October, more than 100 millimeters (3.9 in) of rain falls per month. The annual total precipitation is nearly 1,000 mm (39 in).

Data Collection

Questionnaires were constructed and used to collect cost parameters pertinent to variable costs for 10 tractor models. The questionnaire seek the data related to both tractors characteristic and economic cost which include manufacturing year, the purchase price, the number of operating years, the hours of use, repair and maintenance (R&M) cost, fuel cost, lubrication and oil costs, labor cost in addition to the age of a tractor. 169 questionnaires were administered of which 70 were used for collecting data about Belarus800, 40 for MF375, 40 for JD5503, 6 MF385, 2 JD5510, 1 JD5425, 3 Mahindra800, 2 Mahindra705DI, 2 Sonalika DI-90, and 3 Sonalika DI-75 from the (national ministry of agriculture in juba, Jubek state's ministry of agriculture in Juba, LONAGRO South Sudan LTD in juba, the Borlaug Institute, kolye Association, and Canadian Economic Development Assistance for South Sudan (CEDASS).

The total accumulated repair costs were calculated as a percent of the current list price of the machine, since repair and maintenance costs usually change at about the same rate as new list price (Ag Decision Maker File A3-29).

Repair costs are the expenditures for parts and labour for installing replacement parts after a part failure and reconditioning renewable parts as a result of wear. The anticipated annual cost of repair for any machine is highly uncertain (Ag Decision Maker File A3-29).

Parameters Calculation

Fuel cost

Annual fuel cost was calculated, the mean annual fuel cost was computed and the calculation of accumulated fuel cost which is the summation of mean annual fuel costs for the age of a tractor was also calculated.

Oil cost

Similarly, annual oil cost was recorded, the mean annual oil cost was also calculated and finally, the accumulated oil cost which is the summation of the mean annual oil cost was calculated for the years of operation of a tractor. The oil cost includes cost of brake oil, engine oil, and hydraulic oil.

Repair and maintenance cost

The annual repair and maintenance (R&M) cost which includes the costs of filters replacement, greasing, spare parts, tire replacement and workmanship were recorded. The annual repair and maintenance cost was calculated based on the market prices of spare parts, grease, filters, tire replacement and workmanship.

The mean annual repair and maintenance cost for each group of the ten tractor models surveyed was computed, the accumulated repair and maintenance cost was calculated by summation of the mean annual repair and maintenance costs over years for each group of the selected tractor models (War *et al*, 1985).

After that, the accumulated repair and maintenance cost was presented as a percentage of a purchase (list) price.

Labour (operator) cost

The annual tractors' operator cost for all tractor models studied was calculated for the number of years of operation of each tractor model then the mean annual operator cost was calculated followed by the calculation of the accumulated operator cost which is the summation of the mean annual operator cost.

Annual hours of use

The annual hours of use for each tractor model were calculated then the mean annual hours of use of each age group was calculated. The accumulated hours of use were also calculated by summation of the mean annual hours of use—which was calculated on the basis of effective working hours of the tractor—up to the last year of the age for the selected tractor model (Ward *et al*., 1985).

Variable cost

The annual variable cost which includes, annual R&M cost, annual oil cost, annual operator (labour) cost, and annual fuel cost was recorded.

Then the mean annual variable cost for each group of the ten tractor models surveyed was computed followed by the computation of the accumulated variable cost which was done by summation of the mean annual variable costs over years for each group of the selected tractor models. The accumulated variable cost was then presented as a percentage of a purchase (list) price.

Questionnaire Analysis

Statistical analysis was performed by using a statistical analysis software called (IBM SPSS Statistics 20). Using this software, a regression analysis was performed to find the correlation regression relations (R). Linear, exponential, logarithmic, power and polynomial regression types were all tried (Keshavarzpour, 2011).

Regression analysis of the data was carried out to represent the relation between the (accumulated operating costs per operating years (hours)) and the (operating years (hours)) of the 10 models of tractor studied.

Modelling and Statistical Analysis

The data collected was modelled in such a way that the (accumulated variable costs per operating time) was considered as a dependent variable because the value of it depends on the operating time and thus was plotted on Y-axis, whereas the operating time in years or hours was regarded as an independent variable and was labelled on X-axis.

Results and Discussions

Determination of the Variable Costs

Variable costs of all tractors studied were sought from the following: fuel costs, oil costs, labour costs and repair and maintenance costs which include (spare parts, filters, tires, grease, and workmanship). It was observed that for most of the tractor models studied, the repair and maintenance cost and fuel cost respectively had the highest percentage share compared to other parameters' cost (**Table 1**). Lack of refineries in S. Sudan could be the cause of high fuel cost. Also, most of the tractors in S. Sudan were old and therefore their consumption would be higher than the consumption of a new tractor.

Fig. 2 shows the mean annual operator costs for all tractor models studied. As it is seen, the mean annual operator cost for JD5425 and JD5510 models were the highest among the rest and this could be due to the area of the farm operated by these two tractor models which is an area of 147 hectare or it could be due to the age of operation of these two tractor models which is eight years each. This high mean annual operator cost could also be because of the scarcity in the number of well-trained and skilled tractor operators in the area of the study thus resulting into high pay rate for tractor operators.

Whereas the least mean annual operator costs were for Mahindra8000 and Sonalika DI-90 respectively which could be due to the area of the farm operated by each one of these two tractor models which is 25 hectare or could be due to the relatively low operator cost in this particular area.

Fig. 3 shows the mean annual costs of repair and maintenance (R&M) for all tractor models that are covered by this study. The mean annual repair and maintenance costs is the mean annual costs for the spare parts, mean annual costs for replacing oil and fuel filters, mean annual costs of grease, mean annual costs of workmanship, in addition to the mean annual costs for replacing tires. These costs were high for JD5425 and JD5510 respectively which could be due to the area of the farm on which they have been operating which is an area of 147 hectare or due to their age of operation which is eight years each as well as it could also be due to the filters' replacement time interval or due to some technical faults that are operator oriented such as when a tractor is operated by an operator who is not well trained which could cause frequent break down.

Whereas the least mean annual costs of repair and maintenance were for JD5503 and Sonalika DI-90 respectively and this could be because of the area of the farm on which they have been operating which is an area of 25 hectare or it could also be due to the filter's replacement time interval.

Fig. 4 shows the mean annual costs of oil for all tractor models studied. The mean annual oil costs involve the mean annual costs of brake oil, hydraulic oil, and engine oil. As it is seen, the mean annual costs of oil for Sonalika DI-90 and JD5425 were the highest among the rest and this could be due to the high prices of oil for these two tractor models or due to the age of operation of these two tractor models which is eight years. This high mean annual cost of oil could also be because of the area of the farm on which this two tractor models were operating which is an area of 147 hectares per each tractor or it could also be due to the oil replacement interval.

Whereas the least mean annual costs of oil were for JD5503 and MF375 respectively which could be due to the area of the farm operated by each model which is 25 hectare or could be due to the relatively low prices of oil for these two tractor models or this could be due to their age of operation which is 3 and 2 years respectively.

Fig. 5 shows the mean annual fuel costs for all tractor models studied. As it is seen, the mean annual fuel costs for JD5425 and JD5510 models were the highest costs among the rest and this could be due to the area of the farm on which these two tractor models were operating which is 147 hectares each. This high mean annual cost of fuel could also be due to the high price of fuel in the local market because though the country is an oil producing yet it does not have an oil refinery and as a result the fuel is imported and sometimes due to its scarcity at fuel stations which force the farmers to buy fuel from black market.

In addition to that the government partially lifted the fuel subsidy which led to increase in fuel prices or it could also be due to the age of operation of these two tractor models

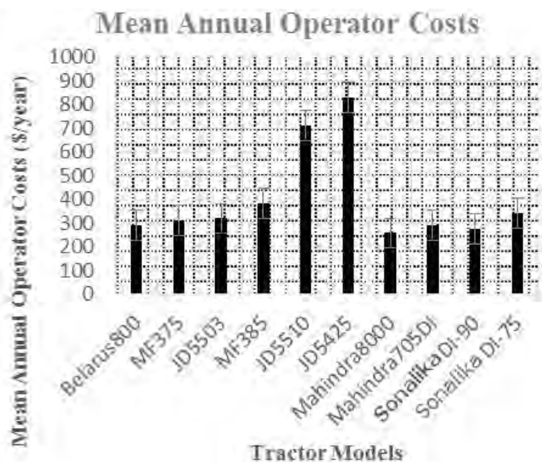


Fig. 2 The mean annual operator (labour) costs

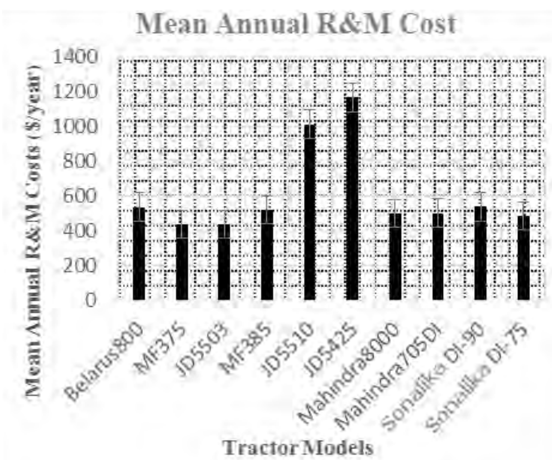


Fig. 3 The mean annual repair and maintenance cost

Table 1 Mean Annual Variable Costs in USD and as a percentage share of the total variable cost for each model

	Labour Cost		R&M Cost		Oil Cost		Fuel Cost		Total	
	($)	%	($)	%	($)	%	($)	%	($)	%
Belarus800	291	21.6	538	39.9	75	5.6	446	33.0	1,350	100
MF375	311	25.2	441	35.8	61	5.0	419	34	1,232	100
JD5503	320	26.0	438	35.5	55	4.5	420	34.1	1,233	100
MF385	382	25.5	524	34.9	75	5.0	519	34.6	1,500	100
JD5510	713	26.6	1,014	37.8	110	4.1	845	31.5	2,682	100
JD5425	831	26.6	1,167	37.3	128	4.1	999	32.0	3,125	100
Mahindra 8000	258	20.3	501	39.4	127	10.0	387	30.4	1,273	100
Mahindra 705DI	290	21.7	504	37.6	79	5.9	466	34.8	1,339	100
Sonalika DI-90	275	20.2	540	39.6	131	9.6	417	30.6	1,363	100
Sonalika DI-75	344	25.2	487	35.7	62	4.5	472	34.6	1,365	100

which is eight years for each model.

Whereas the least mean annual costs of fuel were for Sonalika DI-90 and MF375 respectively which could be due to the area of the farm on which each one of these two tractor models have been operating which is 25 hectares each or could be due to their age of operation.

Tractors Systems Failures and Variable Costs Distribution During The Period of Study

The results of data surveyed showed that the accumulated variable costs for all tractor models studied generally increased with age, but the rate of increase varies from one parameter to another. However, the accumulated variable cost for most tractor models studied showed that the variable costs start to increase drastically from year 4 and above (**Table 2**).

Determination of Mathematical Model to Predict the Variable Costs

The **Tables 3** and **4** present the result of the calculated accumulated variable costs as percentage of list price in USD and the accumulated operating hours of all tractor models studied. The accumulated variable costs as percentage of list price in USD and the accumulated operating hours' values obtained were used to analyze and determine the mathematical model.

Variable Costs Prediction Math Model Development

Regression analysis of the data was carried out to represent the relation between the accumulated variable cost as percentage of purchase price (list price) and the accumulated hours of use of the ten tractor models studied, the model of exponential, linear, logarithmic, polynomial and power with correlation coefficient related to themselves were tried.

The correlation regression method was used for data analysis. It was observed that for most of the tractor models studied, the highest value of coefficient of correlation (R^2) amongst the models was found on polynomial model followed by the power model. The power models were found easy in calculations and gave better cost predictions than the other models. The power function was found to be the best fit for the ten tractor models studied and

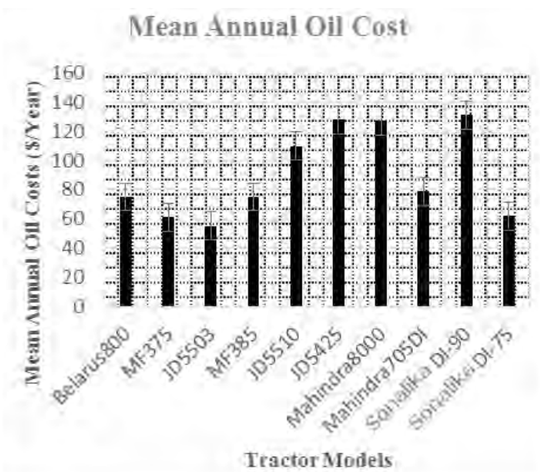


Fig. 4 The mean annual oil cost for the ten models of tractor studied

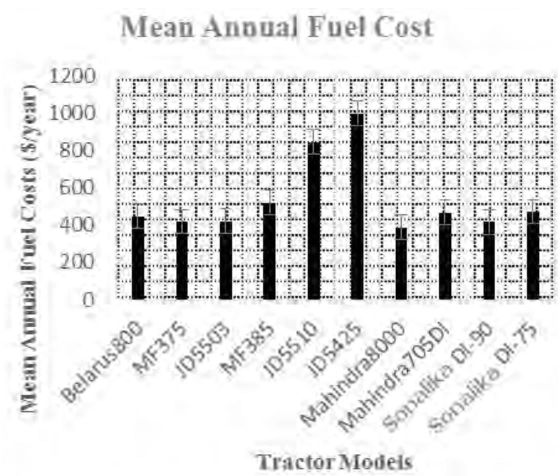


Fig. 5 The mean annual fuel cost for the ten models of tractor studied

Table 2 The accumulated variable cost in USD for each year of operation

Tractor Model	Accumulated Variable Cost Per Each Year of Operation for all Tractor Models Studied								
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Belarus800	-	-	-	-	-	-	-	1,260	2,700
MF375	-	-	-	-	-	-	-	1,137	2,463
JD5503	-	-	-	-	-	-	1,088	2,320	3,698
MF385	-	-	1,203	2,590	4,075	6,265	7,490	9,300	10,500
JD5510	-	1,663	3,627	5,893	8,461	11,331	14,504	17,978	21,453
JD5425	-	1,696	3,736	6,112	8,828	11,885	17,000	20,800	25,000
Mahindra8000	-	880	1,900	3,050	4,240	5,500	6,940	8,540	10,180
Mahindra705DI	-	978	2,060	3,244	4,532	5,922	7,416	9,013	10,712
Sonalika DI-90	927	1,962	3,107	4,360	5,723	7,194	8,775	10,464	12,263
Sonalika DI-75	945	1,995	3,150	4,410	5,775	7,245	8,820	10,500	12,285

accounted for 99% of the observed variations in accumulated variable costs as percentage of list price for each of the ten tractor models studied. These findings are in agreement with results of many researchers (Adekoya and Otono, 1990; Beppler and Hummeida, 1985; Khoub bakht *et al.*, 2008; Konda and Larson, 1990).

Regression Analysis

The equations given in **Tables 5** and **6** were obtained from the graphs in **Fig. 6** for the different models studied.

The Predicted Mathematical Models

See **Tables 6**.

Conclusions and Recommendations

Conclusions

The relationship between the accumulated variable costs as percentage of the initial purchase price of the tractor (y) and accumulated hours of use (x) for all tractor models studied is as follows:

$y = ax^b$

Where;

y = accumulated variable costs as percentage of the initial purchase price

a and b = estimate parameters

x = accumulated hours of use.

Table 3 Accumulated operating hours for each year of operation

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Belarus800	-	-	-	-	-	-	-	251.96	503.91
MF375	-	-	-	-	-	-	-	237.64	475.75
JD5503	-	-	-	-	-	-	145.86	291.87	440.66
MF385	-	-	245.15	495.40	742.98	989.36	1,236.07	1,485.24	1,735.87
JD5510	-	397.72	795.63	1193.34	1,599.65	1,999.54	2,395.69	2,797.91	3,198.77
JD5425	-	511.92	1,035.66	1,550.62	2,065.75	2,580.33	3,097.12	3,720.67	4,231.69
Mahindra 8000	-	96.45	195.94	299.35	396.96	495.46	592.29	693.81	789.13
Mahindra 705DI	-	139.13	279.53	425.26	567.03	715.63	855.59	994.72	1,136.53
Sonalika DI-90	106.45	213.23	320.19	430.24	560.76	670.76	780.51	895.53	997.65
Sonalika DI-75	123.46	247.83	371.09	496.98	622.04	746.07	870.89	997.93	1,125.78

Table 4 Accumulated variable cost as percentage of list price in usd for each year of operation

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Belarus800	-	-	-	-	-	-	-	7	15
MF375	-	-	-	-	-	-	-	6	13
JD5503	-	-	-	-	-	-	7.5	16	25.5
MF385	-	-	6.5	14	22.03	33.86	40.49	50.27	56.76
JD5510	-	5.5	12	19.5	28	37.5	48	59.5	71
JD5425	-	5	11	18	26	35.01	50.07	61.27	73.64
Mahindra 8000	-	8	17.27	27.73	38.55	50	63.09	77.64	92.55
Mahindra 705DI	-	9.5	20	31.5	44	57.5	72	87.5	104
Sonalika DI-90	8.5	18	28.5	40	52.5	66	80.5	96	112.5
Sonalika DI-75	9	19	30	42	55	69	84	100	117

Table 5 Regression analysis of the relationship between the accumulated variable cost as a percentage of purchase price and the accumulated hours of use on power model

Tractor Model	Power Model	R^2
Belarus800	$y = 0.016x^{1.0996}$	1
MF375	$y = 0.0135x^{1.1139}$	1
JD5503	$y = 0.0303x^{1.1053}$	0.9999
MF385	$y = 0.0128x^{1.1315}$	0.9974
JD5510	$y = 0.004x^{1.2017}$	0.9994
JD4525	$y = 0.0015x^{1.2885}$	0.9953
Mahindra8000	$y = 0.0382x^{1.1611}$	0.9985
Mahindra705DI	$y = 0.0334x^{1.1371}$	0.9986
Sonalika DI-90	$y = 0.0989x^{1.0335}$	0.9575
Sonalika DI-75	$y = 0.0317x^{1.1632}$	0.9987

Table 6 The predicted mathematical models

Belarus800	$y = 0.016x^{1.0996}$
MF375	$y = 0.0135x^{1.1139}$
JD5503	$y = 0.0303x^{1.1053}$
MF385	$y = 0.0128x^{1.1315}$
JD5510	$y = 0.004x^{1.2017}$
JD5425	$y = 0.0015x^{1.2885}$
Mahindra8000	$y = 0.0382x^{1.1611}$
Mahindra705DI	$y = 0.0334x^{1.1371}$
Sonalika DI-90	$y = 0.0989x^{1.0335}$
Sonalika DI-75	$y = 0.0317x^{1.1632}$

Where: y = Accumulated Variable costs as % of initial purchase price (List Price).
x = Accumulated hours of use.

The model developed in this study has similarities with models developed by other researchers as show in **Table 7**.

It was found that variable cost increased with an increase in operating hours of all tractor models studied.

Results of this study indicated that average variable costs per hour increased with tractor age. Also, indicated that annual variable costs increase with age of tractor.

The accumulated variable costs increase with tractor age and hours of use.

These results also confirmed that there are considerable variations in variable costs among tractor models as well as individual ones.

The model developed has the tractor accumulated operating hours as the major determining factor of the variable costs.

Recommendations

Further studies should be carried out to cover more areas of the country and more tractors makes to achieve precise estimations for variable costs on different types of soil under different operations conditions.

The governmental companies and schemes that deal with agricultural tractors must concentrate on the effects of variable costs determination on the economical life of agricultural tractors, and therefore should keep a very precise records about them.

Because the source of data was only personal contact, this model may be regarded as an approximation for variable costs in the area of study.

It is recommended that the use of mathematical models developed for tractors variable cost be applied only to those conditions for which they were developed.

Table 7 Models developed by different researchers

Models developed by different researchers	Source (s)
$y = 0.042\ (x / 120)^{1.865}$	Ward *et al*., (1985)
$y = 0.042\ (x / 1000)^{2}$	ASABE (1983)
$y = 0.00865x^{1}$	Culpin (1975)
$y = 0.072\ (x / 120)^{1.6}$	Bowers and Hunt (1970)
$y = (0.00996x^{1.4775})\ 10^{-3}$	Morris (1987)
$y = 0.005x^{1.2}$	Abubakar *et al.*, (2013)

REFERENCES

Anderson A. W. 1998. Factors affecting machinery costs in grain production, ASAE paper No. 88-1057.

ASAE Standards EP496. 2006. Agricultural Machinery Management Engineering Practice. ASAE paper. . No. 80-1017.

Ashtiani, A. R., I. Ranjbar and M.

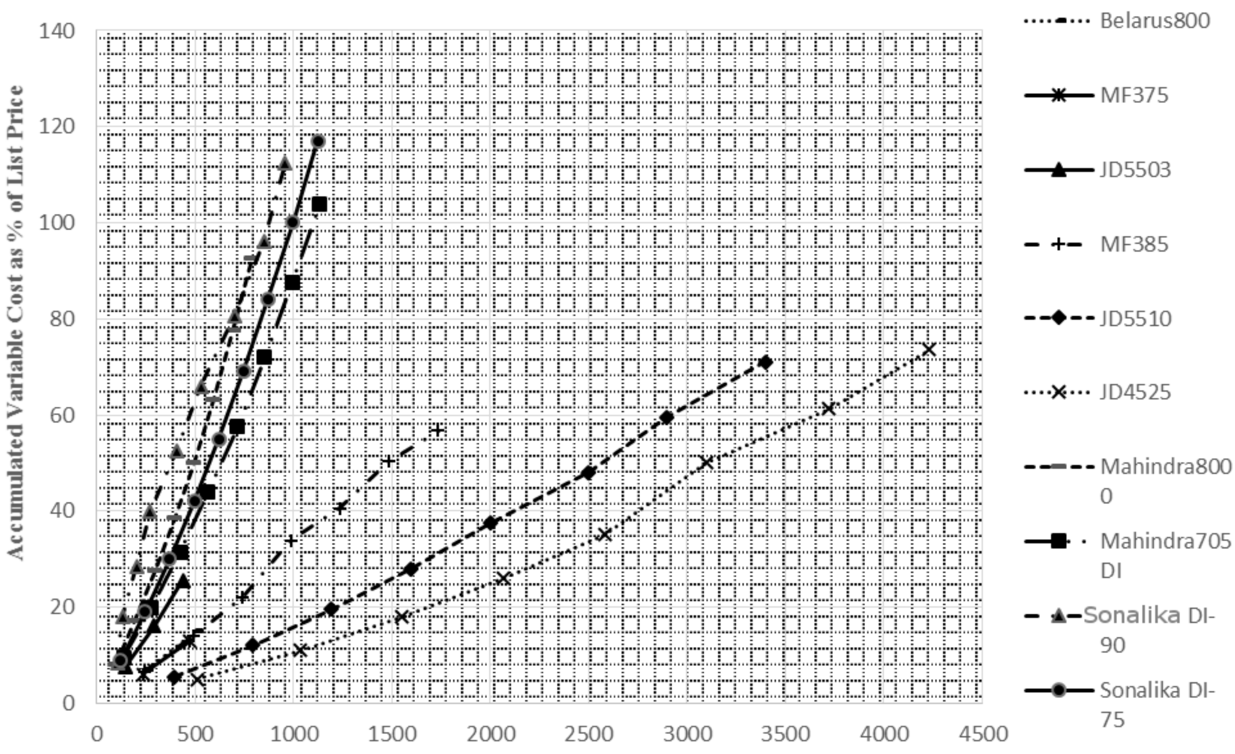


Fig. 6 Comparison of accumulated variable costs for all the ten tractor models studied

Toorchi. 2005. Determining the economic life for three agricultural tractor models in Iran (case study: Mazandaran Dasht-e-Naz Farm Company), Journal of Agricultural Sciences, Islamic Azad University. 12(1): 221-230.

Brian. G. S. and J. Kienzle. 2006. Farm Power and Mechanization for Small farms in Sub-Saharan Africa.

Clarke, L. and C. Bishop. 2002. "Farm Power—Present and Future Availability in Developing Countries". Agricultural Engineering International: ASAE Annual International Meeting / CIGR World Congress, July 30, 2002, Chicago, IL. USA. Vol. IV. October, 2002.

Economic and Social Commission for Asia and the Pacific (ESCAP). 1980. Regional network for agril. Machinery.

FAO. 2004. Agricultural Mechanization in Sub-Saharan Africa.

FAO. 2005. World Agriculture, Towards 2015/2030.

FAO. 2008. Planning Investment for Enhanced Agricultural Productivity

Eltom Abdallah, F., D. Weiming, M. Hassan Dahab, A. E. Idris and M. Alhadi. 2014. Estimation of repair and maintenance cost of a tractor base on HP and Working hours: Case study of Sudan. 1:1 Journal of Environmental and Agricultural Sciences. ISBN: 2313. 8629.

Gebresenbet, G. and P. G Kaumbutho. 1997. Comparative Analysis of the Field Performance of a Reversible Animal—Drawn Prototype and Conventional Mouldboard Ploughs Pulled by a Single Donkey. Soil and Tillage Research 40:169-183.

Gliem, J. A., K. M. Persinger, T. G. Carpenter and R. G. Holmes. 1989. A comparison of ASAE estimated tractor and Combine Repair and Maintenance Costs to Actual Repair and Maintenance Costs of Selected farms. ASAE Paper. No. 89-1024.

Gliem, J. A., D. M. Stinson, T. G. Carpenter, R. G. Holmes and H. E. Ozcan. 1986. Updated Variable costs of Farm Machinery Operation in Ohio, ASAE Paper. No. 86-1024.

Hunt, D. R. 2001. Farm Power and Machinery Management, Tenth Edition, Iowa state University Press, Ames. USA.

Pawlak, J., G. Pellizzi, and M. Fiala. 2002. "On the Development of Agricultural Mechanization to ensure a Long-Term World Food Supply". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited Overview Paper. Vol. IV. June, 2002.

Adebiyi, K., J. O. Ojediran and O. A Oyenuga. 2016. An appraisal of Maintenance Practice in food industries in Nigeria, Journal of food Engineering, Impact factor: 277.

Khoubakht, G. M. 2008. Determination of optimum life (economic life) for MF285 tractor, a case study in west region of Isfahan province, Iran.

Lazarus, W. 2008. Machinery cost estimates, Extension Published by Department of Applied economics, University of Minnesota.

Ahmed, M. H., A. A. K. H. Ahmed, A. B. Saeed and I. Haffar. 2016. Tractor repair and maintenance cost in Sudan- I: Development of a standard model. AMA, Agricultural Mechanization in Asia, Africa and Latin America. Impact Factor: 0.01.

Muhammad Ishag Asif Rehmani. 2014. Estimation of repair and maintenance costs of a tractor based on HP and Working hours: Case study of Sudan. . Full-text Article.

Gifford, R. C. and A. G. Rijk. 1980. Guidelines for Ministry of Agriculture, New Delhi. agricultural mechanisation strategy in development. Economic and Social Commission for Asia and the Pacific (ESCAP), Regional Network for Agril. Machinery.

Rotz, C. A. 1987. A standard Model for Repair costs of Agricultural Machinery. Appl. Engineering in agric. 3(1): 3.

Rotz, C. A. and W. Bowers. 1991. Repair and Maintenance cost data for Agricultural Equipment. ASAE Paper. No. 91-1531.

Saleh, A. Al-suhaibani and M. F. Wahby. 2015. Farm tractor breakdown classification. Full-text Article.

S. M. Niari, I. Ranjbar and M. Rashidi, 2016. Prediction of repair and maintenance costs of John Deere 4955 tractors in Ardabil Province, Iran. World Applied Science Journal. Impact Factor: 0.23.

Sharifi, A. 1994. Determination of a Mathematical Model to Predict the Repair and Maintenance cost of three Models of farm tractors in Iran, Msc Thesis, Faculty of Agricultural Engineering and Technology, Department of Agricultural Machinery Engineering, University of Tehran, Iran.

Singh, G. 2006. Estimation of a Mechanization Index and its Impact on Production and Economic Factors, A case study in India, Biosystems Engineering. 93(1): 99-106.

Singh, G. 2006. Modernization of Agriculture in India (Part 1)-Farm Mechanization. Agricultural Situation in India.

Singh, G. 1997. Data Book on Mechanization and Agro-processing in India after Independence. Technical Bulletin CIAE/97/71, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, India.

Singh, G. and H. Chandra. 2002. Production and Economic factors Growth in Indian Agriculture, Technical bulletin No. CIAE/2002/91, Central Institute of Agricultural Engineering, Nabi Bagh, berasia Road, Bhopal, India.

(Continued on page 117)

Producers Get Together to Step Up Mechanization of Their Family Farms—The Mechanization Cooperatives in Benin

by
Denis Herbel
Senior Advisor for Producer Organizations and Co-operatives
FAO, Rome
ITALY

Koffivi Nouwogou
General Secretary of UNCUMA
BENIN

Gontrand C. Bagan
Directeur de l'Ecole de Machinisme Agricole & de Construction Mécanique (EMACoM)
Université Nationale d'Agriculture (UNA)
BÉNIN

Background Data: Context

In Benin, agriculture is:

- the first sector in the economy with 31% of GDP, 43% of the labor force, 70% of export earning with cotton fiber;
- 400,000 small-scale farms from 1 to 10 ha,

- Extensive farming systems with 75% of land preparation made with hoe, 24% with animal-drawn equipment and only 1% mechanized. But it is also,
- An obvious agricultural potential with less than 20% (approximately 1,375,000 ha) of the utilized agricultural area are cultivated, a young population, and a favorable agro-climatic environmental conditions.

To address the challenges of food security and rural poverty reduction, Benin as other sub-Saharan African agricultures has to set up a sustainable intensification (FAO, 2014) by a combination of increased labor and higher yields. Land productivity must be achieved by a sustainable agricultural intensification practices that produce more output from the same area of land while reducing negative environmental impacts. In order to do this, Beninese farmers have to use improved varieties, more inputs and a significant increase in labor productivity with its gradual mechanization in a sustainable way.

Characteristics and Functions

Dispersed, fragmented and marginalized family farmers must come together to engage in collective action. When small-scale farmers group themselves together in cooperatives and producer organizations, they are able to overcome many of the various barriers that they face. The high cost of farm machinery, processing equipment and the limited savings capacity of farmers make it difficult for family farmers to acquire machinery and equipment needed for intensifying production. Small-scale family farmers do not have the acreage to justify the cost of a full line of modern farm equipment. The combination of the large investment to acquire machinery (capital and interest), and its operating costs (fuel, insurance, maintenance and repair costs) exclude most family farmers from embracing mechanization. By pooling equipment, co-operatives offer an innovative organizational arrangement to share equipment by reducing machinery costs, financial risks and making limited capital available for other uses. In Benin, cooperatives of mechanization, CUMA: Farm Machinery Cooperative (cooperatice d'utilisation de matériels agricoles), are small groups of farmers who pool their resources in order to purchase and use agricultural equipment according to rules of democratic self-management. The system allows the farmers to:

- purchase equipment they could not purchase on their own;
- make optimal use of the equipment; thus minimize the cost of mechanization;
- share risks; benefit from greater exchange and contact among themselves.

Each group is composed of an average of ten farmers for a total area of about 100 hectares. They are located fairly close to one another, at less than 10 or 15 kilometers apart; they are sharing the same modernization and development vision. Distribution of CUMA is shown in **Fig. 1**. Each Beninese CUMA uses the same equipment a tractor of 60 to 75 horsepower, one plough and one 3-tonne trailer. It represents an investment of about 6 millions CFAF.

Fig. 1 Distribution of CUMA in Benin

A Rapid Development of Cooperatives in Terms of Size of Area, Number of Farmers and New Areas of Activity

The CUMA movement over the last 20 years has shown a rapid development as illustrated in **Fig. 2**. Since the first-ever creation of a CUMA in 1997, the CUMAs have grown rapidly in the North of Benin, first in the Borgou district and then from 1999, the CUMAs appeared in the Alibory district. Finally, in 2007 the CUMA development reached the southern part of the country, in the districts of Mono and Couffo. Between 1997 and 2005, the growth rate was low as only ten CUMAs had been created at the end of the period. Between 2006 and 2016, their number increased quickly to reach 86 cooperatives. The increased number of local cooperatives was accompanied by the structuring of the CUMA movement into a network made up of regional and district Unions: the Alibory and Borgou regional union in 2003, the Mono and Couffo regional union in 2009 and finally in the same year the national federation (UNCUMA).

The CUMA movement over the last 20 years has also shown a development in terms of scope: new areas of activity. The first cooperatives were engaged in ploughing and transport activities in the North. Nowadays CUMAs in the South are developing activities of primary transformation of cassava with graters and processing of palm kernel with presses and crushers. Last but not least, in 2012, the T2A (Tracto Agro Africa) which is a company specialized in the importation and marketing of second hand tractors and spare parts was established.

Impacts

The CUMA survey (Balse, *et al.*, 2015) suggests that collective action in shared mechanization cooperatives provides at farm level, household level and to their communities strong socio-economic advantages, improving incomes and rural living conditions.

Impact of the CUMAs at Farm Levels

At farm level, the introduction of motorization has resulted in a strong increase in cultivated crop areas on each farm. On average, the farmers investigated have multiplied their cropped areas by 3.5 since they began ploughing with the tractor belonging to the CUMA (Balse, *et al.*, 2015). As illustrated in **Fig. 3**, this increase concerns both small farms and larger one. The survey undertaken does not provide data on the impact of mechanization on crop yields of the CUMA members. The evolution of crop yields is only based on the qualitative appreciation made by the farmers interviewed.

District	Number de CUMA	Members		
		Men	Women	Total
ALIBORI	49	150	20	170
BORGOU	25	179	24	203
COUFFO	9	56	25	81
MONO	3	21	9	30
OUEME	1	7	0	7
TOTAL	87	413	78	491

Source: UNCUMA, 2017

Fig. 2 Number of CUMAs created

According to them, mechanization is boosting crop yields. They attribute this to a "better quality" ploughing with a deeper work of the soil which allows for a better retention of humidity, to bury the weeds deeply in the soil, and to favor the crop root development. Moreover, other factors can explain crop yield improvement. Private agricultural contractors face a huge farmer demand so ploughing works are extended over an excessively long period. Thus farmers' cultivation operations are delayed and yields are reduced. In addition, according to CUMA members the drivers of the co-operative are better trained, therefore, deliver better quality work. A combination of higher yields and larger areas cultivated have boosted farm income generation.

At household level, agricultural mechanization, thanks to higher incomes, has allowed farmers to send their children to school, to invest in improving their living conditions, for example, by building individual houses in concrete. Some members of CUMAs interviewed, indicated the use of the tractor in transport activities for collecting fuelwood traditionally performed by rural women and girls. In South Benin, the new development zone for the movement, the CUMAs are performing cassava and palm oil primary transformation activities. Considering the women's time burden in the traditional preparation of both products and for collecting fuelwood, these labor-saving CUMA activities induce a deep social transformation with impact on women's daily duties.

The CUMA movement has contributed to a deep social change in the communities where the cooperatives of mechanization are present. The socio-economic impact of the CUMA well exceeds the improvement of the wellbeing of individual, male and female, farmers. CUMAs have a positive impact on the whole community, for example, by supporting social projects or community infrastructures such as youth clubs, markets, grain storage and marketing at village level. One significant example of how the new behavior of small-scale farmers is the creation of the corn's Cooperative of Borgou by members of CUMAs. Indeed, in response to the increase in maize production by their members, the representatives of the CUMAs of Borgou department created the corn's Cooperative of Borgou (CMB) in 2010. The objective was to guarantee input supply to their members, to store the production, to market quality corn and to adapt the selling strategy to the market. Today, the CMB gathers 160 producers and markets more than 900 tons of each year.

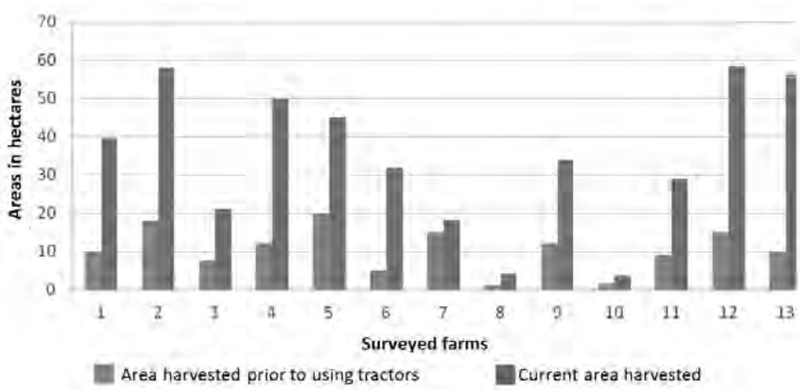


Fig. 3 Evolution of cultivated areas—before and after entering in the CUMA of the farms under survey
Source: Balse M.; Ferrier C.; Girard P.; Havard M.;Herbel D.; Larue F. 2015

In Benin, youth form a major share of rural populations, but many face bleak economic prospects no matter whether they stay in the countryside or migrate to cities. The survey collected youth appreciation on CUMAs. For youth, mechanization means modernization. The CUMAs have created, in rural areas, a new perception of the agriculture profession by youth.

Enabling Conditions: internal Factors of Success

What are the core design elements allowing effective and sustainable cooperatives of mechanization? What are the critical conditions that allow a CUMA to provide for its members enduring mechanization services? The thriving development of CUMAs is grounded in a dense fabric of relations among members of a CUMA, the bonding social capital, and between local CUMAs within federative organizations, the bridging social capital.

CUMAs are single purpose (mechanization) cooperatives, pursuing primarily an economic mission, the need of farm mechanization of the members of the organization (member-oriented). The CUMA is a voluntary cooperation between individual family farmers attempting to improve their socio-economic position; members share a common economic interest (utility principle).

Although the CUMA is primarily organized around economic purposes, the social element should not be underestimated: a CUMA is a voluntary small group sharing a common identity based on:

- A Geographic basis: the cooperative is established as a small organization grounded in a local territory within a particular community, neighborhood or local region;
- A common history of working together;

- Affinity among members: An organization to which adheres voluntarily small-scale farmers sharing the same vision.

Each co-op has a limited number of voluntary members living in the same area. In all co-ops, each member knew one another because they belong to the same village. Generally members shared a common history of working or collaborating together. It is the case when CUMA members were previously belonging to the same youth group. In the latter, before the creation of the CUMA, young people were hiring out their services to farmers to finance social activities in the village. In other cases, farmers belonged to the same farmer input supply group. In these small organizations frequent direct interactions increase mutual trust and the control of the group on individual members (social pressure). A high degree of member homogeneity characterizes the Beninese CUMAs (identity principle). In addition, with high members' homogeneity there are few conflicts of interest. The more homogeneous the cooperative membership, the lower the free-riding problem and the more efficient the decision-making processes.

A very close member control on the organization is another strong characteristic of CUMAs (member control principle). First at all, the creation of a CUMA is a farmers' decision; it is not a government, or donor initiative. Before deciding to form a cooperative, the farmers meet on various occasions to consider the different alternatives of mechanization, and to think together how to gather the necessary resources to establish the organization. In the stages before the Cuma establishment, farmers organize at village level debates and meetings. The farmers before establishing their farmer-owned enterprise, with the support the national union, use a problem-solving approach in which first their problems are identified, analyzed and debated. The decision to create a cooperative, a new CUMA, emerges after weighing the pros and cons, the costs and benefits of establishing a cooperative. The support of local or national farmer union leaders plays a significant role. Having an effective leader in the community creates a catalyst effect for the launch of the cooperative. In many cases, this champion is a local leader of a producer organization such as a cotton organization or a farmer trade union (FUPRO)—FUPRO-BENIN (FEDERATION DES UNIONS DE PRODUCTEURS DU BENIN) is a multi-layered organisation composed of primary cooperatives and associations, district unions (UCP) and regional unions (URP). In some other cases, the most motivated farmers initiate and organize themselves a series of meetings and debates at village level. They catalyze farmers' energies towards the creation of a CUMA by generating the motivation to do so. Each villager is invited to participate in the gathering where he or she is informed about the CUMAs, invited to provide an opinion and has a voice to influence the final decision to engage in cooperative creation. Very often, the facilitator of the regional or departmental CUMA Union has to support this process by providing information on the CUMA movement, its mission and vision and by presenting diverse realizations of the CUMA movement. During the meetings and debates organized at village level, the first compelling vision emerges of what the cooperative and its future members aspire to be and to accomplish in the mid and long term.

Once the cooperative has been set up, decision-making is based on "one person, one vote". The CUMA has its own statutes and its own rules and by-laws. Its general assembly elects the executive director and farmers in charge operational functions: the treasurer, secretary and equipment manager, who are responsible for management of the CUMA. The function of the person in charge of equipment is critical. He or she has to ensure that the equipment is available and monitor it, make field visits, draw up equipment use plans and ensure compliance with these, liaise between the tractor driver and the members, organize repairs to the equipment, request quotes from suppliers, organize maintenance of the equipment and make sure spare parts are available. There are written rules, accepted by all the members, regarding the way the equipment is to be used.

The capacity of an organization to define and implement its strategic choices—its autonomy—depends on its capacity to generate its own resources: its operational costs and its investment costs (autonomy principle). Thus in a CUMA:

- The investment cost for purchasing the agricultural equipment is made on the basis of a financing plan; it involves a minimum of self-financing by the members of the group, in the form of cooperative shares, with the remainder being financed by a loan. The payment of the equipment is made: 60% with order, the balance in the delivery.
- Members are charged for tractor use. The cost of the service provided to each member is calculated according to operating costs (tractor driver, running repairs) and is invoiced on the basis of members' use, while fixed costs (major repairs, annual payments) are charged on the basis of the area involved; the CUMA may ask its members to advance their contribution of variable costs at the start of the season, or even their shares of fixed costs in the case of major repairs.

These four principles:

- The Utility principle: the cooperative mission is a response to its members' needs such as explained above in point I (see the second page of this paper);

- The Identity principle: the cooperative is a group of affinity with shared values, a common history and a common local territory translated into a shared vision;
- The Control principle: CUMAs are Farmers' led organization (governance);
- The Autonomy principle: CUMAs generate their own resources necessary to ensure their effective functioning.

These principles structure the organizational design of each local CUMA providing strong commitments and engagement among members.

The second success factor of the CUMA cooperatives relates to the relations of cooperation among cooperatives: the bridging social capital. The CUMA movement in Benin has developed federative cooperative structures with:

- Two unions at county level: UD-CUMA,
- Two unions at region level: UR-CUMA,
- One national union: UNCUMA

This CUMA network is making great efforts to train tractor operators and farmers to drive and maintain tractors and calibrate ploughs and to promote ploughing that has the least possible negative impact on the soil. Moreover, raising awareness has been relatively effective considering that CUMA farmers acknowledge the fact that CUMA tractor operators offer higher quality ploughing services compared to their private service provider counterparts. This federative network allows the following actions at communal, departmental, regional and national levels:

- coordination and promotion of the CUMAs' development;
- defence of the CUMAs' interests in relations with government offices, relations with financial institutions and suppliers;
- development of finance and supply chains.

Enabling Conditions: External Factors of Success

Finally, the third success factor of the CUMA cooperatives relates to the creation of dense network of relations with multiple actors: the linking social capital. One cause of the numerous mechanization failure of family farming in Africa is the lack of a complete mechanization value chain with all its different actors from the upstream and from the downstream: machinery dealers, spare parts suppliers, repairers, trained drivers, schools of mechanization, etc. The CUMA movement in Benin was able to develop strong linking relations with external actors. It is in the center of an integrated system (see **Fig. 4**).

The CUMA movement has developed a partnership with the French cooperative movement for the support of the Benin CUMAs. They place emphasis on sharing of know-how via exchanges amongst farmers, amongst technicians, or between farmers and technicians. Through this, they are contributing to the training of coordinators, mechanics, tractor operators, and farmers that are members of CUMA. Then, via the establishment of an import/export company, Tracto Agro Africa (T2A), making it easier for CUMA in Benin to gain access to material and spare parts. These

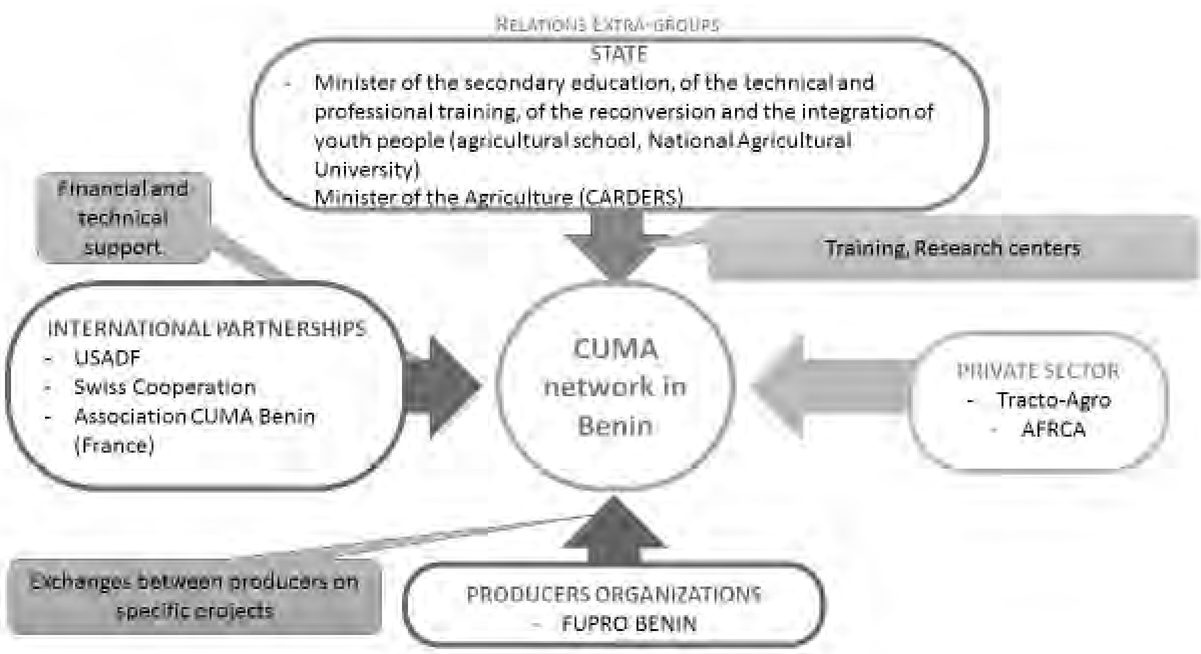


Fig. 4 Integrated mechanization system within an institutional environment

relations have developed new partnerships with education and training in agriculture; it is for example the case of the creation of centers of machinery for training in two agricultural secondary schools in Benin.

Conclusions: Main Lessons

Farming in Africa is at the heart of three major challenges:

- improved food security,
- poverty reduction and
- job creation.

To achieve these three challenges, it is crucial to increase farm production, specifically labor productivity; which will in turn mean an increase in yields. The successful example of BENIN CUMA movement demonstrates that family farming can meet these challenges with cooperative development.

REFERENCES

FAO. 2014. Innovation in family farming: The state of food and agrivculture 2014. ROME: Food and Agriculture organization of the United Nations.

Balse, M., C. Ferrier, P. Girard, M. Havard, D. Herbel and F. Larue. UNE EXPÉRIENCE ORIGINALE DE MÉCANISATION PARTAGÉE EN AFRIQUE LES COOPÉRATIVES D'UTILISATION DE MATÉRIEL AGRICOLE DU BÉNIN. FARM—Champs d'acteurs n°3—Avril 2015

■■

(Continued from page 111)

Singh, R. B. 2000. Environmental Consequences of Agricultural Development: a case study from the Green Revolution state of Haryana, India. Agriculture, Ecosystems and Environ. 82: 97-103.

Taheri, M. R. 1998. Determination of a Mathematical Model to Predict the Repair and Maintenance cost of three Models of Farm Tractors in Parsabad Agroindustry Co., Msc Thesis, Department of Agricultural Machinery Engineering, university of Tabriz, Iran.

UNIDO. 2008. Planning Investment for Enhanced Agricultural Productivity.

Ward, S. M. and M. B. Mucnulty. 1985. Repair Costs of 2 and 4 WD Tractors. Transactions of the ASAE. 28(4): 1074-6.

Xinan, D., L. Yuzhou, D. Suocheng and Y. Xiusheng. 2005. Impact of Resources and Technology on Farm Production in Northwestern China. Agril. Systems. 84: 155-169.

■■

Present Status and Future Prospects of Farm Mechanization and Agricultural Machinery Industry in Nigeria

by

O. E. Omofunmi
Dept. of Agricultural and Bio-resources Engr.
Federal University Oye-Ekiti State
NIGERIA

A. M. Olaniyan
Dept. of Agricultural and Bio-resources Engr.
Federal University Oye-Ekiti State
NIGERIA

Abstract

The future of agricultural mechanization and machinery development are interrelated and the successful implementation of mechanized agriculture not only depends on the availability of machinery but also on the positive response of government and perception of farmers and other users. Agricultural mechanization in Nigeria is based on regional patterns. The market for mechanization services is also based on regions comprising of North East (NE), North West (NW), North Central (NC), South-South (SS), South East (SE) and South West (SW) of Nigeria, with an uneven supply across locations. This paper presents briefly the present status and future prospects of agricultural mechanization and machinery industry in Nigeria. Both public and private institutions in Nigeria are involved in the importation and manufacturing of agricultural machines and equipment. The spare parts of these agricultural machines and equipment are also not left out. Captured in the paper is the percentage of farmers in Nigeria using tractor and animal traction farm power sources. Also discussed in the paper are the challenges facing agricultural mechanization and machinery industry in Nigeria.

Keywords: Agricultural mechanization, agricultural machinery, development plan, challenges, Nigeria

Introduction

Nigeria got independence from the British Government in 1960 and was declared Republic of Nigeria in 1963. Nigeria is a country located in West Africa having an area of 923,768.00 sq. kilometres. The country lies between latitude 4° and 14° north of the equator and longitudes 3° and 14° east of the Greenwich meridian. This is entirely within the tropical zone. The average temperature in Nigeria is 27.5°C in the south and 36.9°C in the north. Nigeria is divided into 36 States and these States were further sub-divided into six geo-political zones, namely North East (NE), North West (NW), North Central (NC), South-South (SS), South East (SE) and South West (SW). At the time of independence, most farm operations were performed with hand tools, farm productivity then was very low, but the population were few and basic food need of the country was met through importation. Increasing population, decreasing agricultural land, increasing demand for food, extensive land degradation and inadequate infrastructure have been the major factors of the agriculture sector in Nigeria (Ladeinde *et al.*, 2009). This situation has forced all stakeholders in the private and government sectors to pay attention to agricultural mechanization. Mechanisation systems are often categorized into man, animal and engine powered technology. Takeshima *et al.* (2013a) reported that 85% of human power, 11% of animal power and 4% of engine power accounts for the overall sources of power for agricultural production in Nigeria.

Overview

In the Ten Year Development Plan which took place between 1946 and 1956, tractor hiring service (THS) was established by the British Government in 1952 for the purpose of assisting those farmers that could not afford to own a tractor (Aboaba, 1967). We also have the first National Development Plan which took place between 1962 and 1968. The Second National Development Plan also took place between 1970 and 1974. The mechanization in agriculture in Nigeria was based on the 1970-1974 National Development Plan on agricultural mechanization; then "no realistic change was observed in Nigerian Agriculture, due to the drudgery attached to it, until the farmer finds an alternative to the hoe and cutlass technique of production. The clearing of bush, preparation of land, the sowing of seeds, the various post-planting operations are all processes in which the farmer's present tools can do little for high productivity per man day or per acre". The over reliance on hand tool technology (over 70%) for agricultural production is one of the greatest technical problems facing the past and present generation of Nigerian farmers. However, the key to mechanization development lies in raising agricultural productivity that directly involves the utilization of more energy resources (Takeshima *et al*., 2014) as compared to previous years of National Development Plan. However, the reason why Nigeria's agriculture has not made any tangible forward movement was that there has been very little engineering component put into it by government, agricultural engineers and farmers. **Table 1** presents some of the agricultural developmental activities that took place in Nigeria between 1946 and 2011.

Fig. 1 presents the number of tractors in use in Nigeria within the period covered.

Other past policies on agricultural mechanization in Nigeria are itemized as follows:

Government Tractor-Hiring Service (THS)

- Expanded (number of tractors) in 1970s.
- Distribution of 250 units of 50 hp tractors across the country in 1983 (Ladeinde *et al*., 2009).

Table 1 Agricultural Developmental Activities that took from 1946 to 2011

Period covered	Activities	Source
1946-1956	● The Colonial masters emphasized commodity crop production mainly oil palm, cocoa, rubber, cotton and groundnuts. The document contained very little or no proposal for increased food production. Majority, 90% of the labour are human power, followed by animal power and few engine powers. ● Establishment of Tractor Hiring Service (THS) in 1952.	Agoegwu and Asoegwu (2007)
1962-1968	● Increase in the number of animals from 7,052 to 36,000. ● Government established loan scheme for farmers to purchase bulls and implements. ● 437 tractors were imported to assist the farmers. ● Human and animal power sources are predominant; agricultural mechanization and labour productivity levels were low.	Agoegwu and Asoegwu (2007)
1970-1974	● Increase in the number of animals from 5,600 to 16, 400. ● Increase in the number of tractors from 460 to 1,699. ● Human and animal power sources are predominant; agricultural mechanization and labour productivity levels were low.	Takeshina *et al*. (2014)
1975-1980	● Establishment of the National Centre for Agricultural Mechanization (NCAM) in 1978. ● Establishment of Nigeria Machine Tools Limited (NMTL) in 1980. ● Establishment of River Basin Development Authority (RBDAs) in 1976. ● Decrease in the number of animals from 5,600 to 3,300. ● Increase in the number of tractors from 1,699 to 3,256.	Takeshima *et al*. (2014)
1981-1992	● Establishment of the National Agency for Science and Engineering Infrastructure (NASENI) in 1992. ● Establishment of the National Agricultural Research Project (NARP) in 1991. ● Decrease in the number of animals from 3,300 to 470 due to Structural Adjustment Programme (SAP) which led to lack of purchasing power to replace these animals. ● Decrease in the number of tractors from 3,256 to 320 due to Structural Adjustment Programme (SAP) which led to the devaluation of our local currency and high number of tractor breakdowns.	Onwualu and Pawa (2004).
1993-2007	● Decrease in the number of animals from 470 to 120 due to availability of mechanical power. ● Increase in the number of tractors from 320 to 1,538.	Ladeinde *et al*. (2009)
2008-2011	● Establishment of the National Food Reserve Agency (NFRA) in 2011. Nigeria has adopted a policy that 15% of the total annual grain harvest should be held in reserve, individual should reserve 5% and each state is to hold another 10%. ● Decrease in the number of animals from 120 to 47 due to availability of the mechanical power. ● Increase in the number of tractors from 1,538 to 1,643.	Ladeinde *et al*. (2009)

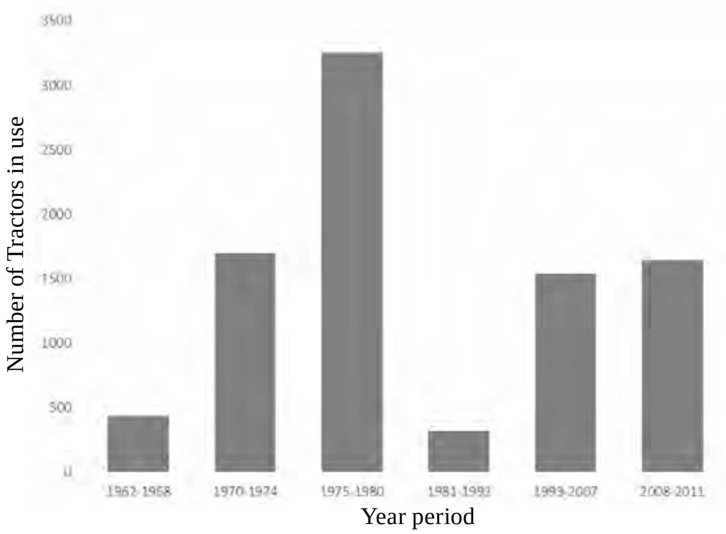


Fig. 1 Bar chart showing the number of tractors in use in Nigeria within the period covered

Subsidized Distribution of Tractors by Federal/State Government (Table 2)

- Federal government tractorization programme (Ladeinde *et al.*, 2009).
- Currency devaluation which gave birth to 8 fold increase in imported tractor prices.
- Reduced tractor subsidy.

Tractor Import From 2000-2005

- 1,000 Tractors and implements were imported by federal government (ladeinde *et al.,* 2009).

Present Status of Agril. Mechanization

The demand for mechanization may be attributed to various factors such as farming systems, population density and labour wages (Pingali, 2007). The market for mechanization services was based on regions comprising of North East (NE), North West (NW), North Central (NC), South-South (SS), South East (SE) and South West (SW) of Nigeria, with an uneven supply across locations. Tractor services in Nigeria are mostly provided by government agencies through either subsidized direct sales or public tractor-hiring services, and to a lesser extent by the private owner-operators (PrOpCom, 2011). Although a commercial market exists in Nigeria where imported tractors are sold, the effective demand may be small and limited to private owner-operators who have managed to accumulate sufficient capital through expansion of business after acquiring subsidized tractors. Given the low operational capacity and poor maintenance of equipment in public tractor-hiring services, the suboptimal distribution of subsidized tractors, and the high fixed costs for starting a private mechanization service, current mechanization may be highly constrained by the lack of supply, leaving potential demand unmet for the majority of smallholder farmers. Labour shortage and necessity to lower production cost in agriculture make mechanization as an inevitable solution in the present agricultural landscape in Nigeria.

Future outlook for agricultural mechanization, it is expected that the demand for agricultural machinery will continue to increase. Agricultural mechanization in Nigeria was based on regional patterns. However, different regions require different mechanization solution. The use of tractors is still relatively rare in Nigeria. In 2010 rainy season, only 6 percent of the country's farmers used tractors in the North West region, either their own or rented (**Table 3**). The share was the highest at 15 percent in the North Central zone. Animal traction is still more commonly used, particularly in the North East, where over 60 percent of farmers used either their own animals or rented animals for traction. Although animal traction can typically reduce labour needs by half in Nigeria (Jansen, 1993), it is intermediary compared with tractors with more than 10 horsepower (hp). As a result, the level of mechanization has remained low in Nigeria (Takeshima and Salau, 2010).

Table 2 Amount of Subsidized distribution on Tractors at given Period

Period	Amount million (USD)/ 5 year
1970 – 1974	85
1975 – 1979	310
1980 – 1985	775
1986	SAP started

Source: Ladeinde *et al.* (2009)

Table 3 Percentage of farmers using tractors or animal traction in 2010 rainy season in Nigeria

Region	Tractor			Animal traction			Non usage of tractor / Animal Traction
	Total	Owned tractor	Rented tractor	Total	Owned animal	Rented animal	
NW	6	2	4	27	17	10	67
NE	2	1	1	62	36	26	36
NC	15	4	11	5	3	2	80
SE	0	0	0	0	0	0	100
SS	0	0	0	0	0	0	100
SW	4	3	1	1	1	0	95

Source: Takeshima *et al.* (2013b)

Mechanization may be low due to significant tractorization observed only for rice, which accounts for a small share of cultivated area (less than 10 percent) in Nigeria (**Table 4**). Approximately half of the rice area, amounting between 0.5 and 1 million hectares (ha), seems tractorized in Nigeria, and that area accounts for about 40 to 50 percent of the total tractorized area in Nigeria (Takeshima *et al*., 2013b).

Present Status of Agril. Macnihery Industry

Nigeria agriculture production at the beginning of 2007 has not met its demand (Ladeinde *et al*., 2009). Farm power sources such as human, animal or mechanical power for crop establishment, irrigation, harvesting, processing, and transport has become a critically important input for agricultural production. Micro-irrigation (drip) is now gaining prominence among the farmers. Agricultural machinery is the major agricultural input in Nigeria. It is ranked the least among the sources of farmer power. Machineries developed for agricultural production in Nigeria under the farm power source includes tractor, track laying tractor, crop thresher and combine harvester. Under implements, there are disc plough, mouldboard plough, disc harrow, mouldboard harrow, disc ridger, mouldboard ridger, boom sprayer, gun sprayer, seed planter, cassava planter, fertilizer spreader and mower. Those for crop processing operation include threshing machine (Rice and Soybean); shelling machine (Maize) and cassava peeler.

Between 2009 and 2012, about 81% of the total land areas accounted for crop production, forestry, livestock and fishery subsectors of the Nigerian agricultural sector, and 0.4 % of gross domestic product (GDP) was used for agricultural research and development (R&D) activities (FAO statistical yearbook, 2013). Institutions and enterprises involved in agricultural machinery are described as follows:

Agricultural Machinery Manufacturer

Agricultural machinery such as tractor and majority of its associated implements for large scale production had not been manufactured in Nigeria. Implements such as seed planter, cassava planter, threshing machine for rice and soybean, shelling machine for maize, cassava peeler, pellet machine, hammer mills, livestock feed mixers, plants shredder and cassava graters are being manufactured in the country for small and medium scale production. There are two major private agricultural machinery manufacturers in the country, these are: Allamit Nigeria limited, Odo Ona, Ibadan and Hanigha Nigeria limited, Kaduna. Nigeria Machine Tools Limited (NMTL), Osogbo is the only public agricultural machinery manufacturer in the country. Locally developed agricultural machinery in NMTL includes tipping trailers, disc harrow, disc plough and ridgers. NASENI is one of the public agricultural machinery manufacturers in the country. More so, NCAM is also into agricultural machinery development for the purpose of providing technologies for Nigerian agriculture.

Import of Agricultural Machinery

Nigeria depends on importation of agricultural machinery. These machines could be in full or parts. Imported agricultural machinery include tractor, power tiller, diesel engine, plough, harrow, ridger, combine harvester, self-propeller transplanter, rice transplanters, threshing machine, etc. Niji-Lukas Nigeria Limited, Famousil Rich Enterprises, Base Bond International Limited, Bertola Machine Tool Limited, Dizengoff West Africa Nigeria Limited, El-Hanan-Ventures Limited, Mantric Nigeria Limited, Jopfack International Limited, Centro Machinery Nigeria Limited, TaboV Nigeria Limited and ATC Nigeria Limited are the main importers of these machines. The two leading importers in Nigeria are Dizengoff West Africa Limited and Bertola Machine Tool Limited.

Growth of Local Manufacturing Industry

During the last quarter of 1993, the establishment of NMTL in 1980 and NASENI in 1992 has triggered expansion of rural non-farm activities, especially, manufacturing of farm machinery and equipment spare parts, machinery installation, repair and maintenance services. NMTL and NASENI are the public establishments, while the Allamit Nigeria Limited and Hanigha Nigeria Limited are the private enterprises that are leading in spare parts manufacturing in Nigeria. Spare parts of tractor, diesel engine, threshers and power tiller are both imported and locally produced. This saves a huge amount of foreign currency and decrease dependency on import. The spare parts sub-sector

Table 4 Tractorized areas in Nigeria by Crop (10,000 hectares)

Methods	Rice	Maize	Sorghum	Millet	Cowpea	Groundnut	Cassava	Yam	Veg.	Total
LSMS	86	24	15	5	8	6	13	7	1	185
FAO	118	35	25	8	11	12	34	16	1	258

Sources: LSMS (2010) and FAO (2013)

is employing a significant number of skilled and semi-skilled labour forces.

Challenges of Agril. Mechanization and agricultural machinery industry

The challenges confronting agricultural mechanization and agricultural industry in Nigeria are discussed under the following subsections:

Infrastructure Deficit

The agricultural sector of Nigeria suffers a lot from infrastructure challenge. Infrastructure such as motor vehicle roads, railroads and irrigation dams are either insufficient, or when available, not cost competitive.

Access to Land and Land Management

- Current Land Use Act is not conducive for agricultural activities (e.g. short-term lease does not allow for agricultural loans, particularly small holder farmers).
- Small and fragmented landholdings.
- Process of securing and perfecting title is cumbersome, time-consuming and often expensive.
- Policies implemented have less to do with ensuring the inclusion of women in agriculture i.e. gender biasness in accessing land, with women facing more difficulty accessing land than men.

Access to Inputs (Seeds/Seedlings, Fertilizer, Livestock/Fish feeds, etc.)

Access to inputs remains a challenge for achieving optimal productivity of agricultural outcomes.

- Majority, fish seed were still collected from wild which could lead to the introduction of disease into the cultural unit.
- Low productive fish breeds in aquaculture.
- Poor water quality (e.g. pollution).
- Security constraints in fisheries areas.
- Low yields due to overfishing.

Water/Irrigation Systems

- Under-utilization of large dams due to decline in water dispersion systems e.g. pipes, pump stations and related supporting infrastructure.
- Insufficient water for full year agricultural production.
- Insufficient investment in irrigation systems and equipment whether drip or otherwise.
- Reducing water availability and increasing drought due to climate change and deforestation.
- Substandard quality of water (e.g. due to overuse of agrochemicals and dumping of wastes).

Mechanization

- Insufficient network of entrepreneurial service centres to provide fee for service mechanization.
- Lack of access to machines, equipment and spare parts at affordable rates.
- Underdevelopment and poor funding of mechanization research and development.
- Poor resource base and poor technical skills leading to low patronage of fabricators.
- Insufficient number of trained mechanics and technicians in the country to support equipment maintenance.
- Irrigation and tractor use is negligible.
- Few households use credit to purchase modern inputs.
- There are gender differences in input use.

Storage

- Finance is critical to storage; for instance, farmers who need cash quickly are reluctant to store. Thus they sell products at the point when poor pricing prevails.
- Poor management of storage facilities, including silos.

Processing

- Inadequate infrastructure provision around high agricultural produce areas.
- Lack of extension services and poor capacity for post-harvest handling.
- Lack of quality standards for produce inspection, grading, food safety and traceability, customized to Nigerian conditions for both large and small-scale growers.

Marketing and Trade

- Lack of infrastructure such as road, railways, power, etc.
- Lack of quality market information to enable identification of market opportunities, coordination among market actors and transparency.
- Lack of coordination of efforts to improve efficiency between concerned government agencies.

Access to Finance

- Insufficient access to credit and insurance products.
- Non-recognition of cooperative and other farming-based organizations by financial institutions.
- Inadequate capacity of financial institutions to lend to the agricultural sector resulting from low crop yield and so many other unforeseen factors attributed to the inherent risk of the sector.
- Inadequate capacity of the Federal Ministry of Agriculture and Rural Development (FMARD) to facilitate agribusiness investment.

Research and Innovation

- The research-extension linkage system is weak; so the technologies or innovations generated are not effectively delivered to farmers or commercialized for the benefit of end users.
- Research outputs not demand-driven.
- Poor and irregular funding for ag-

ricultural research and extension.
- Inadequate linkage with R&D institute.

Shortage of Power, Dearth of Experts, Instrument and Raw Materials
- Using ageing machineries and technologies resulting in quality compromised products.
- High price of raw materials.
- Poor quality of raw materials.
- Lack of skill and technical knowledge related to metal casting, heat treatment, etc.
- Lack of instrumentation.
- Lack of non-interrupted supply of electricity.

Future Prospects of Agril. Mechanization and Machinery Development in Nigeria

The future prospect of agricultural mechanization and machinery development in Nigeria are somehow interrelated and the successful implementation of mechanization not only depends on the availability of machinery but also on the positive response of government and perception of farmers and other users. Government role is very crucial to future development of agricultural mechanization and machinery.

Things Government Must Further Do to Enhance Agricultural Mechanization and Machinery Development in Nigeria Are As Follows
- Strengthen NCAM that is currently into the development of low cost labour saving agricultural machinery and equipment.
- Encourage and promote agricultural machinery testing done at NCAM.
- To further promote standardization of agricultural machinery and equipment through Standards Organization of Nigeria (SON).
- To strengthen the Cassava Enterprises Development Project (CEDP) goals through the International Institute for Tropical Agriculture (IITA).
- To revive the operations of the African Regional Centre for Engineering Design and Manufacturing (ARCEDEM) which is meant to develop and produce equipment prototypes in priority areas like agriculture.
- Strengthen the Agricultural Machinery Mechanics and Operators Training Centre (AMMOTRAC) which was specifically established to train operators and mechanics to drive and maintain farm machinery.
- Set-up of the Growth Enhancement Scheme (GES) to register small holder farmers and provide targeted input subsidies (E-Wallet).
- Give meaningful loans to farmers at low interest rates.
- Aggressive promotion of rural infrastructure development.
- Policy options for zero tariff/nominal tariff on import of modern capital machinery and essential raw materials for agro-machinery production sub-sector.
- Access to soft and flexible long and mid-term credit facilities for capital machinery and working capital.
- Resuscitation of delta steel company for the production of raw materials for industry.
- Funding research activities in the educational institutions through educational tax fund obtained at state and federal levels.
- Set up policies to consolidate fragmented holdings through land act.
- Policies to be put in place by Federal government to increase the use of tractors in Nigeria, include:
  - ♦ Promotion of private tractor hiring services.
  - ♦ To promote Mechanization Implementation Program (MIP).
  - ♦ Establish Agricultural Equipment Hiring Enterprise (AEHE)—private-sector managed tractor hiring enterprises.
  - ♦ Subsidized tractor hiring services for small farmers (0.5-4 ha).
  - ♦ Establish Agriculture Machinery Data Tracking Centre (Agro-Mach DTC)—electronically monitor various information of tractors (tracking the locations, uses, storing of records) (FMARD, 2015).

Conclusions

- To meet the target of implementing mechanization for agriculture production in Nigeria, the availability of appropriate machinery must be given the appropriate attention it deserves at the moment through the design and development of agricultural machinery and equipment using local materials.
- Between 1975 and 1980, Nigeria has witnessed development in agricultural mechanization.
- Agricultural mechanization in Nigeria was based on regional patterns. However, different regions require different mechanization solution.
- Agricultural mechanization is an inevitable solution to provide conditions that allow rural population to manage their farmlands with limited and expensive labour, while permitting specialised farmers/entrepreneurs to invest and innovate.
- Mechanization will continue to play an increasing important role in agricultural production and it is expected that demand for agricultural machinery will increase in future.
- Agricultural mechanization was unable to meet its agricultural demand.

Recommendations

- Government role will improve agricultural mechanization, hence, there is need to enhance agricultural production in Nigeria.

- Nigeria still depends on importation of agricultural machinery and Government should strengthen the growth of local agricultural machinery industry through access to soft and flexible long and mid-term credit facilities for capital machinery and working capital.
- Landholdings in Nigeria are small and fragmented. Consolidation of fragmented holdings helps in organizing resources and inputs more efficiently and provides easier access to farm machineries even on small holdings. Government should have policies to consolidate fragmented holdings.
- Manufacturing processes need improvements to provide quality machines with improved safety standards.
- Government should provide support services for R&D; and also for human resources development in supporting agricultural mechanization.
- Local enterprises are expected to venture in manufacturing locally adapted agricultural machinery, based on R&D.
- Government should strengthen the Standard Organization of Nigeria (SON) for the protection of consumers need (farmers and other users) through the quality control for standardization.

REFERENCES

Aboaba, F. O. 1967. Tractor Hiring Units of the First Steps Towards Mechanized Farming. Proc. Nigeria Society of Agricultural Engineering. pp. 1-7

Asoegwu, S. N. and A. O. Asoegwu. 2007. "An Overview of Agricultural Mechanization and its Environmental Management in Nigeria". Agricultural Engineering International: the CIGR E journal. Invited Overview No. 6. Vol. IX. May, 2007.

FAO (Food and Agriculture Organization of the United Nations). 2013. FAOSTAT 2013. Rome, Italy. Accessed May 10, 2013. FAO Statistical Yearbook. 2013.

FMARD (Federal Ministry of Agriculture and Rural Development). 2015. "National Policy on Agricultural Mechanization Development.

Jansen, H. 1993. "Ex-ante Profitability of Animal Traction Investments in Semi-arid Sub-Saharan Africa: Evidence from Niger and Nigeria." Agricultural Systems 43:323-349.

Ladeinde, M. A., E. O. Atanda, A. J. Ageh, S. O. Idowu, and S. O. Olayemi. 2009. Agricultural Machinery Operators and Mechanics Training in Nigeria: An overview of Contributions. Journal of Agricultural Engineering and Technology 17(2), 11-18.

LSMS (Living Standards Measurement Study). 2010. Integrated Survey on Agriculture, pp. 247.

Onwualu, A. P. and N. P. Pawa. 2004. Engineering infrastructure for the manufacture of agricultural engineering machines in Nigeria: The role of NASENI. Proc. 2nd International Conference of the West African Society of Agricultural Engineering, Kumasi, Ghana. 20-24 Sept. 2004.pp. 142-148.

Pingali, P. 2007. Agricultural Mechanization: Adoption Patterns and Economic impact. Handbook of Agricultural Economics 3, 2779-2805.

PrOpCom. 2011. Making Tractor Markets Work for the Poor in Nigeria: A PrOpCom Case Study. PrOpCom, Nigeria, pp.96-104.

Takeshima, H. and S. Salau. 2010. Agricultural Mechanization for Smallholder Farmers in Nigeria. IFPRI Nigeria Strategy Support Program Policy Note 22. Washington, DC: International Food Policy Research Institute, pp 231-238.

Takeshima, H., A. Nin Pratt, and X. Diao. 2013a. Mechanization and Agricultural Technology Evolution, Agricultural Intensification in Sub-Saharan Africa: Typology of Agricultural Mechanization in Nigeria. American Journal of Agricultural Economics 95(5), ASSA Proceeding Issue), 1230-1236.

Takeshima, H., A. N. Pratt and X. Diao. 2013b. Agricultural Mechanisation Patterns in Nigeria, Insights from Farm Household Typology and Agricultural Household Model Simulation, International Food Policy Research Institute (IFPRI), Washington, DC, pp. 3-6.

Takeshima, H., E. Edeh., A. Lawal and M. Ishiaka. 2014. Tractor owner operators in Nigeria: Insights from a small survey in Kaduna and Nasarawa states. Forthcoming in IFPRI Discussion Paper, pp.68-72.

■■

Government Policies and Programmes Involved with Agricultural Mechanization in Nigeria: A Case Study of Selected Agencies

by

J. C. Adama
Associate Professor (Farm Power and Machinery systems Engineering)
Dept. of Agricultural and Bioresouces Engineering
College of Engr. and Engineering Technology
Michael Okpara University of Agriculture
Umudike, P.M.B. 7267, Umuahia, Abia State
NIGERIA
adamajoseph@yahoo.com

C. A. Ezeaku
Chief Lecturer (Farm Power and Machinery Systems Engineering)
Dept. of Agril. and Bio-environmental Engineering
Federal Polytechnic
P.M.B. 0231, Bauchi, Bauchi State
NIGERIA
Clement85e@gmail.com

B. N. Nwankwojike
Associate Professor (Industrial Engineering)
Dept. of Mechanical Engineering
College of Engr. and Engineering Technology
Michael Okpara University of Agriculture
Umudike, Abia State
NIGERIA

Abstract

Over the years especially in the 40s and down to the 60s, the Nigeria economy was agro-based. Government formulated strategies, policies and programmes suitable for developing the agricultural system of the country. Projects were established to executive the policies, strategies and programmes. The objective of this paper is to present a study of some past and present government schemes with mandates related to agricultural mechanization in Nigeria. The schemes studied include Farm Settlement; National Agricultural Land Development Authority and National Centre for Agricultural Mechanization. The formation, operation, achievement constraints and status of each of the agencies were extensively discussed. Information and supporting data were obtained from literature, study visits to some of the sites and the use of structured questionnaire. Findings show that these agencies have had laudable programmes on agricultural mechanization which have made considerable contributions to the economy of Nigeria. One of the organizations considered for this study is nonoperational with their functions, staff and other assets transferred to other agencies while others are still operational.

Introduction

The history of agricultural mechanization in Nigeria throws some challenges to the stakeholders namely government, farmers, researchers, donor agencies, etc. The subject has been given extensive discussion by many researchers (Ige, 1987; Idachaba, 1979; Liman, 1979; Igbeka, 2010). In the 40s and 50s (during the colonial era) agricultural production systems were at the most basic level of mechanization. That is, all operations from bush clearing down to processing were carried out using hand tool technology. The colonial masters mobilized millions of small scale farmers with cutlasses and hoes for the production of crops for the purpose of serving oversea markets and industries (Ijere, 1976; Liman, 1979). Then, high level of food production was achieved, as food was in abundance and effective demand was satisfied without resort to the importation of essential food items. The foundation for agricultural research and extension manned by expatriates was laid (Liman 1979). Adama (2006) reported that the colonial agriculture recorded successes though at hand powered level due to the following reasons:

- There were no local industries to compete with the foreign ones for raw materials.
- The population of the country was

small and the demand for staple food was not higher than the quantity being produced locally.

- Majority of the population were farmers thereby making them to produce what they ate with small marketable surpluses.
- Labour was cheap and abundant.
- There was no demand for processed food as the need for food processing industries was not there.

After independence in 1960, the demand of Nigerians gradually changed and with increased population, the demand for staple food began to increase. At the same time, the government had to continue with the production of cash crops for foreign exchange earnings. To achieve these objectives, the source of agricultural production system was modernized. Mechanical systems were gradually introduced for some operations such as bush clearing, ploughing, harrowing, ridging, spraying, harvesting, trailing, processing storage and irrigation. Local crops such as rice, maize, millet, cassava and yam were added to that of export crops and industries were established to process the crops. Subsidies were also given to farmers without much bureaucracy. The success recorded by this effort was reflected in the huge foreign exchange earnings with agriculture contributing over 80% to the Nigerian economy.

Past and Present Government Efforts

In an effort to realize the objectives of the agricultural sector, the governments of Nigeria, past and present, at all levels have been formulating policies, programmes and strategies and setting up agencies and projects. Some of these agencies are shown in **Table 1**.

Table 1 Some Government Programmes and Agencies with Agricultural Mechanization Related Mandates

Programme and Agency	Acronyms	Remarks
Farm Settlement Scheme	FSS	Regional level
National Accelerated Food Production Project	NAFPP	Federal level
Agricultural Development Project	ADP	State level
Nigerian Agricultural Co-operative and Rural Development Bank	NACRDB	Federal level
Operation Feed the Nation	OFN	Federal level
Commodity Board	CB	Federal level
National Agricultural Credit Guarantee Scheme	NACGS	Federal level
River Basin Development Authority	RBDA	Federal level
Land use Policy	LUP	Federal level
Green Revolution	GR	Federal level
National Centre for Agricultural Mechanization	NCAM	Federal level
Directorate of Foods, Roads and Rural Infrastructure	DFRRI	Federal level
National Directorate of Employment	NDE	Federal level
Rural Agro Industrial Development Scheme	RAIDS	Federal level
Crop Storage Unit	CSU	Federal level
Strategic Grains Reserve	SGR	Federal level
Rural Artisan Training and Support Unit	RATSU	Federal level
Agricultural Machinery Mechanics and Operators Training Centre	AMMOTRAC	Federal level
Tractor and Equipment Hiring Units	TEHU	State level
National Agricultural Land Development Authority	NALDA	Federal level
Departments of Rural Development	DRD	Fed and State levels
Family Economic Advancement Programme	FEAP	Federal level
National Poverty Eradication Programme	NAPEP	Federal level
National Economic Empowerment and Development. Strategy	NEEDS	Federal level
State Economic Empowerment and Dev. Strategy	SEEDS	State level
Local Economic and Environmental Management Programme	LEEMP	State level
National Programme for Food Security	NPFS	Federal level
National Food Reserve Agency	NFRA	Federal level
National Agricultural Seed Council	NASC	Federal level
Ministry of Agriculture	MOA	Federal and State levels
Raw Materials Research and Development Council	RMRDC	Federal level
National Office for Technology Acquisition and Promotion	NOTAP	Federal level
Bank of Industry Limited	BOI	Federal level

(Continued on the following page)

Materials and Methods

The information and data used in this research were obtained through three modes. These include the use of structured questionnaire, study visits to the agencies and then secondary source of information through literature. The structured questionnaire was developed and used to obtain information and data. The enumerators were final year students belonging to the 2013/2014 set of the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The questions sought for information on the ownership, status (whether functional or scrapped), problems, achievements, etc. of the agencies. The authors then made trips to the sites of the agencies to validate the information and data collected by the enumerators. Other information and data on the agencies were collected from published works, manuals and blue prints of the agencies. The questionnaires were administered on the staff of the agencies who were found on the site at the time of visit. The field research started in 2013 and was concluded in 2016. The field survey for the farm settlements was limited to farms in the old eastern region. The

Table 2 Some mechanized farms operated in the old Eastern region under the Farm Settlement scheme

Name/Institution	Product	Location/State
Uzo Uwani Farm Settlement	Rice	Adani, Enugu state
Igbariam Farm Settlement	Oil palm, citrus, rice, cassava, vegetable	Igbariam, Anambra state
Ohaji Farm Settlement	Oil palm and rubber	Ohaji Egbema, Imo state
Erei Farm Settlement	Oil palm and cocoa	Erei, Ebonyi state
Boki Farm Settlement	Rice	Boki, Cross River state
Ulonna (N and S) Farm Settlement	Oil palm and rubber	Ulonna, Abia state
Obudu Cattle Ranch	Cattle	Obudu, Cross River state
Elele Rubber Estate	Rubber	Elele, River state
Elele Oil Palm Estate	Oil palm	Elele, River state
Etche Rubber Estate	Rubber	Etche, River state
Bonny Coconut Plantation	Coconuts	Bonny, River state
Emeabiam Rubber Estate	Rubber	Emeabian, Imo state
Ameke Abam Rubber Estate	Rubber	Ameke Abam, Abia state
Obubra Rubber Estate	Rubber	Obubra, Cross River state
Byakpan Rubber Estate	Rubber	Biakpan, Cross River state
Dunlop Rubber Estate	Rubber	Calabar, Cross River state
Oban Rubber Estate	Rubber	Oban, Cross River state
Ikotmbo Rubber Estate	Rubber	Ikotmbo, Cross River state
Calabar Oil Palm Estate	Oil Palm	Calabar, Cross River state
Calabar Rubber Estate	Rubber	Calabar, Cross River state
Kwa Falls Estate	Oil palm	Cross River state
Calaro Oil Palm Estate	Oil palm	Cross River state
Eket Oil Palm Estate	Oil palm	Eket, Akwa Ibom state
Biase Oil Palm Estate	Oil Palm	Biase, Cross River state
Nsadop Oil Palm Estate	Oil palm	Nsadop, Cross River state
Ikom Cocoa Estate	Cocoa	Ikom, Cross River state
Ibia Cocoa Estate	Cocoa	Ibia, Cross River state
Boje Cocoa Estate	Cocoa	Boje, Cross River state
Obrenyi Cocoa Estate	Cocoa	Obrenyi, Cross River state

Source: Adama *et al*. (2016)

(Continued from the previous page)

Federal Institute for Industrial Research	FIIRO	Federal level
National Board for Technology Incubation	NBTI	Federal level
Colleges of Agriculture	-	Federal and State levels
Universities of Agriculture	-	Federal level
Project Development Institute	PRODA	Federal level
Bank of Agriculture Limited	BOA	Federal level
Agricultural Transformation Agenda	ATA	Federal level
Community Tractor Hiring Programme	-	Federal level
The Green Alternative	-	Federal level
The Forest Policy	-	National Level (by colonial government
The Agricultural Policy	-	National Level (by colonial government)
Policy for Marketing Oils, Oil Seeds and Cotton.	-	National Level (by colonial government)
The Nigeria Policy of Agricultural and Natural Resources	-	National Level (by colonial government)
The New Partnership for Africa Development	NEPAD	Federal level
Roots and Tuber Expansion Programme	RTEP	Federal level

Sources: Ijere, 1976; Odigboh and Onwualu, 1994; FMARD, 2004; Onwualu *et al*., 2006; FMAWR, 2008; Adama *et al*., 2009; Ikuru, 2013; Orthman, 2017 old eastern region of Nigeria comprised of Abia, Akwa Ibom, Anambra, Bayelsa Cross River, Ebonyi, Enugu, Imo and River states. This is partly because the schemes have impacted greatly on the farmers in the region.

Government Policies and Programmes

The Farm Settlement Scheme (FSS)

Formation, objective and achievements

One of the ways the government attempted to mechanize agriculture and achieve integrated rural development and increase production of food and agro raw materials is the introduction of the Farm Settlement scheme. The objectives of the scheme were to rejuvenate agriculture, generate employment, enhance production and provide infrastructure in certain neglected communities. The scheme involved bringing young farmers together in a settlement and providing necessary amenities and inputs to make farming attractive. These include residential house, schools, market, roads, irrigation, farm machinery seeds and seedlings, fertilizer, etc. Farm settlement scheme was established by the governments of the old eastern and western regions. The settlers were involved in production of such crops as rice, rubber, palm produce and cocoa. This programme recorded success in the areas of youth employment, increase in food and raw materials production, improved standard of living of the settlers, etc. At that time, the regions witnessed migration of the youths from urban areas to the settlements.

Table 3 Farm settlements operated in the old Eastern Region of Nigeria their present status, ownership, size at inception and present

Name	Ownership		Area cleared and planted (ha)			Year established	Present Name
	At inception	At Present	Inception (A)	Presently (B)	Change (B-A)		
Uzo Uwani Farm Settlement	Regional E.N.D.C	Enugu State Government	4,152.40	822	3330.4^{R}	1961	Adarice Production (Nig.) Limited
Igbariam Farm Settlement	Regional E.N.D.C	Anambra State Govt.	2,624.00	8,192	5568^{P}	1961	Igbariam Farm Settlement
Ohaji Farm Settlement	Regional E.N.D.C	Imo State Government	5,971.60	3,854	2,117.6^{R}	1961	Ada Palm Limitrd (Imo Palm Plantation)
Erei Farm Settlement	Regional E.N.D.C	Ebonyi State Government	3,528.00	Na	-	1961	
Boki Farm Settlement	Regional E.N.D.C	Cross River State Government	4,616.40	456.7	4,159.7^{R}	1961	
Ulonna North Farm Settlement	Regional E.N.D.C	Abia State Government	3,236.00	714.3	2,521.7^{R}	1961	
Ulonna South Farm Settlement	Regional E.N.D.C	Abia State Government	10,000	10,000	-	1961	
Obudu Cattle Ranch	Regional E.N.D.C	Cross River State Government	102.4	102.2	0.2^{R}	1960	
Elele Rubber Estate	Regional E.N.D.C	Rivers State Government	12,00.0	120	1,080^{R}	1960	
Elele Oil Palm Estate	Regional E.N.D.C	River State Government	2,663.60	3,000	336.4^{P}	1960	Riso Palm Limited
Etche Rubber Estate	Regional E.N.D.C	Rivers State Government	400	931	531^{P}	1960	Delta Rubber Estate
Bonny Coconut Plantation	Regional E.N.D.C	Rivers Sate Government	388	480	92^{P}	1960	Siat Farms Limitied
Emeabiam Rubber Estate	Regional E.N.D.C	Imo State Government	800	1,262	462^{P}	1960	Imo Rubber Estates Ltd
Ameke Abam Rubber Estate	RegionalE. N.D.C	Abia State Government		3,392	--	1960	Abia Rubber Company
Obubra Rubber Estate	RegionalE. N.D.C	Cross River State Government	300	-	-	1960	_
Biakpan Rubber Estate	RegionalE. N.D.C	State Government	300	-	-	1960	_
Dunlop Rubber Estate	Dunlop Nig Limited Private	Private	5,600	14,000	8,400^{P}	1960	Enghuat Industries Limited.
Oban Rubber Estate	NJAL	Cross River State Government	3,120.00	_	_	1960	+

(Continued on the following page)

In eastern region, there were 29 of such schemes as shown in **Table 2**.

Problem and status

This scheme was abruptly disrupted by the civil war especially in the East. In the West, the cost of operation was forbidding and this rendered the management ineffective (Ijere, 1991). Despite government measures to abolish the settlements, most settlers have continued to make reasonable income through their individual efforts, and participating in new government projects. The present ownership, status and year of establishment of some of the farm settlements in the old eastern region are shown in **Table 3**. It can be deduced from **Table 3** that these farms were established in 1960 and 1961. Some of these farms have witnessed some changes such as privatisation, experienced name change, reduced scope/size of area cultivated, etc. For instance, the Uzo Uwani Farm Settlement inherited by Enugu State government is now named Adarice Production Nig. Limited operates 822.0 hectares of land as against 4152.4 hectares of land at inception. Also, the Ohaji Farm Settlement inherited by Imo State government now called Ada Palm Limited presently farms 2117.6 hectares of palm plantation less than 5971.6 hectares of palm plantation at inception. However, some of these farms which were handed over to private companies experienced increase in size of land cultivated. For instance, Elele Oil Palm Estate in River state which now bears Riso Palm Limited after privatization, increased area of land cultivated by 336.4 hectares from 2,663.6 ha to 3,000 ha.

National Agricultural Land Development Authority (NALDA)

Formation

The need for tractor services in Nigeria continued as the revenue from oil continued to dwindle. After many years of suffering by farmers due to lack of tractor services, government decided to fashion a means of assisting the farmers to get tractor services. The National Agricultural Land Development Authority was therefore established in 1992 vide Decree No. 92 of 1992 to tackle in a realistic approach and on project by project basis, the development of large areas of land for agricultural production and so solve the problems which the small scale agriculture and rural dwellers as a whole have found themselves in the last two and half decades of independence.

The objectives

The objectives of the authority as reported by NALDA (1992) include:

- Provision of strategic public support for land development.
- Promotion and support of optimal utilization of the nation's rural land resources for accelerated production of food and raw materials.
- Encouragement of evolution of economic size holdings and consolidation of scattered and fragmented holdings.
- Provision of gainful income and

(Continued from the previous page)

Ikotmbo Rubber Estate	Private	Cross River State Government	1,550.00	_	_	1960	_
Calabar Oil Palm Estate	Private	Cross River State Government	4,800.00	_	_	1960	_
Calabar Rubber Estate	Private	Cross River State Government	1,280.00	+	+	1960	_
Kwa Falls Estate	Regional E.N.D.C	Cross River State Government	1,800.00	+	+	1960	+
Calaro Oil Palm Estate	Regional E.N.D.C	Cross River State Government	399	5,549	5,150^{P}	1960	+
Eket Oil Palm Estate	Regional E.N.D.C	Akwa Ibom State Government	682	80	602^{R}	1960	Akwa Palms Limited
Biase Oil Palm Estate	Regional E.N.D.C	Cross State Government	853.2	5,599.91	4,746.71^{P}	1960	Ibiae Oil Palm Estate
Nsadop Oil Palm Estate	Regional E.N.D.C	Cross River State Government	189.2	+	+	1960	+
Ikom Cocoa Estate	Regional/ E.N.D.C	Cross River	1,726.00	+	+	1960	+
Ibia Cocoa Estate	Regional/ E.N.D.C	Cross River State Government	1,437.60	+	+	1960	+
Boje Cocoa Estate	Regional/ E.N.D.C	Cross River	888.4	+	+	1960	+
Obrenyi Cocoa Estate	Regional/ E.N.D.C	Cross River State Government	615.6	+	+	1960	+
Crail Rubber Estate	-	Private	-	843	_	-	Enup Rubber Estate

Source: Ofomata, 1975; Adama *et al*., 2016

Key: E. N. D. C. = Eastern Nigerian Development Corporation, P = Progress, R = Retrogress employment opportunity for rural Nigeria.

To achieve these objectives, the authority acquired and developed large tracts of land in each state and the Federal Capital Territory, developed network of physical infrastructures and instituted a strategic land use planning scheme to deal with major allocation problems. The programmes and sub-programmes of the authority are shown in **Table 4**. There were eight programmes with each operating at least three sub-programmes.

Farm machinery disposition

The authority acquired tractors and implements (**Table 5**) and distributed them to the directorates in the states. From the Table, the authority acquired and distributed 201 tractors of various makes and models, 178 disc ploughs, 177 disc harrows, 164 disc ridgers. 80 tipping trailers and other specialized machinery such as bund former, ditcher, pto compressor, rotary slashers,

Table 4 Programmes and Sub-Programmes of NALDA

Programme	Sub-programme
Planning Coordination and Monitoring	Programme and Project plan; Technical Consultancies; Field Operation, Monitoring and Evaluation
Land Resources Inventory and Planning	Project Site and Land Characterization; Soil Survey and Mapping Farm Erosion and Fertility Status Survey Farm Layout Design
Land Development	Cadastal Survey and Mapping; Bush Clearing and Seedbed Operations, Farm Parcellation; Procurement and Maintenance of Agricultural Machinery.
Farm Infrastructural Development	Farm Workshop Sheds, Farm Stores, Residential Quarters, Farm Offices and Farm Roads, Culverts and Bridges
Soil Conservation and Fertility Management	Environmental Impact Assessment; Flood and Erosion Control; Soil Fertility Maintenance and Management Sustainable Farming Promotion
Cooperative/Extension Services	Routine Extension Services. Development and Dissemination of Production Technologies; Women and Youths Outreach Activities.
Agricultural Production and Post Harvest Services	Production, Procurement and Distribution of Input; Livestock Integration; On Farm Adaptive Research Diagnostic Survey and Farm Management Processing Support Services; Quality Control and Monitoring Services, Agricultural Finance and Recovery. Small Scale Investment Promotion.
Programme Documentation and Data Bank	Management Information System; Library and Publication, Fairs and Exhibition

Sources: NALDA, 1992, 1994a, 1994b; Adama and Elesa, 2009

Table 5 List of Tractors and Implements Acquired and Operated by NALDA which were inherited by Department of Rural Development (Federal Ministry of Agriculture and Rural Development)

State	No. of Tractor	Number of Implements										
		Disc plough	Disc harrow	Disc ridger	M/B plough	Bund former	Ditcher	Tipping trailer	Rotary slaher	Stihl c/ saw	Pto compressor	Water Bowser
Abia	1	1	1	1	1	1	1	1	-	3	-	-
Adamawa	8	8	7	6	-	2	2	3	1	-	1	1
A/Ibom	2	2	2	1	-	2	2	2	1	1	-	-
Anambra	2	2	2	2	-	2	2	2	1	-	-	-
Bauchi	7	6	5	5	-	1	2	2	-	-	1	1
Bayelsa	1	1	1	1	-	1	1	1	1	-	-	-
Benue	5	4	4	4	1	2	2	3	1	-	1	1
Borno	7	7	6	6	2	2	2	2	-	-	1	1
C/River	4	3	3	2	-	2	2	2	1	2	-	-
Delta	2	2	2	2	-	2	2	2	1	-	-	-
Ebonyi	3	3	3	2	-	2	2	2	1	-	-	-
Edo	3	3	3	4	1	2	2	2	1	-	-	-
Ekiti	5	4	4	4	1	1	1	1	1	-	-	-
Enugu	3	3	3	3	-	1	1	1	1	-	-	-
FCT	6	6	6	5	-	2	2	2	1	-	-	1
Gombe	7	7	6	6	-	1	1	2	-	-	-	-
Imo	3	2	2	2	1	2	2	2	1	-	-	-
Jigawa	10	8	9	8	1	2	2	4	-	-	1	1

(Continued on the following page)

etc. The bush clearing projects were done free of charge for the farmers.

Tillage operation

Soil classification and charge rate

The classes of soil and charging rates per hectare for tillage operations by private tractor hiring services and NALDA are shown in **Table 6**. It can be deduced from **Table 6** that for the different soil classifications, the authority subsidized their tillage operations within the range of 66.55% and 67.89%. These charges are as at 1999 when the authority was still in operation.

Table 6 Soil classification, private charge rates and NALDA charging rate for different tillage operations

Operation	Soil Classes	Private Charging Rate, N/ha	NALDA Charging Rates, N/ha
Ploughing	Heavy	6,166.62	1,980
	Medium		
	Light		
Harrowing	Heavy	2,752.96	900
	Medium	2,202.37	720
	Light	1,835.31	600
Ridging	Heavy	5,138.85	1,710
	Medium	3,854.14	1,290
	Light	3,083.31	1,020

Source: Gana, 1999 (1$ US = 360 NGN or 1,000 NGN = $2.8US)

Tillage operation in the first year after bush clearing was free. In subsequent years, the farmers were paying the subsidized rates.

Fund generation

Table 7 shows the operations carried out and incomes generated from the states and FCT in 1998 farming season. From the Table, for the year under consideration, the authority ploughed 11,600 ha, harrowed 23,100 ha and ridged 5,350 ha across the country and generated N23,546,500.00.

Problem and status

In 1999, the Federal government set up a penal to examine the functions of all agencies in the country with a view to restructuring them. In January 2000, NALDA was scrapped by the Obasanjo/Atiku led government. The functions, technical staff and property were transferred to the Federal Ministry of Agriculture and Rural Development. Presently, the functions are being performed by the Department of Rural Development of the Ministry. There is a strong indication that the nation's National Assembly has passed a bill to restore NALDA.

National Centre for Agricultural Mechanization (NCAM)

Formation and objectives

National Centre for Agricultural Mechanization was established in 1978 by the Decree (now an Act) No. 35 of 1990 with the general objective of accelerating mechanization in the agricultural sector of the economy in order to increase the quantity and quality of agricultural products through the process of agricultural machinery development, testing and standardization and the dissemination of the knowledge of industrial manufacture, its efficient

(Continued from the previous page)

Kaduna	8	8	7	7	1	2	2	3	-	-	1	-
Kano	8	8	7	7	1	2	2	3	-	-	1	1
Katsina	10	9	8	8	1	32	5	1	-	1	-	1
Kebbi	8	8	7	7	1	2	2	2	1	-	1	1
Kogi	6	5	5	5	-	2	2	3	1	-	1	1
Kwara	7	7	7	8	1	2	2	3	1	2	1	-
Lagos	5	4	4	4	-	2	2	2	1	-	-	-
Nasarawa	6	6	6	6	1	1	1	1	-	-	-	-
Niger	6	6	5	4	1	2	2	3	-	-	1	-
Ogun	3	3	2	2	-	2	2	2	1	-	-	-
Ondo	4	3	3	3	1	1	1	1	1	1	-	-
Osun	3	3	2	2	-	2	2	2	1	-	-	-
Oyo	5	4	4	4	1	2	2	2	1	-	-	-
Plateau	11	10	10	8	1	1	1	3	1	-	1	1
Rivers	2	2	2	1	-	1	1	1	1	4	-	-
Sokoto	8	5	7	6	3	1	1	1	-	-	1	1
Taraba	8	8	7	6	-	3	2	3	1	-	1	1
Yobe	7	5	6	6	-	2	1	2	-	-	1	1
Zamfara	7	4	7	6	2	1	1	1	-	-	-	-
Total	201	178	177	164	23	63	62	80	25	14	16	14

Sources: Elesa, 2003; Adama and Elesa, 2009 application and maintenance capacity.

Functions

The functions of the Centre, according to Azogu (2009), are:

- to encourage and engage in adaptive and innovate research towards the development of indigenous machines for farming and processing techniques;
- to design and develop simple and low-cost equipment which can be manufactured with local materials, skills and facilities;
- to standardize and certify, in collaboration with Standard Organization of Nigeria (SON), agricultural machines, equipment and engineering practices in use in Nigeria;
- to bring into focus mechanical technologies and equipment developed by various institutions, agencies or bodies and evaluate their suitability for adoption;
- to assist in the commercialization of prove machines, equipment, tools and techniques;
- to disseminate information on methods and programmes for achieving speedy agricultural mechanization;
- to provide training facilities by organizing courses and seminars specifically designed to ensure sufficient trained manpower for appropriate mechanization; and
- to promote cooperation in agricultural mechanization with similar institutions in and outside Nigeria and with international bodies connected with agricultural mechanization.

NCAM achievements

In performing her functions which is aimed at realizing the set objectives, the Centre over the years have recorded tremendous achievements. Some of these achievements as itemized by (Azogu 2009; Kasali, 2016) include the design and development of:

- Seed treatment drum for chemically treating seeds prior to storage or planting
- Hand seed planter for planting such grains as maize, soya bean guinea corn, etc.
- Manual seed and fertilizer broadcaster
- Improved long handle weeding hoe. A device for weeding and hoeing
- Rotary hand push weeding hoe
- Cassava lifter for uprooting cassava tubers
- Cassava peeling tool
- Pedal operated cassava grater
- Tractor mounted groundnut digger
- Groundnut decorticator
- Far level parboiler
- Integrated palm fruit processing equipment.
- Maize shellers
- Seed dehuller
- Melon washer
- Multi-purpose thresher
- Okra slicer
- Vegetable slicer
- Manual yam chipping machine
- Motorized melon sheller
- Tractor drawn tuber harvester
- Modified tuber dicer

Some of the machines and implements designed by the Centre and which have been tested certified and granted patents by the Standards

Table 7 Field Operations in States and FCT and Revenue Generated for 1998 Cropping Season

States	Operations carried out and area covered (ha)			Soil textural class	Revenue, N
	Ploughing	Harrowing	Ridging		
Abia	100	100	-	Medium	126,500.00
Adamawa	100	100	-	Heavy	165,000.00
	300	750	250	Medium	756, 250.00
				Subtotal	921,250.00
Akwa Ibom	200	200	-	Medium	253,000.00
Anambra	200	200	-	Medium	805,750.00
Bauchi	300	700	350	Medium	805,750.00
Bayelsa	100	100	-	Heavy	165,000.00
Benue	100	100	-	Heavy	165,000.00
	300	700	200	Medium	698,500.00
				Subtotal	863.500.00
Borno	300	300	-	Heavy	495,000.00
	300	1000	350	Medium	937,750.00
				Subtotal	1,432,750.00
Cross river	100	100	-	Heave	165,000.00
	200	400	-	Medium	341,000.00
				Subtotal	506,000.00
Delta	100	200	50	Medium	206,250.00
Ebonyi	100	100	-	Heavy	165,000.00
Edo	100	100	50	Medium	162,250.00
Ekiti	250	300	50	Medium	374,000.00
Enugu	200	250	5	Medium	310,750.00
FCT	200	200	100	Medium	325, 500.00
Gombe	500	1000	300	Light	825,000.00
Imo	100	200	-	Medium	170,000.00
Jigawa	300	300	-	Heavy	495,000.00
	300	1000	150	Medium	794,750.00
				Subtotal	1,289,750.00
Kaduna	200	200	-	Heavy	330,000.00
	400	1,000	200	Medium	913,000.00
				Subtotal	1,243,000.00

(Continued on the following page)

Fig. 1 NCAM sedimentation tank

Fig. 2 NCAM motorized cassava grater

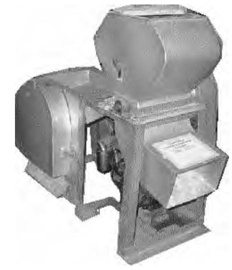


Fig 3 NCAM combined cassava grater/ chipper

Fig. 4 NCAM Marumbi maize sheller

Fig. 5 NCAM mult-crop thresher in demonstration

Fig. 6 NCAM mechanically operated cassava harvester in demonstration

(Continued from the previous page)

	200	200	-	Heavy	330,000.00
Kano	500	1,000	200	Medium	995,500.00
				Subtotal	1,325,500.00
Katsina	500	1,250	250	Medium	1,141,250.00
	200	600	250	Light	508,750.00
Kebbi	150	200	-	Medium	211,750.00
				Subtotal	720,500.00
	150	150	-	Heavy	247,500.00
Kogi	300	500	100	Medium	539,000.00
				Subtotal	786,500.00
Kwara	400	1,000	250	Medium	948,750.00
Lagos	100	150	-	Medium	148,500.00
	300	300	-	Heavy	495,000.00
Nassarawa	200	500	150	Medium	492,250.00
				Subtotal	987,250.00
	100	100	-	Heavy	165,000.00
Niger	300	500	200	Medium	610,500.00
				Subtotal	775,500.00
Ogun	100	150	50	Medium	184,250.00
Ondo	150	200	50	Medium	247,500.00
Osun	100	150	50	Medium	184,250.00
Oyo	100	150	50	Medium	184,250.00
Plateau	600	1,500	400	Medium	1,441,000.00
Rivers	100	100	-	Heavy	165,000.00
Sokoto	300	1,500	250	Light	871,750.00
	300	300	-	Heavy	495,000.00
Taraba	300	1,000	200	Medium	830.500.00
				Subtotal	1,325,000.00
Yobe	300	1,250	250	Light	748,000.00
Zamfara	500	1,500	250	Light	962,500.00
Total	11,600	23,100	5,35 0	-	23,546,500.00

Source: Elesa, 2003; Adama and Elesa, 2009
(1$ US = 360 NGN or 1,000 NGN = $2.8US)

Organization of Nigeria are shown in **Figs. 1** to **6**.

The National Centre for Agricultural Mechanization is still functioning to date and has been charged to handle all matters related to agricultural mechanization in Nigeria.

Acknowledgements

The authors wish to acknowledge the following persons for their contributions in this work. They are, the 2013/14 set of the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture Umudike; Dr Simeon Ogbu of Enugu State University of Science and Technology, Dr A. O. Ogunjiri of National Centre for Agricultural Mechanization, Ilorin and Mr and Mrs Fredrick Obeta

REFERENCES

Adama, J. C. 2006. Mechanizing agro industrial raw materials production in the South East Zone of Nigeria. Proceedings of Workshop on Refocusing Agro Raw Materi-

als Processing in Nigeria. Nigerian Institution of Agricultural Engineers, South East Region and Raw Materials Research and Development Council. pp 78-84.
Adama, J. C., A. P. Onwualu and C. O. Akubuo. 2009. A Proposed Community-Based Participatory Technology Development Programme for Mechanization of Small Farms in Nigeria. Journal of Agricultural Engineering and Technology. Vol. 17.No. 2. December, 2009. Pg 19-32.
Adama, J. C. and B. Y. Elesa 2009 Mechanized tillage operations in Nigeria: The National Agricultural Land Development Authority experience. Journal of Agricultural Engineering and Technology, Vol. 18. No.1 ISSN 014-2222. Pg 14-23.
Adama, J. C., C. A. Ezeaku and B. N. Nwankwojike. 2016. A Survey of agricultural projects operated in the old Eastern region of Nigeria. Unpublished Research Report, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria.
Azuogu, I. I. 2009.Promoting Appropriate Mechanization Technology for Improved Agricultural Productivity in Nigeria: The Role of the National Centre for Agricultural Mechanization. Journal of Agricultural Engineering Technology.17(2). pp. 1-10.
Elesa, B. Y. 2003. Reports on Post Graduate Experience at National Agricultural Land Development Authority. Submiitted to the Council for the Regulation of Engineering in Nigeria for Professional Registration. pp 35-36.
FMARD. 2004. Federal Ministry of Agriculture and Rural Development .Rural Development Sector Strategy. Main Report 2nd Edition. Fest Faze Publishers Ltd, Lagos. pp 1.
FMAWR 2008. Federal Ministry of Agriculture and Water Resources. Supplement on National Food Security Programme. In the Fresh Fact. June 2-8. pp 23.
Gana, G. I. 1999. Machinery service delivery in NALDA farms. Lead Paper in the Proceedings of National Conference of Nigerian. Society of Agricultural Engineers, Vol. 21. Bauchi
Idachaba, F. S. 1979. Some Considerations in Agricultural Input Policies in the Fourth National Development Plan. In the Crop Sub-sector in the Fourth National Development Plan (1981-85). Durapress Ltd, Ibadan, Nigeria.
Ige, M. T. 1987. Development and management of appropriate farm power and machinery technology for achieving a self-integrated rural development. Proceedings of 11th Annual Conference of Nigerian Society of Agricultural Engineers held at University of Nigeria Nsukka. Vol. 11. Pp 71-93.
Igbeka, J. C. 2010. Introduction to Agricultural Power Systems Stirling-Horden Publishers Ltd. Gaaf Buiding 110-112, Oyo Road, Ibadan–Nigeria. pg 5.
Ijere, M. O. 1976. Role of Government in Accelerated Food Production in the Rainforest Zones of Nigeria. Symposium Proceedings. Department of Agric. Engineering, University of Nigeria, Nsukka, pp. 3-8.
Ijere, M. O. 1991. The Challenges of Rural Development in Nigeria. Unpublished Research Report, Centre for Rural Development and Co-operatives, Faculty of Agriculture, University of Nigeria, Nsukka.
Ikuru, T. R. 2013. Politics of Agricultural Mechanization and National Food Security.
Being the Lecture Delivered at the 2nd Prof U.G. N. Anazodo Memorial Lecture Michael OkparaUniversity of Agriculture, Umudike, Nigeria.
Kasali., M. Y. 2016. Developments in machineries for mechanizing root and tuber production and processing in Nigeria. Lead paper in the Proceedings of Conference on Mechanization of Root and Tuber Production and Processing in Nigeria. Organized by the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia state. pp 1-47.
Liman, M. 1979. Overview of the Crop Sub-sector in the Fourth National Development Plan (1981-1985). Durapress Ltd, Ibadan Nigeria. pp 1-2.
NALDA. 1992. National Agricultural Land Development Authority. Blue Print. Abuja, Nigeria.
NALDA. 1994a. National Agricultural Land Development Authority Programme Implementation Manual. Abuja, Nigeria.
NALDA. 1994b. National Agricultural Land Development Authority. Guidelines and Specifications for Land Development Activities in NALDA Farms.
Odigboh, E. U. and A. P. Onwualu. 1994. Mechanization of agriculture in Nigeria. A critical appraisal. Journal of Agricultural Technology, 2(2):1-58.
Ofomata, G. E. K. 1975. Nigeria in Maps: Eastern States. Ethiope Publishers, Benin City. Nigeria.
Onwualu, A. P. Akubuo, C.O. and Ahaneku, I. E. 2006. Fundamentals of Engineering for Agriculture. Immaculate Publications Limited. Enugu, Nigeria.
Othman, M. K. 2017. Improving food security and sustainable livelihood in Nigeria. A critical analysis of theoretical and practical perspective. Paper presented at the 2017 Annual International Meeting in Spokane Washington, USA. July 16-19.

■■

Present Status and Future Prospects of Agricultural Machinery Research Activities in Nigeria

by
M. Y. Kasali
Ph.D
Ag. Executive Director
National Centre for Agricultural Mechanization
(NCAM)
Ilorin, Kwara State
NIGERIA
yommekasali1@gmail.com

Abstract

The National Centre for Agricultural Mechanization (NCAM) is the only Nigeria's federal government parastatal with the mandate of promoting agricultural mechanization practice. Agricultural machinery research activities in Nigeria have been bedeviled by some challenges which if appropriately addressed will promote the wide array of machinery for farming and agro-processing activities in Nigeria. The success of agricultural machinery research activities in Nigeria will also limit, if not eliminate, the use of traditional hand tools, implements and equipment. This paper discusses the present status and future prospects of agricultural machinery research activities in Nigeria.

Keywords: prospects, machinery, research, activities

Nigerian Agriculture: An Overview

Agriculture has been described as the mainstay of the Nigerian economy since independence, and despite several bottlenecks, it remains a resilient sustainer of the populace. In the 1960s, Nigeria was the world's largest exporter of groundnut, the second largest exporter of cocoa and palm produce and an important exporter of rubber and cotton (Sekunmade, 2009). The sector has several untapped potentials for growth and development in terms of the availability of land, water, labour and its large internal markets. It is estimated that about 84 million hectares of Nigeria's total land area has potential for agriculture. However, only about 40 percent of this is under cultivation. Productivity of the cultivable lands is also low due to small farm holdings and the continuous use of the traditional farming methods. Nigeria therefore has become heavily dependent on food imports. In addition to diverse and rich vegetation that can support large livestock population, it also has potential for irrigation with a surface and underground water of about 267.7 billion cubic meters and 57.9 billion cubic meters, respectively (Chauvin *et al*., 2012; Lipton, 2012).

The agricultural sector is classified into four sub-sectors namely, crops, livestock, fisheries and forestry subsectors. The crops, livestock, fisheries and forestry sub-sectors of the Nigerian agricultural sector contributed 85%, 10%, 4% and 1%, respectively, to agricultural GDP. The crops and livestock sub-sectors have maintained their shares in recent years, while the fisheries has been expanding and the forestry shrinking. Given the large size of the crops sub-sector relative to the other three, growth performance in the crops sub-sector drives overall growth performance in agriculture. Among Nigeria's food staples, cereals account for the largest share of cultivated areas while roots and tubers account for the largest share of production due to their much higher yields per unit land area. Millet and sorghum, which are drought resistant crops, are grown in the northern part of the country while the growth of maize and rice, which require more moisture, are concentrated in the middle belts. Yam and cassava are grown extensively in the humid southern part of the country. Since 1990, production of most major food crops has increased steadily. Food crop production in Nigeria has been driven entirely by expansion in area planted rather than by increase in productivity. Crop land expansion is increasingly taking place on marginal land where yields are lower. With the reduction of unused crop land, the current agricultural growth strategy, based on expansion of land area planted, becomes clearly unsustainable over the longer term.

In the Nigerian agricultural sector, the major crops grown in the country are cowpea, sesame, cashew nuts, cassava, cocoa beans, groundnuts, gum arabic, kola nut, maize (corn), melon, millet, palm kernels, palm oil, plantains, rice, rubber, sorghum, soybeans and yams. These crops have commercial potentials of boosting the economy if mechanized through the use of modern techniques and equipment.

Agricultural Machinery Development and Marketing

Agricultural mechanization is a major limitation inhibiting increased agricultural production and the threat of food insecurity in the country (Alabadan and Yusuf, 2013). The continuous increase in the prices of agricultural produce is due to the lack of food security resulting from poor storage structures. In addition to this, farmers still depend on the use of traditional tools for carrying out their farming operations as the cost of purchasing and maintaining farm machineries in Nigeria is high.

Daudu (2011) postulated agricultural mechanization is an important concomitant for increased agricultural production and development. The need to feed the ever-increasing Nigerian population and the acceptance of the use of modern farm machinery as the best means of increasing food production and farm income by all stakeholders in the agricultural sector had led to a heightened marketing of agricultural machinery in Nigeria.

Agricultural machinery in Nigeria consists of farm field and farmstead machinery used for the production of crops and livestock. The major grouping of agricultural machinery are tractors; planting, seeding and fertilizing machinery; ploughing and cultivating machinery; harvesters; hay machinery; other agricultural machinery (including poultry equipment, dairy machinery, irrigation equipment, sprayers and processing machinery), and parts and attachments (Mehta and Gross, 2007). Farm tractors, considered as the "workhorse" of agriculture and the most versatile machine represent the largest segment, ploughing and cultivating machinery represent the second largest segment, and harvesting and threshing machinery represent the third largest segment. The Nigerian market provides a huge potential with regard to sourcing as well as selling of agricultural machinery even though it is an extremely price-sensitive market. The key elements that constitute the marketing programme of any organization are product, price, promotion and place or distribution.

According to Oni (2005), there had been two tractor assembly plants established in Nigeria in the 1970s. These were the Nigeria Trucks Manufacturers (NTM), assemblers of Fiat tractors as well as Fiat trucks, and the Steyr Nigeria Ltd., assemblers of Steyr tractors and Steyr trucks. It is rather disheartening that both companies have folded up or seized to perform the functions for which they were established. Even while in operation, both companies were complementing their tractors with imported implements and equipment, a situation that did not make for the completeness of the marketability of their products. Besides, the Federal government policy that a minimum of thirty percent (30%) local content be incorporated into the machinery as was the case with automobiles was hardly adhered to. However, the ready supply of the machinery to service the Nigerian agriculture industry made tremendous impact on local agricultural production while conserving a lot of foreign exchange for the nation. The scenarios have changed ever since the closure of these plants.

There exists a critical mass of local fabricators in Nigeria producing agricultural mechanization technologies for end users (Ajibola and Zalla, 2007). These fabricators include blacksmiths, artisans, micro, small and some medium scale entrepreneurs. They produce a wide range of products such as hand tools, draft animal implements, ridgers, shears, milling machines, threshers, shellers, hullers, expellers, grinding machines, cassava processing machines, oil palm processing machines, etc. Most of these local manufacturers are always not willing to risk production for an unknown, risky market without evidence of demand or pre-paid, firm order. Adekoya (1990) classified agricultural machinery manufacturers into four dominant groups namely research and development institutions, established manufacturers, cottage manufacturers and roadside manufacturers.

CBN (2010) reported that farm machinery market is linked to agricultural mechanization development in Nigeria. The level of mechanization of the Nigerian agriculture is relatively low with relatively low tractor density. There are only 7 tractors available for 100 hectares of land area, even though agriculture has remained the largest contributor to real Gross Domestic Product contributing 42.8 percent in 2008 and 41.8 percent in 2009. FAO (2011) reported that there were 24,800 agricultural tractors in use in Nigeria as at 2007. Daudu (2011) also reported that agricultural machinery was predominantly based on importation, assembly, and probably a few local manufacture of mostly agricultural processing equipment that did not enjoy any degree of protection against imports from other parts of the world. The manufacture of basic agricultural implements was largely by village artisans, tiny units, and small-scale industries. Agricultural machinery and equipment products such as land development machinery, tractors, post-harvest and processing machinery and dairy equipment are imported either as completely knocked down (CKD) parts to be assembled or fully built by large corporate organizations and offered to market through a network of dealers. **Table 1** presents the inflow and outflow of agricultural machineries in Nigeria. It can be deduced from **Table 1** that Nigeria did not export any agricultural machineries other than depending fully on imported agricultural machineries within the period under review.

Some of the challenges of agricultural machinery marketing in Nigeria, according to Daudu (2011) include (i) low purchasing power of most small-scale farmers, (ii) high cost of agricultural machinery, (iii) inadequate agricultural credit and unfavourable interest rates, (iv) huge machinery pool with only a few functional and others not functional (v) complex agricultural machinery (vi) lack of well-trained operators and mechanics for agricultural machinery, (vii) lack of suitable machinery packages for main agricultural operations, (viii) importation and production of tools, equipment and machinery of poor quality, (ix) poor technical expertise, (x) poor infrastructure, (xi) inadequate after sales service support, and (xii) corruption.

Agricultural Research Activities in Nigeria

Agricultural research in Nigeria started formally with the establishment of a botanical garden in Lagos during the late 19th century. In 1914, with the amalgamation of Nigeria's protectorates, a new Department of Agriculture was created. Research continued to focus, however, on export crops like oil palm, rubber, cotton and cocoa. The British colonial government established various regional agricultural research centres, some of which were later transformed into national Institutions at independence; such Institutions included the West African Institute for Oil palm Research (WAIFOR) which was transformed into Nigerian Institute for Oil Palm Research (NIFOR), the West African Institute for Trypanosomiasis Research (WAITR) was transformed into Nigerian Institute for Trypanosomiasis Research (NITR) and the West African Stored Products Research Unit (WASPRU) was transformed into Nigerian Stored Products Research Institute (NSPRI). Research activities were regionalized, which eliminated Federal Government involvement. These efforts however, did not yield the expected results prompting the Federal Government to once again intervene in the 1960s, which was followed by major reorganization and expansion of research institutes in the 1970s. In 1974, the Federal Ministry of Agriculture and Natural Resources realized the need to establish a Centre to coordinate mechanization activities as contained in a report titled "Proposal for the Establishment of National Centre for Agricultural Mechanization". This paper presents the present status and future prospect of agricultural machinery research activities in Nigeria

Agricultural Mechanization in Nigeria

Brief History of Agricultural Mechanization in Nigeria

Agricultural holdings in Nigeria are small and fragmented. Farming is carried out with simple traditional tools. Large-scale agriculture is not common. The drudgery involved with this hand tools coupled with the 'neglect' of the agricultural sector by various governments since the discovery of crude fossil fuel and the resulting oil boom caused many farmers and prospective ones to abandon farming in pursuit of oil and solid mineral resources. This resulted in the current low level of mechanization. According to Oni (2011a), there are long-handled-hoe and short-handled hoe but the short-handled hoe predominates in Nigeria. The short-handled hoe is shown in **Fig. 1**.

Nigeria has no single manufacturing plant for tractors and machinery; however, there are three assembly plants which imported completely knock down (CKD) components into the country for subsequent assembly. There are also a few indigenous local fabricators that attempt to fabricate simple farm tools, machines and other equipment that are used for various activities on the farm to meet the need of small scale farmers. Currently, an estimated 45,000 tractors with implements, 3,500 power tillers and their accessories and over 200,000 irrigation pumps of different sizes are in the country. Other machinery available in very low quantity includes reapers, planters, sprayers of different types and description and combine harvesters. These equipment have been in use in the country since

Table 1 Inflow and Outflow of agricultural machineries

	2013	2014	2015 (estimated)	2016 (estimated)
Total Market Size	63,000	68,000	72,000	104,500
Total Local Production	3,000	3,000	5,000	7500
Total Exports	0	0	0	0
Total Imports	60,000	65,000	67,000	97,000
Imports from the U.S.	15,000	18,000	10,000	20,000
Exchange Rate: 1 USD	197	197	197	197

Source: www.export.gov

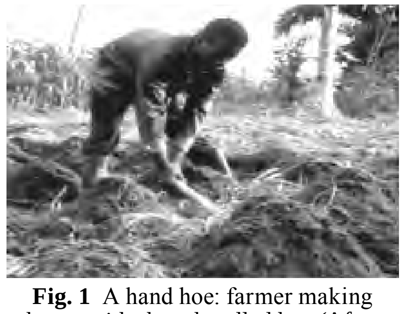


Fig. 1 A hand hoe: farmer making heaps with short-handled hoe (After FAO, 2005)

1970, hence responsible for the very low farm power availability. The units of tractor available for Nigerian agriculture which consists of different makes and models as fully built tractors (FBT) are obtained through massive importation from over 22 countries.

The constraints and challenges of agricultural mechanization are (i) it is capital intensive; (ii) small and fragmented land holdings, (iii) low investment capacity of farmers; and (iv) inadequate agricultural production infrastructures. The choice and level of mechanization will therefore depend on the support and capital availability. Indigenous capability of local manufacturing industries is still very low because the iron and steel industries which should provide the much needed raw materials for manufacturing plants and fabrication outfits have not been fully developed; and human resources development in the broad field of agricultural engineering and in specific areas of mechanization technology is still low and, where available, is under-utilized.

Population Growth and Food Insecurity in Nigeria

According to www.geohive.com, Nigeria has a population over 190 million people. This makes Nigeria the seventh most populous nation in the world and the first in Africa. The high population growth in Nigeria is giving rise to rapidly increasing demand for food (**Table 2**). The present productivity of agricultural sector in Nigeria is insufficient to meet her current population demand. This poses a major threat to people's survival and wellbeing. The country still largely depends on importation of such food produce as rice, sorghum, wheat, barley, millet, etc, to augment its local production and food needs of its populace.

Establishment of the National Centre for Agricultural Mechanization (NCAM)

The establishment of the National Centre for Agricultural Mechanization (NCAM) was in response to the need for Nigeria to attain self-sufficiency in food and fibre production. Government was convinced of the indispensable role of agricultural mechanization to the actualization of Nigeria's self-sufficiency in food and fibre. This, coupled with the ever-present constraints of imported agricultural mechanization technologies some of which are not compatible with Nigeria's pre-climatic conditions, crops and cropping patterns with their attendant poor after sales back up services, irregular supply of spare parts and other socio-economic considerations, informed the establishment of NCAM, to address these mirage of problems.

Mandate of NCAM

NCAM which has a land area of about 950 hectares was established in 1978 by the Act of the Nigeria's National Assembly, No. 35 of 1990 with the mandate to accelerate the positive transformation of the agricultural sector of the Nigerian economy in order to increase the quantity and quality of agricultural products. The mandate is being achieved through adaptive and innovative research and development activities which include:

- to encourage and engage in adaptive and innovative research towards the development of indig-

Table 2 Gaps in Nigeria Demand and Supply across Key Crops and Activities (2016 Estimate)

Crop	Demand (tons)	Supply (tons)	Observations
Rice	6.3 million	2.3 million	Insufficient supply chain integration remains issue.
Wheat	4.7 million	0.06 million	Driven by demand for various types of wheat (white, hard, durum), etc. for bread, biscuits and semovita.
Maize (Corn)	7.5 million	7.0 million	Limited imports required but can shift due to feed demand.
Soya Beans	0.75 million	0.6 million	Animal feed and protein cost are driving demand.
Chicken	200 million birds	140 million	Gap filled by illegal imports that enter market at lower price point than domestic producers; gap also a moving target based on fast food/QSR demand.
Fish	2.7 million	0.8 million	Fall off in ocean catch and weakness in aquaculture yields due to cost of fish feed a constraint on growth.
Milk/Dairy	2.0 million	0.6 million	Driven by insufficient milking cows and low yields (~15-25 liters/day versus norm of 35-40 liters NZ/US).
Tomato	2.2 million	0.8 million	Actual production is 1.5 million tons but 0.7 M ton is lost post-harvest.
Yams	39 million	37 million	Limited gap today but volumes expected to rise in planning period.
Oil Palm	8.0 million	4.5 million	Refers to fresh fruit bunch (FFB) from which oil is extracted at a 10-15% efficiency rate.
Cocoa	3.6 million	0.25 million	Demand is global demand which will rise to 4.5 M by 2020.
Cotton	0.7 million	0.2 million	Demand is for seed cotton and could rise to 1.0-1.5 million tons subject to textile sector revival.
Sorghum	7.0 million	6.2 million	Demand will rise further as use in feed grows in 2016-2020. Import of malt extracts and glucose syrup is currently used to manage gap, hence a commercial threat for Nigerian farmers.

Source: FMARD (2016)

enous machines for farming and processing techniques;

- to design and develop simple and low-cost equipment which can be manufactured with local materials, skills and facilities;
- to standardize and certify, in collaboration with the Standards Organization of Nigeria (SON), agricultural machines, equipment and engineering practices in use in Nigeria;
- to bring into focus mechanical technologies and equipment developed by various institutions, agencies or bodies and evaluate their suitability for adoption;
- to assist in the commercialization of proven machines, equipment, tools and techniques;
- to disseminate information on methods and programmes for achieving speedy agricultural mechanization;
- to provide training facilities by organizing courses and seminars specially designed to ensure sufficient trained manpower for appropriate mechanization; and
- to promote cooperation in agricultural mechanization with similar institutions in and outside Nigeria and with international bodies connected with agricultural mechanization.

Agricultural Mechanization Policy in Nigeria

Proposed Agricultural Mechanization Policy in Nigeria

Presently in Nigeria, there is no separate National policy on Agricultural Mechanization. It was covered under Agricultural policy. Over different periods, successive Governments have emphasized on selective mechanization through importation and procurement of tractors, implements and other farm machinery. Effort has also been intensified through the promotion of animal draught and the use of energy saving but appropriate tools among the small scale farmers. This combined efforts contributed marginally to increase the farm power availability from the low level of 0.03 hp/ha in early 70s to attain 0.27 hp/ha; this is still low in comparison with what is obtainable in developed countries of the world.

The imperatives and objectives of Agricultural Mechanization Policy as contained in the proposed policy include (i) Nigeria's Agriculture is to boost food production to cope with ever increasing population growth, change in nutritional and dietary status and the demand for raw materials to feed the local industries; (ii) over 70% of the labour force is deployed to agriculture and food production on the farm. The need to free this labour force to other productive subsector of the economy while maintaining increase in food production is imperative; (iii) mechanization technology is to be viewed within the context of

Table 3 Activities of Agric-Based Research Institutes in Nigeria

Research Institute	Mandate	Ecological Zone Covered
National Centre for Agricultural Mechanization (NCAM), Idofian, Ilorin, Kwara State. E-mail:ncamcontact@yahoo.com; info@ncamng.org	Research into agricultural mechanization through the development of sustainable indigenous mechanization technologies.	All ecological zones in Nigeria.
Cocoa Research institute of Nigeria (CRIN), Ibadan. E-mail: enquiries@crinig.org	Research into the genetic improvement and production of cocoa, cashew, kola, tea and coffee.	Ecological zones covered by the specified crops.
Forestry Research Institute of Nigeria (FRIN), Ibadan. E-mail: info@frin.gov.org	Research into forestry, agro-forestry, wildlife, and environmental production and conservation. Total farming systems for the ecological zones encompassing Kano, Sokoto, Katsina, Kaduna and Kebbi and Zamfafa States.	Ecological zones encompassing Kano, Sokoto, Katsina, Kaduna, Kebbi and Zamfara states.
Institute for Agricultural Research (IAR), Zaria. E-mail: iar2000201@yahoo.com	Research into genetic improvement of sorghum, groundnut, cowpea, cotton, sunflower, maize. Total farming systems for the ecological zones covered by Kano, Sokoto, Katsina, Kaduna Kebbi and Zamfara States.	Northern and Western zones of Nigeria.
Institute of Agricultural Research and Training (IAR&T), Ibadan. E-mail: directoriart@yahoo.com	Research into kenaf, jute and soil and water management. Total farming systems for the ecological zones encompassing Lagos, Ogun, Oyo, Osun, Ondo, Ekiti, Edo and Delta States.	Lagos, Ogun, Oyo, Osun, Ondo, Ekiti, Edo and Delta States.
Lake Chad Research Institute (LCRI), Maiduguri. E-mail: info@lcrimaid.gov.ng	Research into genetic improvement of millet, wheat and barley. Total farming systems for the ecological zones covered by Borno, Jigawa, Yobe, Gombe, Bauchi and Adamawa States.	Ecologies encompassing Borno, Yobe, Gombe, Jigawa, Bauchi and Adamawa states.

(Continued on the following page)

(Continued from the previous page)

National Agricultural Extension and Research Liaison Services (NAERLS), Zaria. E-mail: director@naerls.gov.ng	Co-ordination of all agricultural extension and specialized support activities in crops, livestock, fisheries, forestry, irrigation and food technology	All ecological zones of Nigeria.
National Animal Production Research Institute (NAPRI), Zaria. E-mail: info@napri_ng.org	Research into animal production and animal products.	Ecological zones covered by the specified animals.
National Cereals Research Institute (NCRI), Badeggi. E-mail: ncri@skannet.com	Research into the genetic improvement and total farming systems of rice, soyabean, benniseed and sugarcane; and extension services in the middle belt.	The middle belt zones.
National Institute for Freshwater Fisheries Research (NIFFR), New Bussa. E-mail: contact@niffrnigeria.org	Research into genetic improvement of fresh water fish species, other aquatic resources and their production in Nigeria; and Research into long term effects of man-made lakes on ecology and environment.	Ecological zones covered by the fisheries and aquatic resources.
National Institute for Horticultural Research (NIHORT), Ibadan. E-mail: nihortinfo@yahoo.com	Research into genetic improvement and production of fruits and vegetables as well as ornamental plants.	Ecological zones covered by the specified plants.
National Root Crops Research Institute (NRCRI), Umudike. E-mail: nrcri.gov.ng	Research into the genetic improvement of cassava, yam, coco-yam, irish potato and ginger. Total farming systems, research and extension services in South-East zones.	Anambra, Enugu, Cross River, Ebonyi, Imo, Abia, Rivers State, Akwa Ibom, Bayelsa and Plateau States.
National Veterinary Research Institute (NVRI), Vom, Jos. E-mail: nvri24@yahoo.com	Research into all aspects of livestock and animal diseases; their treatment and control. Development and production of animal vaccines and sera, etc.	Ecological zones covered by the animals.
Nigerian Institute for Oceanography and Marine Research (NIOMR), Lagos. E-mail: info@niomr.org	Research into the resource and physical characteristics of Nigerian territorial waters and the high sea beyond; and Research into genetic improvement of marine and brackish water fish species oceanography and aquatic resources, their production and processing.	Ecological zones covered by the ocean and territorial waters.
Nigerian Institute for Oil Palm Research (NIFOR), Benin City. E-mail: info@nifor.org.ng; nifor@infoweb.abs.net	Research into the genetic improvement, production and processing of oil palm, raphia, date, coconut and ornamental palms.	Ecological zones covered by the specified plants.
Rubber Research Institute of Nigeria (RRIN), Benin City. E-mail: rubberresearching@yahoo.com	Research into the genetic improvement, production and processing of natural rubber and other latex producing plants, such as gum arabic.	Ecological zones covered by the specified plants.
Federal Institute for Industrial Research (FIIRO), Lagos. E-mail: info@fiiro-ng.org	Research into agro-industrial and food processing technology and upgrading of indigenous production and processes; and Food science and technology, design and fabrication of machines.	Ecological zones covered by the plants.
Nigerian Institute for Trypanosomiasis Research (NITR), Kaduna. E-mail: nitr-kaduna@yahoo.com	Research into tsetse and simulium flies and diagnostic methods on the control of trypanosomiasis and onchocercieisis.	Ecological zones covered by the animal.
Nigerian Stored Product Research Institute (NSPRI), Ilorin. E-mail: nspriheadquarters@yahoo.com	Research into the improvement of storage and preservation systems on major food and industrial crops; and Studies on stored product pests, pesticides formulation and residue analysis.	Ecological zones covered by the plants.
National Research Institute for Chemical Technology (NARICT), Zaria. E-mail: info@narict.gov.ng	Research into hides, skins, leather, industrial chemicals, polymers and plastics.	Ecological zones covered by the specified plants and animal.
National Institute for Pharmaceutical Research and Development (NIPRD), Abuja. E-mail: dgniprd@yahoo.com	Research into medicinal plants/herbs and drugs development and formulary.	Ecological zones covered by the specified plants.
National Centre for Genetic Resources and Biotechnology (NAGRAB), Ibadan. E-mail: info@nacgrab.gov.ng	Husbanding of plant and animal genetic resource. Development resources in genetics.	Ecological zones covered by the specified plants and animal.

Source: Oni (2004)

Fig. 2 (a) NCAM Trike-tor 300, (b) NCAM motorized hammer mill with cyclone, and (c) NCAM mechanical gari fryer, all in operation

declining soil productivity, reduced accelerated soil degradation due to erosion and desertification, provide livelihood for local fabricators and developed indigenous capability to develop machinery for export to regional and international markets; (iv) sustainability of research effort and development for crops and livestock production system and processes; (v) provide a potential market for new information technology, products and other innovative applications that may lead to increased productivity; (vi) contribute to the development of human resource, on all spheres of Agricultural Mechanization; and (vii) development of test and performance evaluation standards on all Agricultural Machinery to assess their functional suitability.

NCAM's involvement in the Proposed Agricultural Mechanization Policy in Nigeria

In pursuance of the imperatives and objectives of the Agricultural Mechanization Policy, NCAM is expected to conduct test and certification on all forms of farming machinery imported into the country. Without prejudice to local fabricators and developers, all locally developed or adopted machines shall be subjected to testing, standardization and certification before being introduced for commercialization to protect the interest of the farmer.

Agricultural Machinery Research Activities in Nigeria

Agricultural Research Institutes Established in Nigeria

Table 3 presents the activities of various agro-based research institutes in Nigeria. It was observed in **Table 3** that none of these agro-based research institutes were into agricultural mechanization. Based on this, NCAM remains the only Federal Government owned parastatal in the Federal Ministry of Agriculture and Rural Development that is into agricultural mechanization.

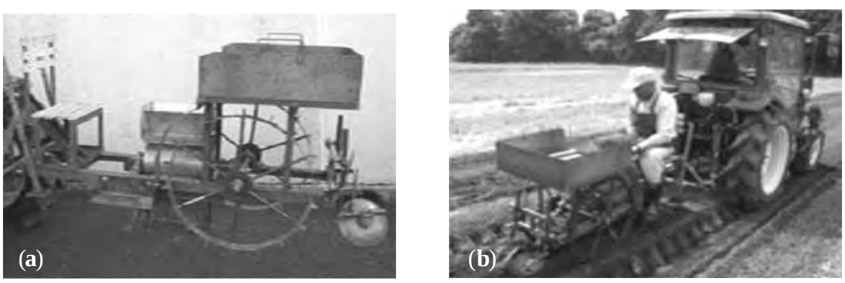


Fig. 3
(**a**) NCAM-developed semi-automated cassava stem planter (Source: Oni, 2011b)
(**b**) NCAM-developed semi-automated cassava stem planter in operation (Source: Oni, 2011b)

Extent of NCAM's Contribution to Agricultural Mechanization in Nigeria

Machinery development

As part of the Centre's mandate to develop low cost machines, the Centre has developed several machines and equipment for the various types of crop grown in Nigeria. **Table 4** presents the various types of machines developed by the Centre. It is clear from **Table 4** that NCAM has in recent times paid more attention to root and tuber crops, most especially cassava. This came as a result of government's involvement in promoting cassava for export of cassava chips to China and for the incorporation of 10% cassava flour with 90% wheat flour for the making of bread in Nigeria. **Fig. 2** presents the array of agricultural machinery and equipment developed by NCAM.

Among the equipment developed by the Centre that is worthy of note is the semi-automatic cassava stem planter which is shown in **Fig. 3**.

Machinery testing and certification

As part of the Centre's mandate to test any agricultural machinery and equipment imported into the country for use in Nigerian agriculture, NCAM has evaluated 79 tractors of different makes and models since 2001 to date. **Table 5** presents the list of tractors evaluated by the Centre. Most of these tractors evaluated by the Centre were tractors imported mainly from India and China. **Fig. 4** presents the array of tractors awaiting evaluation at NCAM. **Fig. 5** presents the courtesy visit paid by Mahindra and Mahindra Ltd.

Table 4 List of Agricultural Machineries and Equipment developed by NCAM

Type of Crop					Other use
Cereals	Legumes	Roots & Tubers	Fruits and Vegetables	Tree	
i. Hand held maize cone sheller	i. Tractor mounted groundnut digger/shaker	i. semi-automated cassava stem planter	i. Melon sheller (manual and motorized)	i. Motorized palm fruit stripper	i. 64 tray cabinet dryer (kerosene fired)
ii. Bench mounted maize sheller	ii. Groundnut decorticator	ii. Cassava lifter (Manually operated)	ii. Okra slicer (Manually operated)	ii. Motorized palm fruit sterilizer	ii. Batch dryer (kerosene fired)
iii. Marubi maize sheller	iii. Cowpea thresher	iii. Tractor drawn cassava harvester	iii. Motorized mango juice extractor	iii. Palm fruit digester (Manually operated and motorized)	iii. Fish smoking kiln (Charcoal fired)
iv. Seed planter	iv. Seed dehuller	iv. Improved cassava peeling tool (Manually operated)	iv. Plantain slicer	iv. Motorized palm oil clarifier	iv. Motorized multi-purpose milling machine
v. Jab planter		v. Cassava peeler (Motorized)	v. Shelled melon seed separator	v. Fibre separator	v. Motorized oil expeller
vi. Multi-crop thresher		vi. Cassava washer (Motorized)		vi. Hydraulic press	vi. Trike-tor 300 (Farm bike)
vii. Rice destoner		vii. Cassava grater (threadled and motorized)		vii. Palm kernel cracker	vii. Seed treatment drum
viii. Farm level paddy parboiler		viii. Motorized cassava chipper (for producing i) Threadlike shaped cassava chips and ii) cubic shaped cassava chips)		viii. Motorized coffee depulper	viii. Manual seed and fertilizer broadcaster
ix. Hand-held rice harvester		ix. Cassava grater cum chipper (Motorized)		ix. Motorized coffee dehuller cum polisher	ix. Improved long hand weeding hoe
x. Rice trans planter (under testing)		x. Cassava dewatering press (single and double pole types)		x. Motorized cocoa oil expeller	x. Rotary hand push weeding hoe
xi. Rice thresher		xi. Spring loaded cassava dewatering press			xi. Mixing machine
		xii. Motorized cassava mash shifter (vertical and horizontal types)			xii. Long handle hoe
		xiii. Cassava sedimentation tank			
		xiv. Gari communal fryer			
		xv. Gari industrial fryer			
		xvi. Motorized hammer mill with and without cyclone			
		xvii. Motorized yam dicer			

Table 5 List of Tractors Evaluated by NCAM: 2001–To Date

Name of Tractor	Type of Tractor	Engine Rated Power (Hp)	Country of Origin	Year Evaluated
VITEC	Four-Wheel	16	China	2001
Eicher 485DI	Four-Wheel	42	India	2002
Mahindra 585DI	Four-Wheel	50	India	2002
Eicher (Euro Power) 6100	Four-Wheel	60	India	2003
Changzhou Walking Tractor	Two-Wheel	13.2	China	2004
Mahindra B-275 DI	Four-Wheel	39	India	2005
Mahindra 575 DI	Four-Wheel	45	India	2005
Mahindra 605 DI	Four-Wheel	60	India	2005
SWARAJ 855	Four-Wheel	55	India	2005
SWARAJ 978FE	Four-Wheel-Drive	78	India	2005
HRT-195 Walking Tractor	Two-Wheel	12	China	2005
Mahindra 585 DI	Four-Wheel	50	India	2005
UMZ 6AKM 40.2	Four-Wheel	65	Ukraine	2005-2006
Foton 450	Four-Wheel	45	China	2006
Foton 650	Four-Wheel	65	China	2006
Foton 824	Four-Wheel-Drive	80	China	2006
Top Tech	Four-Wheel-Drive	69	China	2006
SONALIKA DI-75	Four-Wheel	70	India	2006
URSUS 5312	Four-Wheel	70	Poland	2006
Merry tiller	Two-Wheel	5	United States of America	2006
FARMTRAC 60	Four-Wheel	50	India	2007
FARMTRAC 70	Four-Wheel	60	India	2007
FARMTRAC 80	Four-Wheel	73	India	2007
POWERTRAC 455	Four-Wheel	55	India	2007
TAFE 7502	Four-Wheel	75	India	2007
Balwan 500	Four-Wheel	50	India	2007
CLAAS CELTIS 426 RA	Four-Wheel-Drive	74.4	Germany	2007
lEad sOLUTION u60	Four-Wheel-Drive	57	Korea	2008
YTO x-704	Four-Wheel-Drive	69	China	2008
Foton Europard 704	Four-Wheel-Drive	69	China	2008
Foton Europard 600	Four-Wheel	59	China	2008
DONGFENG 700	Four-Wheel	69	China	2008
BELARUS 82.1	Four-Wheel-Drive	82.1	BELARUS	2008
KAMA 550	Four-Wheel	54.3	China	2008
WEITUO SWT-854	Four-wheel-Drive	83.8	China	2008
BELARUS 800	Four-Wheel	80	BELARUS	2008
RICH combine harvester	Two- Wheel	6.9	China	2008
Mahindra B-275	Four-Wheel	39	India	2008
Mahindra 605 DI	Four-Wheel	60	India	2008
Mahindra 705 DI	Four Wheel	70	India	2008
Mahindra 8000 2WD	Four-Wheel	80	India	2008
TAK 750 DI	Four-Wheel	50	India	2009
TAK 75 DI	Four-Wheel	75	India	2009
TAK 90 DI	Four-Wheel-Drive	90	India	2009
ZETOR (PROXIMA 75)	Four-Wheel-Drive	72	Czech Republic	2009
AGROLUX 75e	Four-Wheel	70	India	2009
FARMTRAC 80E	Four -Wheel	80	India	2009
SONALIKA DI75	Four-Wheel-Drive	75	India	2010
YTO-X750	Four-Wheel	74	China	2010
YTO-X754	Four-Wheel-Drive	74	China	2010
BASAK 2073 SH	Four-Wheel	75	Turkey	2010
Landini 7860	Four-Wheel-Drive	73.5	Italy	2010
Landini Global farm 100	Four-Wheel-Drive	97.3	Italy	2010

(Continued on the following page)

Fig. 4 An array of imported tractors awaiting evaluation at NCAM (Source: Oni, 2011b)

Fig. 5 Courtesy visit to NCAM paid by representative of Mahindra and Mahindra Tractor Limited of India (Source: NCAM Achievements, August 2001-July 2009)

Fig. 6 Coupling of the strain gauged dynamometer for draught (force) determination (Source: Oni, 2011b)

of India to NCAM while about to establish their Mahindra tractor Assembly plant at Ibadan, Oyo State of Nigeria. Presented in **Figs. 6** and **7** are some of the activities performed during tractor evaluation at NCAM.

Standards and test codes

The Standards Organization of Nigeria (SON) was established to provide standards and quality assurance services for all products, services and processes in Nigeria in line with international best practices and to ensure continual improvement. The Centre, in collaboration with SON, has developed seven Standards and Test Codes for agricultural equipment namely:

- Nigerian Standard Test Code for Grain and Seed Cleaners.
- Nigerian Standard Test Code for Maize Sheller.
- Nigerian Standard Test Code for Agricultural Tillage Discs.
- Nigerian Standard Specification for Agricultural Tillage Disc: Part I – Concave Discs.
- Nigerian Standard Specification for Agricultural Tillage Disc: Part II – Flat Discs.
- Nigerian Standard Terminology for Tillage and Tillage Equipment.
- Nigerian Standard Test Code for Groundnut Sheller.

The Centre had equally, in collaboration with the Standards Organization of Nigeria (SON) prepared

(Continued from the previous page)

VARI Multipurpose Mini-Tractor	Two-Wheel	5.1	Czech Republic	2011
Millat MF 375	Four-Wheel	72	Pakistan	2011
Farm Bike (Trike-tor)	Three-Wheel	20	Nigeria	2011
Bull 55 Series Utility	Four-Wheel	55	Czech Republic	2011
Rumptstad Single Axle Tractor	Two-Wheel	12	Netherlands	2012
Luzhong 700 Tractor	Four-Wheel	59	China	2013
Foton Europard 820	Four-Wheel	82	China	2013
Hi Power Single Axle Tractor	Two-Wheel	13	Japan	2013
Foton Europard 824	Four-Wheel-Drive	82	China	2014
Shuhe SH 750	Four-Wheel	73.8	China	2015
Belarus 510	Four-Wheel	57	Belarus	2015
Belarus 522	Four-Wheel-Drive	62	Belarus	2015
Belarus 820	Four-Wheel-Drive	81	Belarus	2015
ZoomLion RM754-A	Four-Wheel-Drive	73.8	China	2015
New Holland TT75	Four-Wheel	75	India	2015
RD 110 DI-2T	Two-Wheel	11	Indonesia	2016
RD 85 DI-2S	Two-Wheel	8.5	Indonesia	2016
DANMAR Mini Tractor and its associated implements	Two-Wheel	6.5	Slovakia	2016
JS-800	Four-Wheel	79.1	China	2016
JS-1204A	Four-Wheel-Drive	118.2	China	2016
TS 604	Four-Wheel-Drive	59.1	China	2016
SAME Explorer 85 Special	Four-Wheel-Drive	80.2	Italy	2016
TS 804III	Four-Wheel-Drive	79.1	China	2016
Dakr Mini Tractor and its associated implements	Two-Wheel	5.5	Czech Republic	2016
PREET 9049	Four-Wheel-Drive	90	India	2017
Mahindra 6005 2WD	Four-Wheel	60	India	2017

four Standards and Test Codes awaiting approval of the Nigerian Standards Council. The draft standards are:

- Draft Nigerian Standards Test Code for Grain planters.
- Draft Nigerian Standards Test Code for Grain harvesters.
- Draft Nigerian Standards Test Code for Weights and Measures.
- Draft Nigerian Standards Test Codes for Grain Threshers.

Trainings organized by the Centre

NCAM saddled with the responsibility of mechanizing Nigerian agriculture conducted series of trainings over the years to impact the current trend of practice to farmers, tractor operators and agro-processors in the six geo-political zones of Nigeria. **Figs. 8** and **9** present the photos taken during one of the training programmes organized by the Centre.

Extension services

The Centre over the years has been involved in the fabrication and installation of NCAM equipment for adoption by some of the States in the six geo-political zones of Nigeria. Presently, these agricultural machinery and equipment have become quite reliable products that farmers in the country could rely upon for their farming and agro-processing operations. Some of the Nigerian and foreign agencies that have patronized NCAM include Food and Agriculture Organization (FAO); Agricultural Development Programme (ADP); LADMOK Company; Sierra Leone government; Federal Ministry of Agriculture and Rural Development (FMARD); Food for All International (FFAI); Rivers State; Nigerian Stored Product Research Institute (NSPRI); and Agric Input Supply, Akure, Ondo State.

Fig. 7 Wheel slip determination during field evaluation of a tractor (Source: Oni, 2011b)

NCAM's participation in agricultural shows / techno expo / trade fairs

The Centre over the years has been participating in series of agricultural shows / techno expo / trade fairs organized either at the Federal or State level. These series of exhibitions which the Centre has attended have publicized NCAM proven technologies within and outside Nigeria. The purpose of attending these events is to extend NCAM's proven technologies beyond the precincts of the Centre. The Centre has won several awards which include:

- 1st prize on "Machinery and Equipment Exhibition". Award won in May 2007 Agricultural show held in Tudun-Wada, Nassarawa State, Nigeria.
- 3rd prize on "Local Exhibitor". Award won in February 2016 Techno Expo show held in Raw Materials Research and Development Council (RMRDC), Abuja, Federal Capital Territory, Nigeria.

Technical meetings

The Centre over the years has conducted series of internally arranged seminars during their Technical Meetings held in the Centre where meaningful and laudable projects are approved for NCAM research engineers and scientists to carry out in order to assist farmers to boost food production in Nigeria. In the area of irrigation and drainage research, a preferable solution have been found to replace concrete canal lining which is extremely expensive to construct due to the recent high cost of cement in the country. A preferable alternative to concrete canal lining is the burnt cementitous clay canal lining shown in **Fig. 10** which is made from locally sourced material that is readily available, appropriate, easy to maintain and affordable.

Role NCAM played with other Agricultural Engineering Bodies in Nigeria

The National Centre for Agricultural Mechanization (NCAM) over the years has played host to series of National Executives Council (NEC) meetings held by the Nigerian Institution of Agricultural Engineers (NIAE), the Nigerian Branch of the International Soil Tillage Research Organization (ISTRO) and the Agricultural Machinery and Equipment Fabricators of Nigeria (AMEFAN). The National Secretariat of the three

Fig. 8 Participants trained on how to identify the engine component parts of a tractor

Fig. 9 Participants trained on how to couple the trailer to the tractor

Fig. 10 Burnt Cementitious Clay Channel (Source: Kasali, 2015)

bodies (NIAE, ISTRO and AMEFAN) are all domiciled at NCAM.

Publications

In Nigeria, the only way to measure research output is through research article publications. There are four of such publications in agricultural engineering namely Journal of Agricultural Engineering and Technology (JAET), Nigerian Journal of Soil and Tillage Research (NJSTR), Proceedings of the Nigerian Institution of Agricultural Engineers (NIAE) and the Proceedings of the Nigerian Branch of the International Soil Tillage Research Organization (ISTRO) where research articles published on agricultural mechanization practices in Nigeria could be found. Most research works conducted in many Universities and Research Institutions in Nigeria have more to do with Farm Power and Machinery, Soil and Water Engineering, and Processing and Storage Engineering studies.

Challenges of Agricultural Machinery Research Activities in Nigeria

Funding of Research Activities

Research activities which is a major source contributing to increased productivity in the agricultural sector has not been adequately funded by government. Most research findings originating from government established Universities and Research Institutions in Nigeria have not been properly coordinated and disseminated to farmers who are supposed to be the ultimate beneficiaries of these findings.

Ratio between Extension Agent and Farmer

As essential as the extension agent (EA) services are to agricultural productivity, no serious attention is paid to the extension services by both federal and state governments. The retired ones are not replaced and the few available are not motivated. This has hindered many research successes getting to the end users who really need them. **Table 6** presents the ratio that exists between the extension agent and farm families in Nigeria. It can be deduced from **Table 6** that the average extension agent to farm families ratios obtained for the five year periods ranged from 1:1700 to 1:3011.

Low Private Investment

Most farmers in Nigeria are smallholder farmers who are managing few hectares of land for farming operation. The output in their farm is low resulting from low return on investment. Most of these farmers are used to the traditional way of farming which involve the use of hoes and cutlasses. This has really made it difficult for farmers in the country to adopt the use of agricultural machinery in boosting their farm produce which is expected to lead to high return on investment because of lack of technical know-how, among other limitations.

More so, the agricultural research activities in Nigeria have seen low interest from the private investors. This has tactically left these research activities in hands of government unlike in developed world where it is driven by the private sector. This was due to the neglect of agriculture by the government and her inability to see agriculture as business. The role of government should be policy formulation and the creation of conducive environment for private sector participation.

Lack of Synergy between Stakeholders

This also has greatly slowed down the development of agricultural machinery research and development in Nigeria. Academic and research institutions, financial institutions, farmers, investors and other stakeholders in the sector have weak linkages and working relationship. This has resulted in the poor dissemination of breakthroughs in research to the farmers; lack of adequate information to access loan facilities, etc. This needs to be tackled through various appraisal seminars, conferences between relevant stakeholders and exhibitions/farmers field days in the sector.

Future Prospects of Agricultural Machinery Research Activities in Nigeria

Government and the Promotion of Made in Nigeria Products

The present Nigerian government has intensified effort in ensuring Nigerians embrace products that are locally made. Those into agricultural machinery development in Nigeria are not relenting in their efforts in producing these agricultural machinery and equipment for use in improving production and processing operations in the farm.

Job Creation

Nigeria has over 80% of its populace engaged in agricultural activities to earn their livelihood either directly or indirectly (Azogu, 2009). They practice agriculture without using machines. Positive government policies toward mechanization of the agricultural sector through tractor hiring schemes, production of indigenous agricultural machineries by NCAM and other institutions has made agriculture attractive to youths and encourage them in agro industries and raw materials production.

Standardizing Nigeria Manufactured Equipment

The Centre has a lot to do by sensitizing our local fabricators in ensuring standardize products come out from their workshops so that the issue of availability of spare parts would not be a problem in the future which has been identified as one of the factors militating against the growth of agricultural mechanization in Nigeria. Fabricators are to be encouraged to use materials that have strength to sustain the output of the machinery they intend to develop. NCAM also has mandate of ensuring that these fabricators conform with the required standard.

Promotion of Food Sufficiency and Security

Agricultural machinery research is a sure way of improving agricultural productivity globally. American agricultural sector was transformed to situation where one farmer fed 5 people in 1880 to another level where one farmer was able to feed 80 people in 1982 (ITF, 2012). Looking at the 70% of Nigerian population that practice agriculture, 90% of them use hand tools, 7% use animal-drawn tools and only 3% engage engine powered technologies. With 70% of the population in agriculture, there is no food self-sufficiency in the nation since mechanization is still very low at just 3% (Onwualu and Pawa, 2004). It is therefore very clear that, development of agricultural machinery will offer a veritable tool towards food security, sufficiency and exportation.

Table 6 Nigeria's Extension Agent: Farm Families ratio, 2008 - 2012

States of Nigeria	EA: farm families ratio trend				
	2008	2009	2010	2011	2012
Borno	1:1971	1:1971	NA	1:1964	1:1964
Yobe	1:1800	1:1800	1:1000	1:2472	1:2472
Bauchi	1:1300	1:1300	1:1700	NA	1:1731
Gombe	1:1350	1:1741	1:1225	1:1225	1:1225
Adamawa	1:2549	1:2459	1:1000	1:1212	1:1212
Jigawa	1:1500	1:1500	1:1389	1:2054	NA
Katsina	NA	NA	NA	1:3000	1:3000
Sokoto	NA	1:4013	1:4050	1:4050	1:4000
Kebbi	1:1600	1:3749	1:3749	1:2608	NA
Zamfara	1:1490	1:1400	1:1479	1:1944	1:1944
Kano	NA	NA	NA	1:844	NA
Kaduna	1:3000	1:3000	NA	1:3240	1:3240
Taraba	1:3200	1:3200	1:3200	1:3200	1:3200
Plateau	1:1000	1:1800	1:3038	1:3187	NA
Nasarawa	1:2313	1:3200	1:1317	1:1156	1:1368
FCT	1:1148	1:1700	1:1282	NA	NA
Niger	1:2280	1:2160	1:3000	1:2000	1:2000
Kwara	1:4025	1:3843	1:4000	1:2500	1:2190
Kogi	1:1526	1:1526	1:2160	1:1000	1:1000
Benue	1:2630	1:3640	1:1747	1:3500	1:4000
Oshun	1:3217	1:3097	NA	1:1984	1:1984
Oyo	1:500	1:500	1:3773	1:800	1:800
Ekiti	1:42	1:42	1:2750	1:3000	1:3000
Ogun	1:3711	1:3711	1:2812	1:3364	1:3364
Lagos	1:1100	1:1350	1:1612	1:1612	1:1612
Edo	1:2100	1:2100	1:3750	1:3750	1:3750
Delta	1:800	1:800	1:1559	1:1559	1:1559
Ondo	1:1500	1:1500	1:1480	1:1480	NA
Anambra	1:6048	1:3799	1:9409	1:9409	1:9409
Enugu	1:746	1:850	1:6013	1:6848	1:3081
Ebonyi	1:6046	1:1960	NA	NA	NA
Cross river	NA	NA	1:4458	1:4013	1:4721
Rivers	NA	NA	1:6748	1:6749	1:3450
Abia	1:2632	1:2952	1:2700	1:2700	1:2700
Akwa Ibom	NA	NA	1:3086	1:3086	1:2902
Imo	1:3333	1:3333	NA	1:1300	1:1000
Bayelsa	NA	NA	NA	1:10,568	1:10,568
Year average EA:FFs ratio	1:1700	1:2132	1:3385	1:2950	1: 3011

Source: NAERLS Field survey (2012)

Exporting Agricultural Machinery to Other Countries in West African Sub-Region

It is believed that any agricultural machine manufactured in Nigeria shall be exported to other countries in the sub-region that require the assistance of the Nigerian government for use in boosting their food production. Nigeria has the wealth of knowledgeable individuals in the area of agricultural machinery development both in the private and public sector who are capable of achieving this great task for the nation and continent.

Advancement in the Level of Information Dissemination

The use of modern machineries and methods of transmission of research findings and new innovations to end users is another opportunity to make exploits in agriculture. According to Reid (2011), today's increasingly automated agricultural production systems depend on the collection, transfer, and management of information by ICT to drive increased productivity.

Training of Stakeholders in Agricultural Value Chain Development

As part of NCAM's mandate, NCAM has organized several trainings cutting across farmers, tractor operators, local fabricators and agro-processors in the six geo-political zones of Nigeria. These trainings are designed to equip trainees with the current day to day practice on farming and processing operations in order to improve their performance.

Land Tenure System and the need for Increased Cultivable Land Area

Communities and individuals with big portions of land can lease part out for mechanized farming as a means of generating income and facilitating large scale farming. The present land tenure system in the country which encourages fragmentation of farmlands should be removed in order to allow more land for cultivation without much bureaucracy.

Conclusions

- Nigeria is not relenting in developing her agricultural sector through agricultural machinery research activities, although, research and development on agricultural machinery and equipment in Nigeria is progressing at a space slower than expected.
- The agricultural sector has the potential for national development through job creation, food security and also improving GDP through foreign exchange earnings, if properly mechanized.
- The Nigerian economy is a robust economy with a sustained growth potential that is driven by significant domestic demand in various sectors. The present demand for agricultural machinery is limited by the low purchasing power of farmers and currently does not ensure the simple replacement of existing machines. Opportunities abound in the agricultural machinery market for both imported and local manufacture as Nigeria continues its move to diversify her economy especially through agriculture.

REFERENCES

Adekoya, L. O. 1990. Agricultural and food processing machinery manufacture in Nigeria: Prospects and potentials. Proceedings of the Annual Conference of the Nigerian Society of Engineers, 1990: 162-167.

Ajibola, F. and T. Zalla. 2007. Value chain study of small-scale agricultural mechanization. Monograph Series No 9.

Alabadan, B. A. and Y. Yusuf. 2013. Tractor hiring schemes in Nigeria: A case study of Federal Capital Territory (FCT). African Journal of Agricultural Research, 8(47): 5962 - 5966. DOI: 10.5897/AJAR09.149.

Azogu, I. I. 2009. Promoting Appropriate Mechanization Technologies for Improved Agricultural Productivity in Nigeria: the Role of the National Centre for Agricultural Mechanization. Journal of Agricultural Engineering and Technology (JAET), Special Edition on Mechanization of Agriculture in Nigeria, 17(2):1-10.

CBN. 2010. Central Bank of Nigeria Annual Report for 2009. arp-2009-13. Abuja. p.118.http://www.cenbank.org/OUT/2010/PUBLICATIONS/REPORTS/RSD/Link%20Files/ART%20 TWO.pdf

Chauvin, N., F. Mulangu and G. Porto. 2012. Food Production and Consumption Trends in Sub-Saharan Africa: Prospects for the Transformation of the Agricultural Sector. UNDP Working Paper for African Human Development Report, pp. 1-74.

Daudu, J. O. 2011. Marketing of Agricultural Machinery in Nigeria: Challenges and Prospects. A Lead Paper presented during the NIAE Conference held in Ilorin, Kwara State. Pg. 43-51.

FAO. 2005. Contribution of Farm Power to Small-holder Livelihoods in Sub-Saharan Africa. Natural Resources Management and Environment Department. FAO, Rome.

FAO. 2011. Food and Agriculture Organization Statistics Division, Rome.http://faostat.fao.org/site/576/DesktopDefault.aspx?PageID=576#ancor

Federal Ministry of Agriculture and Rural Development. 2016. Demand and Supply across Key Crops and Activities. Online: www.fmard.gov.ng

Industrial Training Fund (ITF). 2012. Issues in Mechanized Farming in Nigeria by Consultancy,

Research and Information Technology department (CRIT).
Kasali, M. Y. 2015. Evaluation of the Potential of some Local Materials for Irrigation Canal Lining. Unpublished Ph.D. thesis of the Agricultural and Biosystems Engineering Department, University of Ilorin, Ilorin, Nigeria.
Lipton, M. 2012. Learning from Others: Increasing Agricultural Productivity for Human Development in Sub-Saharan. United Nations Development Programme, Regional Bureau for Africa. http://web.undp.org/africa/knowledge/WP-2012-007-Lipton-Agriculture-Productivity. pdf.
Mehta, A. and A. C. Gross. 2007. The global market for agricultural machinery and equipment. www.allbusiness.com/economy-economic-indicators/economic-indicators/5497022-1.html.
National Agricultural Extension and Research Liaison Services (NAERLS). 2012. Executive summary of Agricultural performance survey of 2012 wet season in Nigeria. October
Nigerian Investment Promotion Commission, 2016. Agriculture: General Overview of the Nigerian Agricultural Sector. Available online on www.nipc.gov.ng.
National Population Commission, 2017. Nigeria population growth Forecast. Available: npc.gov.ng.
Oni, K. C. 2004. The roles of Research Institutes, Government, and the Private Sector in Maximizing Social and Economic Benefits from Public Investment in Research Development (R&D) in Nigeria: The Way Forward. Invited paper presented at IPG-sponsored Workshop on commercialization of RED Results of FIRRO, NBRRI PRODA, SEDI – E, SEDI – M and NCAM, Abuja, 29th June, 2004; 35pp.
Oni, K. C. 2005. Socio-Economic Impact of Tractor Assembly Plants in Nigeria. Paper presented at the Commissioning of Tractor Assembly Plant of Mahindra and Mahindra Limited in Nigeria at Ibadan, Oyo State, 15th September, 2005.
Oni, K. C. 2011a. Tillage in Nigerian Agriculture. Proceedings of the Nigerian Branch of International Soil Tillage Research Organization held at the University of Ilorin, Ilorin, Kwara State, Nigeria from 21-24 February, 2011.
Oni, K. C. 2011b. Man, Machine and Food Insecurity. The Ninety-Fourth Inaugural Lecture of the University of Ilorin, Ilorin, Nigeria. University Press.
Onwualu, A. P. and N. P. Pawa. 2004. Engineering infrastructure for the manufacture of agricultural engineering machines in Nigeria: The role of NASENI. Proc. 2nd International Conference of the West African Society of Agricultural Engineering, Kumasi, Ghana. 20-24 Sept. 2004.
Reid F. J. 2011. The Impact of Mechanization on Agriculture. Agricultural Information technology, The Bridge National Academy of Engineering. Vol. 41, No. 3, fall 2011. pp.22-29.
Sekunmade, A. 2009. The effects of petroleum dependency on agricultural trade in Nigeria: An error correlation modeling (ECM) approach. Scientific Research and Essay, 4 (11): 1385 - 1391.
www.export.gov. Accessed 21/03/2017.
www.geohive.com. Accessed 21/03/2017.

■■

Status of Research on Agricultural Machinery Development in Nigeria: A Case Study of Cassava Tuber Processing Machineries

by
M. C. Ndukwu
Dept. of Agricultural and Bioresources Engineering
Michael Okpara University of Agriculture
Umudike
P.M.B 7267Umuahia Abia state
NIGERIA
ndukwumcu@gmail.com

S. N. Asoegwu
Dept. of Agricultural and Bioresources Engineering
Federal University of Technology
Owerri
NIGERIA

I. E. Ahaneku
Dept. of Agricultural and Bioresources Engineering
Michael Okpara University of Agriculture
Umudike
NIGERIA

Abstract

This paper briefly discusses research and development activities in agricultural machinery development in Nigeria placing emphasis on cassava tuber processing machines. Effort from the various research institutes and local fabricators involved in the development of cassava processing machineries were also highlighted. It is worthy to mention that these organizations are also involved not only in cassava tuber processing research but also in other agro-production machine research. Generally, research in agricultural machinery development in Nigeria is moving in an uncoordinated way with the tendency to duplicate efforts as shown in cassava tuber processing machines. This is by extension also in other agro-machines in Nigeria. This paper is highlighting the challenges facing research activities and offered suggestions on ways to address them.

Keywords: Farm machinery, post-harvest machines, cassava peeling, tuber crops

Background

The Nigerian agricultural sector is currently driven by the demand for food with less emphasis on cash crops. This was the reverse of the 1960's when both food and cash crops were at the center of the country's economic growth, contributing to the GDP of about 54.7% in the 60's and 40.3% between 2000 and 2009 (NBS, 2010). The country's GDP further decreased to about 40% in 2011 but grew by 4.0% in 2012 (Ndukwu *et al*., 2015). This is the fall out of crude oil discovery in Nigeria which has dominated the Nigerian economy, although agriculture still constitutes the highest employer of labour in the country. However, serious progress has not really been made to increase agricultural productivity as the Nigerian agricultural sector is still dominated by many small scale farmers using hand operated tools. Generally agricultural machinery development in particular lacks a clear master plan in the Nigerian Agricultural Policy but lumped together with other units of agricultural production. The policy which was primarily designed to mobilize people into agriculture to reduce hunger has no clear roadmap to fully transform agricultural practice from low level of mechanization to the highest level through the introduction of machines. This can be revealed from the work of Mrema and Odigboh (1993) and Gert (1998) where about 10% of agricultural power sources are from mechanized sources. Twelve years down the line, things have not changed much over time as the number of tractors available in Nigeria in 2011 was about

30,000 in a country of over 150 million population (Abdulla, 2011). However there are considerable variations among regions with the belief that the northern part of the country has a greater share of these tractors and machines. Yusuf (2011) reported that these machines are found in the hand of rich and powerful individuals and government agents. These are mostly imported and used for production and processing mostly for grains like maize and sorghum. Therefore, the useful life of these imported machines is low as these frequently break down.

The challenge facing research and development of agricultural machines is in the development of locally adaptable machines to meet the need of our peasant farmers in the country. The National Centre for Agricultural Mechanization (NCAM), International Institute of Tropical Agriculture (IITA), Project Development Agency (PRODA), universities, private individuals and organizations are at the fore front of tackling this challenge. These institutions have developed tillage, planting, harvesting and processing machines. However processing equipment and machines are of much demand. Therefore, focus is on processing machines which can come in different capacities and cost range and can suit various grade of farmers with appreciable level reduction in time spent in processing. These processing machines can compete favourable with imported machines at a cheaper cost. These developed machines are available for the different types of crops grown in Nigeria. These are wide spread for almost all the crops available in Nigeria which includes grain and tubers. However, one of the major stable crops where research and development (R&D) activities have thrived in Nigeria is in the area of machinery development for cassava tuber processing. Though, some challenges still exists most especially in the area of peeling due to response of tuber formation to soil type, obstacles, available nutrient and variety (Odigboh, 1976).

Cassava (*Manihot utilisima*) originally from South America is the most important food crop in Nigeria after rice and maize with over 600 million people depending on it across Africa, Asia and Latin America (FAO, 2002). Nigeria is the largest producer of cassava tuber in the world with about 230 million tons produced in 2008 (Kolawole *et al*., 2010). Cassava tuber is locally consumed in Nigeria as fufu, gari, tapioca or as cassava flour. Its products and byproducts are utilized in the industry and as livestock feeds (Egbeocha *et al*., 2016). Remarkable progress has been made in developing improved varieties of cassava, especially by the National Root Crop Research Institute (NRCRI), Umudike Abia State and the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State. Now we have high yielding varieties of cassava which can mature as early as 6 months and naturally fortified with β- carotene. Processing the large tonnes of cassava produced in Nigeria to a targeted product for local consumption or export depends to a greater extent on the machinery inputs available. Therefore, the overall goal of cassava processing in Nigeria through agricultural mechanization practice is to enhance productivity, add value to products, reduce losses and drudgery, increase turnover of product which can increase house hold income and improve their overall welfare.

Research in Cassava Processing Machineries in Nigeria

Cassava processing has received considerable attention in Nigeria due to increased demand and government policy. A policy was created in Nigeria for bread producers that involve adding 10% of cassava flour to wheat flour in the making of bread. Farmers look up to the agronomist to provide them with improved varieties; they look up to engineers to help them solve complex issues of value addition by providing appropriate machines and equipment. This challenge has been undertaken by indigenous manufacturers, research institutes, universities and similar higher institutions. These facilities have designed and developed hand tools, manual, electric and engine operated machines and equipment for processing cassava tuber and other crops. Egbeocha *et al*. (2016) stated that all the unit operations involved in cassava processing have been successfully mechanized in Nigeria with the exception of cassava peeling. The reason being that existing cassava tuber peelers in Nigeria still suffer loses of up to 8-42%. Their study also revealed that existing designs include single and double gang peelers, spring loaded assembly, fixed outer peeling drum peeler machine, rotary brush peeler, double action-self-fed cassava peeling machine, automated peeling cassava machine, knife-edged automated cassava peeling machine and abrasive rotary drum peeler. None of these designs have been able to completely peel cassava as a result of the irregular shape of cassava. Beside this, the remaining part of the skin is manually removed with knife after the peeling machine has done its part.

Research and Development Activities into Cassava Processing Machines in Nigerian Research Institutes

NCAM (National Centre for Agricultural Mechanization)

The NCAM is a research institute under the Federal Ministry of Agriculture and Rural Development. It is located in Ilorin, Kwara State of Nigeria. The institute is saddled with the responsibility to research into different agricultural machines with emphases in solving the local needs. NCAM has conducted extensive research into cassava production and processing machines that include hand and machine operated tools. NCAM have developed cassava lifter, manually operated cassava peeling tool, cassava grater, cassava chipper, cassava chipper, etc. Some of these machines and equipment are shown in **Fig. 1**.

IITA

The IITA stands for the International Institute of Tropical Agriculture. It is located in Ibadan, Oyo State of Nigeria. The institute conducts research mainly on tropical crops. Apart from dealing with the agronomy aspects of these crops, the institute also deals with their processing aspect. The Institute has been heavily involved in the development of small and medium scale cassava processing equipment and machines. IITA have developed cassava peeling tool, cassava grater, cassava mini grater, manual disc grater, cassava chipper, etc. The collaboration of IITA with the Federal University of Technology, Akure (FUTA) in 2005 brought the development of a single and double gang hand-fed cassava peeling machine which peels by using a rotary brush. IITA also collaborated with FUTA, FATAROY, Ibadan and A&H, Iwo to develop a 1,000 kg/h capacity cassava peeler which recorded 8% tuber flesh loss during testing. Some of the cassava processing machines and equipment developed by IITA are shown in **Fig. 2**.

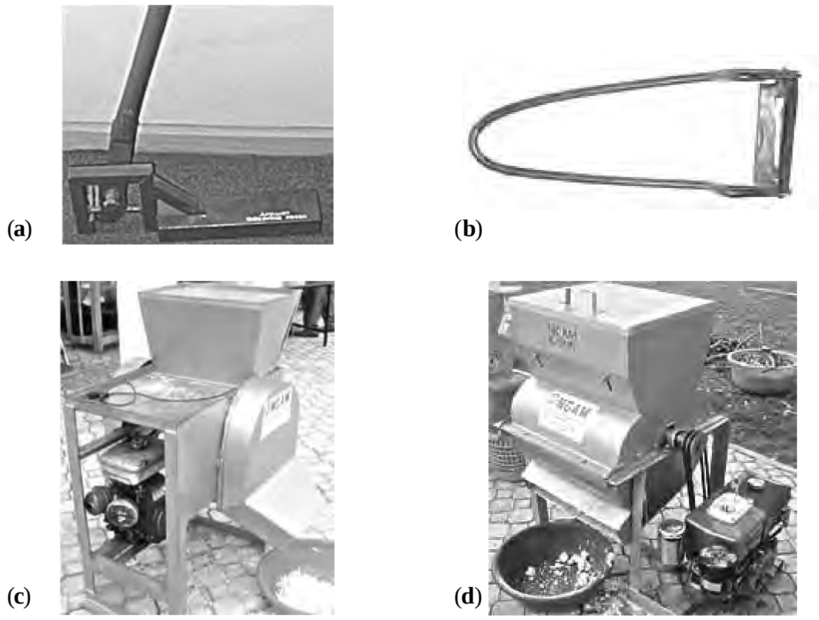


Fig. 1 Some cassava processing machineries developed by NCAM
(**a**) cassava lifter, (**b**) manually operated cassava peeling tool, (**c**) cassava chipping machine (**d**) cassava grater (Source: IITA, 2005)

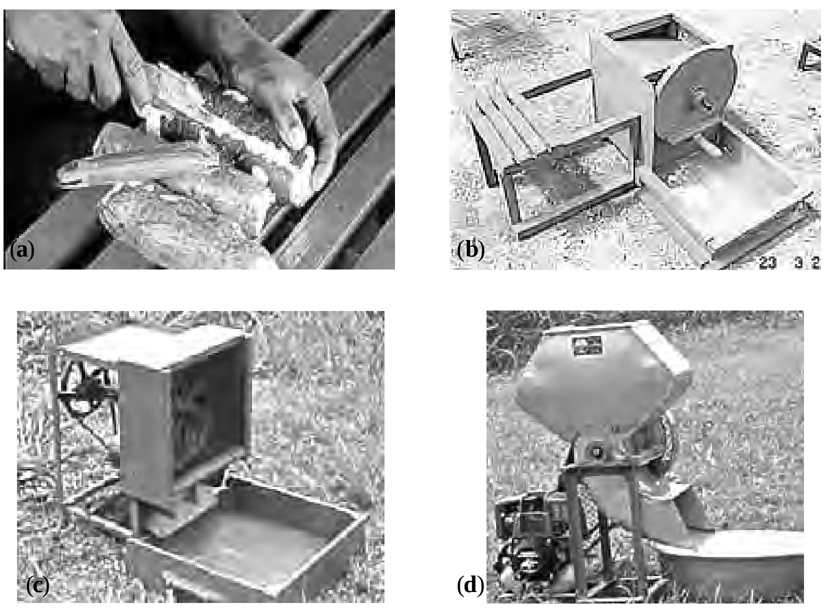


Fig. 2 Some cassava processing machineries developed by IITA
(**a**) manual cassava peeler, (**b**) manual disc grater, (**c**) cassava power chipper (**d**) mini cassava grater. (Source: IITA, 2005)

PRODA

The PRODA stands for Project Development Agency. It is located in Abakpa-Nike, Enugu state of Nigeria. It is a research institute that is involved in the development of machines and equipment in Nigeria. PRODA has developed self-action cassava peeler, double barrel cassava grater, self-action grater, rotary sieve and fryer, kero-heated oven/dryer or industrial electric dryer for cassava chips, microniser with cyclone bagging hopper, depulping, bagging, and manually operated cassava tuber harvester. Some of these machines are shown in **Fig. 3**.

ARCEDEM and FIIRO

The ARCEDEM stands for African Regional Centre for Engineering Design and Manufacturing. It is located along Ibadan -Osogbo Highway, Oyo State of Nigeria. The FIIRO also stands for the Federal Institute of Industrial Research, Oshodi. It is located in Lagos state of Nigeria. Both institutes are into

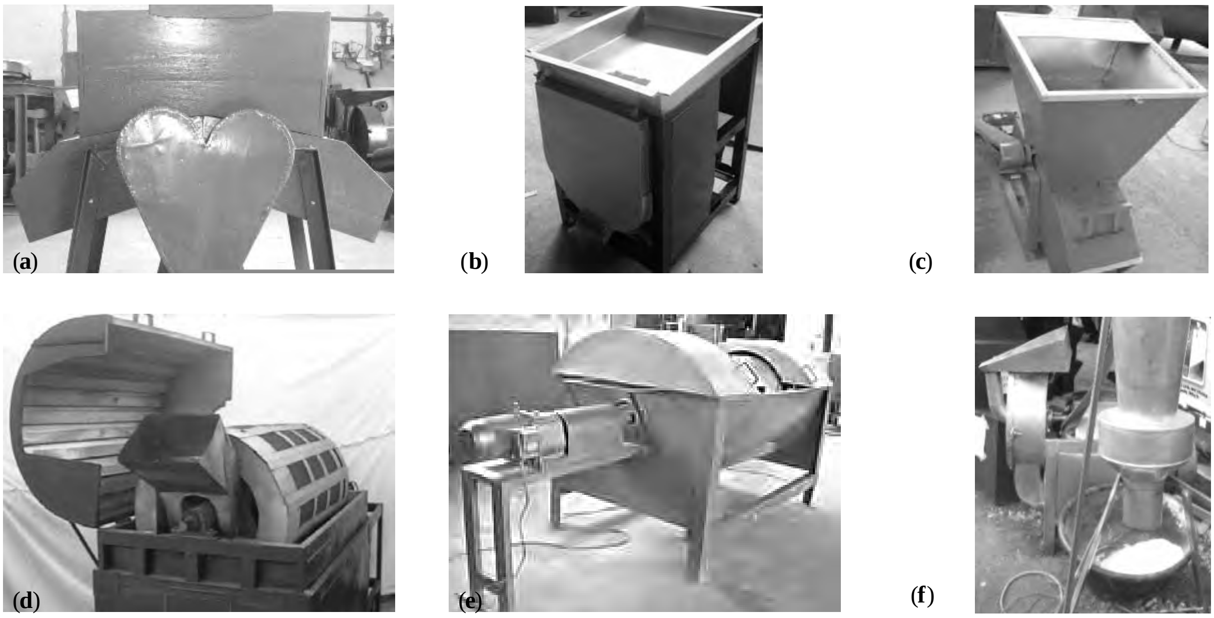


Fig 3 Some cassava processing machineries developed by PRODA
(**a**) double barrel grater (**b**) chipping machine (**c**) single barrel grater (**d**) rotary sieve (**e**) self-action peeler (**f**) microniser
(Source: www.proda-ng.org)

machinery development for solving the local needs of farmers. Because of the stable nature of cassava and its wide consumption, its processing has become of great concern to almost all research institutes in Nigeria. These centres have developed cassava grater powered by a petrol engine, manually operated cassava chipper which can also be powered by a 3 hp gasoline engine. Some of the machines are shown in **Fig. 4**.

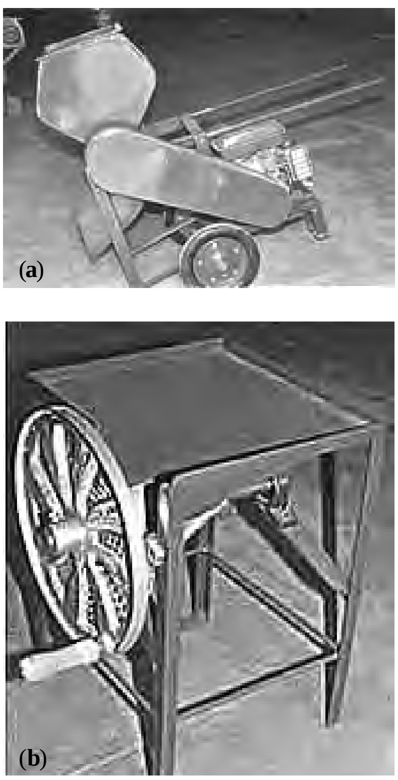


Fig. 4 Some cassava processing machineries produced by ARCEDEM
(**a**) cassava grater (**b**) manual chipper

Local Fabricators

Several indigenous companies are also involved in machinery development in Nigeria. The user of these machines gets their machines mostly from these local fabricators. This has been successful because these companies are closer to the farmers and the bureaucratic bottlenecks experienced in acquiring these machines from research institutes or government agencies does not exists. Some of these local fabricators are Addis Engineering Limited who is known for developing 1 ton/h capacity cassava washer, chipping machine; Starron Nigeria Limited who is known for developing 150 kg/h capacity cassava grater; Niji-Lukas Nigeria Limited who is known for developing 300 kg/h capacity electric grater; Nova Technologies who is known for developing grater, 1.2 ton/h chipping machine; OCTEC Limited who is known for developing cassava rasping machine; KEDEY Engineering Metal Fabrication who is known for developing grater; OGMEC Nigeria Limited who is known for developing grater; Obincowelds Construction Co. Nigeria Limited that is known for developing grater; Adebash Manufacturing Company that is known for developing 2 ton/h capacity grater; Edozie Construction Company that is known for developing roller cassava grater; B & T Ventures that is known for developing grater, chipping machine; Intermech Engineering Limited that is known for developing grater; DOALA AGEH (NIG.) LIMITED that is known for developing 500 kg/h capacity chipping machine; FATAROY Steel Industry Company that is known for developing 5-roller improved cassava peeling machine; and HANIGHA Nigeria Limited that is known for developing chipping machine.

Universities, Polytechnics and other Higher Institutions of Learning

Higher institutions of learning in

Nigeria that are notably involved in the development of cassava processing machineries include Federal University of Technology, Akure (FUTA), University of Nigeria Nsukka (UNN) and the Federal University of Technology, Owerri (FUTO). Some of the cassava processing machines developed by individuals in these institutions include self-fed cassava peeling machine (Olukunle and Akinnuli, 2012), electrically operated cassava peeling and slicing machine (Aji *et al*., 2016), cassava peeler with two opposing abrasive surface drums, cassava peeling tool as a rotating cylindrical drum with a blade, cassava peeler with continuous tuber feeding systems, cassava peeler with stationary outer abrasive drum and a rotating inner abrasive drum, cassava peeler with two chambers joined together as a single machine (Egbeocha *et al*., 2016), all action cassava (**Fig. 5**) dewatering, pulverizing and sifting machine (Kolawole *et al*., 2012), continuous-process gari frying machine (Odigbo and Ahmed, 1984), cassava pulp dewatering machine (Olusegun and Ajiboye, 2009), cassava milling machine (Nwaigwe *et al*., 2012), automated gari fryer (Ajayi *et al*., 2014), pulverizing and sieving machine for dewatered grated cassava (Mohammed *et al*., 2015).

Fig. 5 All action cassava processing machine (Kolawole *et al*., 2012)

Challenges in Machineries R&D activities in Nigeria

The major challenge facing R&D activities in the area of cassava machineries development in Nigeria is lack of fund and inadequate basic infrastructure for their fabrication. There is little or no coordination between public, private organizations and farmers in research effort and implementation. Transfer of modern technology to small-scale farmers, is by engaging contractors who are usually not researchers or engineers rather than using the researchers themselves. This has largely proven unsuccessful. Most private industries are more interested in the finished product which has been made easy by global integration through importation resulting in competitive market. Although these establishments may not be expected to establish R&D section but collaboration with research institutions should be the key. This is where government can come up with policies and financial incentives like research grants and waivers. There is no clear government policy to fund research with the exception of the educational tax fund (ETF). However, assessing the fund by credible researchers has been bogged down by government bureaucracy and internal politics of various institutions. Improving on existing research efforts is a problem in Nigerian higher institutions because of lack of fund and infrastructure. Seasonal demand of machines is a challenge to producer due to non-practice of all the year round agriculture with irrigation in some part of Nigeria. Generally, farmers in Nigeria depend on rain for crop production. Therefore, processing and other machine acquisition and utilization follows the same trend. High tariffs when components for local manufacturing are imported stalls R&D activities, too. A lot of opportunities abound in the adoption of farm machines but cost and other factors puts off ownership by small farm holders which is a major challenge. Therefore, the farmers will need industrial clusters where this machine can be assembled for pay as they use or user hire service can be obtained. Government can also come in with financial incentives like power purchase agreements and feed-in tariff.

Conclusions

Research on machinery development in Nigeria using cassava processing machines as a case study is progressing in an uncoordinated way. R&D activities in cassava processing focus more on grating and chipping of cassava, leaving out the other unit operations like peeling of cassava. Both government and private institutions are involved in R&D activities especially in cassava processing but there is the need to harmonize these research activities to avoid duplication of efforts. Gradually, challenges in cassava peeling are being overcome with new designs like the FATAROY's cassava peelers and its adaptations. Field demonstration of new machine will encourage adoption and technological transfer. Setting aside a pool of resources purely for agro-machine research will reinvigorate R&D activities in this area.

REFERENCES

Abdullah, A. 2011. Investment opportunities in Nigerian agricultural sector. 1st West Africa Islamic Investment Forum. Tahir Guest Palace, Kano, Nigeria. 28th February-1st March, 2011.

Ajayi, O. O., O. J. Olukunle and M. Dauda. 2014. Performance Evaluation of an Automated Gari Fryer. The International Journal of Engineering and Science .3 (2): 39-46.

Aji, S. I., M. U. Emmanuel, S. A.

Abdulrahman and O. F. Franklyn. 2016. Development of an Electrically Operated Cassava Peeling and Slicing Machine. Arid Zone Journal of Engineering, Technology and Environment, 12:40-48.

Egbeocha, C. C., S. N. Asoegwu and N. A. A. Okereke. 2016. A Review on Performance of Cassava Peeling Machines in Nigeria. Futo Journal Series, 2 (1) 140-168.

Food and Agricultural Organization (FAO). 2002. Agricultural Statistics, Food and Agricultural Organization of the United Nations, Rome, Italy.

Gert, V. M. 1998. Motorized soil tillage in West Africa. A survey on the current use and consequences of tillage done with engine-driven machinery. Food and Agricultural Organization of the United Nations, FAO Regional Office for Africa, Accra, Ghana.

International Institute of Tropical Agriculture (IITA). 2005. Integrated cassava project. Retrieved from http//: www.cassavabiz.org/postharvest/1_posthvst_0.1htm on 15th May, 2017.

Kolawole, O. P., L. A. S. Agbetoye and A. S. Ogunlowo. 2010. Sustaining world food security with improved cassava processing technology: The Nigeria Experience. Retrieved from www.mdpi.com/journal/sustainability on 12th of May, 2017

Kolawole, O. P., L. A. S. Agbetoye, A. S. Ogunlowo, L. Sanni and A. Adebayo. 2012. Innovative Development of Cassava Processing Machine as Solution to Crisis against Agricultural Systems. Conference on International Research on Food Security, Natural Resource Management and Rural Development. Tropentag 2012, Göttingen, Germany September 19-21, 2012.

Mohammed, A., A. B. Hassan and K. C. Bala. 2015. Fabrication and Performance Evaluation of a Pedal Driven Pulverizing and Sieving Machine for Dewatered Grated Cassava. American Journal of Engineering Research, 2, 146-152.

Mrema, G. C. and E. U. Odigboh. 1993. Agricultural development mechanization in Africa: Policy perspectives. Network for Agricultural mechanization in Africa Newsletter 1(3): 11-50.

National Bureau of Statistics (NBS). 2010. Nigerian gross domestic product report issue 4. Quarter 4.

Ndukwu M. C, A. A. Akani, K. J. Simonyan. 2015. Nigeria's grain resource structure and government sustainable policy: a review. Agricultural Engineering International: CIGR Journal, 17: 441-457.

Nwaigwe, K. N., C. Nzediegwu and P. E. Ugwuoke. 2012. Design, Construction and Performance Evaluation of a Modified Cassava Milling Machine. Research Journal of Applied Sciences, Engineering and Technology 4: 3354-3362

Odigboh, E. U. 1976. A cassava peeling machine: development, design and construction, Journal of Agricultural Engineering Research, 21; 361-369.

Odigboh, E. U. and S. F. Ahmed. 1984. Design of a Continuous-Process Gari Frying Machine. Nigerian Journal of Technology, 8: 25-33.

Olukunle, O. J. and B. O. Akinnuli. 2012. Performance Evaluation of a Single Action Cassava Peeling Machine. Journal of Emerging Trends in Engineering and Applied Sciences 3(5): 806-811.

Olusegun, H. D. and T. K. Ajiboye. 2009. The design, construction and testing of a vertical squeeze cassava pulp dewatering machine. International Journal of Engineering and Applied Science. 2(1): 27-43.

www.proda-ng.org. Accessed on 12th March, 2017.

Yusuf, D. D. 2011. Role and challenges of agricultural mechanization in meeting the needs of tomorrow's agriculture in Nigeria. Proceedings of the 11th International Conference and 32nd Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE Ilorin 2011), October 17-20, 2011, Ilorin, Nigeria.

■■

Mechanizing Nigerian Agriculture for an Improved Economy: A Case Study of Niji Group

by
Kola L. Adeniji
10, Kufisile Street, Niji Lukas B/Stop,
Isheri Round About
Off LASU-Isheri Road, Isheri-Idimu
Lagos
NIGERIA
adeniji@nijigroup.com

Introduction

Nigeria is the world most populous black nation, accounting for over 15% of Africa's population. The nation shares half of Africa's arable land mass, yet imports almost 70% of its food products.

Nigeria has a land mass of about 98 million hectares, out of which 83 million hectares are suitable for cultivation (Ashaye, 1983; Oni, 1996; FMA, 2001; EEPC, 2003). Though, 39 million hectares of arable land has been cultivated, the lack of adequate agricultural machineries and agro processing equipment is undermining the inputs of smallholder farmers and agroprocessors in keeping up with the food demands of this irrepressibly rising population.

In August 2016, a special news column was featured on Vanguard Newspaper in respect of a meeting held by the Agricultural Research Council of Nigeria (ARCN) which reported that Nigeria spends over $3 billion USD on the importation of 3 food items, namely wheat, rice and sugar. Nigeria is still the largest importer of rice. Beyond the great economic losses witnessed in Nigeria today, food insufficiency is already contributing majorly to social instability.

The productivity of farmers is very low. For instance, the average harvest per hectare of cereal is 1,438 kg/ha. Between 2004 and 2008, the average harvest per hectare of cereal has been 1,438 kg/ha. This low yield would have been improved by 50% with appropriate mechanization. India is a practical example, how mechanization is creating resilience and fast economic pace for its Agricultural sector. The demand of farmer's up-scaling production has also sparked local machineries manufacturing.

Agriculture is seen as an obvious economic growth for the African continent. For instance in Nigeria, agriculture contributed over 33% to the nation's GDP in 2005 and employed 30% of the nation's workforce in 2010. However, the World Bank 2016 Report shows that the contributory index of agriculture to the GDP of the nation has dropped to 12 (http://wdi.worldbank.org/table/4.2#). This can be attributed to lack of appropriate government policies that gave room for discouraging scenarios for private investors which created great lethargy in the Oil Palm (1950-1982), Groundnut pyramid (1919-1970) and Rubber (1894-1957). Most of these great losses occurred within the period when oil was discovered around 1952. The lack of economic sensitivity was the major cause.

Presently in Nigeria; lots of opportunities are slipping off the hands of the nation. The nation still imports as much food that it produces. For instance, Nigeria is the world largest producer of beans. However, a recent report by the National Biotechnology Development Agency (NABDA) shows that the nation spends over N10 billion annually for the importation of beans to meet up with the 250,000 tons of beans. (https://www.dailytrust.com.ng/news/business/nigeria-beans-imports-hit-n10bn-annually-nabda/184344.html).

According to World Bank, the average African farmer struggles to earn less than $2 US Dollar per day. Human efforts and the use of hand tools are still as high as 90% of the total farm power. For instance, one tractor is allocated to 0.2/100 sq.km, which is far below the FAO recommendation of 1.5/100 sq.km, where nations such as Thailand, China and some African countries are using an average of 3 tractors per 10,000 hectare of farmland. This situation greatly affects the productivity of the nation's smallholding farmers and makes them to be better contributors to the economy.

A survey was conducted by the Federation of Indian Chambers of Commerce (FICC) which showed how mechanization has transformed the Indian Agricultural sector. The report which is a lead work by the equipment manufacturers shows that India has succeeded within a space of 53 years to have successfully implemented 75% of agricultural local economy policies. The nation currently uses one tractor with full implement per 30 hectare of farmland on the average. Their GDP is as high as 14% from Agriculture and remains the largest manufacturer of tractors and modern farm implements in the world. In the same vein, African nations are still battling with mechanization crisis and failed government policies. Right from 2004 till this present moment, African countries have made decisions to transform their agricultural sector, but most of them failed due to lack of consistency. For instance, the Democratic Republic of Congo imported 920 tractors with several range of farm implements but had issues arising from inappropriateness of choice of implements and sales after services. Mali also experienced similar challenge in 2006. Similar incidence was witnessed in Nigeria in 2008; however, all the plans of government to set-up tractor assembling plants never saw the light of the day. This resulted in massive failures.

One thing that is not consistent about Nigeria agricultural reforms is the lack of firm policy and strategy framework. Government commitment is low. Nigeria currently losses over $11 billion USD to food importation in its processed and raw food form due to insufficient local supply of major food constituents in the country.

Niji Farms and Allied Services Limited which is a subsidiary of Niji Group due to her tremendous achievements over the years in adopting mechanized farming and value-addition tends to present a paper that discusses the pathway to harness the unlimited potentials for us as a nation. This paper also presents a discussion on how the nation can retrace her path to developing the appropriate policy framework to turn this huge amount of expenditures that can possibly be turned to forming over 43% of the annual budget, instead of acute reliance on crude oil. Agriculture is a goldmine. This paper will be divided into two major areas as contained in sections 2 and 3 which can possibly lead to the transformation of the nation's agricultural sector.

Benefits of Mechanization and Value-Addition

There are enormous benefits in mechanization and value-addition. Agriculture is responsible for over C$111 billion CAD of the Canadian economy. The export alone from agricultural produce and processed food accounted for 16% of the GDP and generated almost three times the Nigerian 2017 budget. This is a massive economy input. These amazing results when the nation became purposeful in taking agriculture as one of the key components in its national development agenda. The advantages include:

Production Efficiency

To define how Nigeria is still struggling with growth in Agriculture, what is referred to as smallholder farmer in Thailand are the Agribusiness owners in Nigeria. This was made possible through mechanization. Mechanization reduces labour intensiveness of the farming process and makes the farmer more productive.

The average Thailand smallholder farmer can do as much as 2 hectares per day. In Nigeria, The cultivation process alone can take up to 30 days with external supports. This implies that the farmer has wasted 28 days to cultivation alone. It also means that the 28 days germination has been lost. These productive hours would have been spent on other activities on the farm. The reverse is the case for nations such as India where the average smallholder farmer do as much as 15 hectares per day.

A special survey conducted to evaluate the performance of smallholder farmers in African countries and India shows that the average smallholder farmers in India use less than 20% of human power in all its farm operations against 90% of African farmers. The production efficiency is wide apart and the yield difference for the African farmer does not always justify the labour input.

Volume is Key

Hoe at best can only make a living. Vibrant economies adopt intelligent ways of labour. There is little a farmer could do with hoes and cutlasses. From the foregoing analogy, with a hoe, a smallholder farmer can only do much to plant 2 hectares of cassava in a month; and because of labour intensiveness, the business would always deliver low yield. The tillage and land preparation would not be adequate. No farmer can make a meaningful living by earning less than $2 dollar per day.

Volume is a key factor that mechanization supports. It significantly drops the overhead and makes produce to be available at a reduced rate. Niji Farms and Allied Services Limited currently, engage seamless mechanized operations across its 5000 acres of cassava farm (**Fig. 1**).

Fig. 1 Land preparation ongoing at Niji Farms (Subsidiary of Niji Group)

This makes the farm to produce 1 ton of cassava tubers with less than $15 USD. This enhances the company's competitiveness in the market.

More Value

Crude is cheap. Nothing in its raw state ever commands real worth. It takes not less than 12 months to produce 30 tons of cassava from one hectare of cassava farm. The same is processed within 6 hours. While the raw cassava is sold at about N15,000.00 to N20,000.00 per ton, the value-added product (VAP) is priced for N50,000.00 ($2.8 US = 1,000 N). A simple arithmetic to establish the profitability with respect to the production cost. The VAP is 50% higher than the raw materials.

Value-addition brought out its real value. This means that Nigeria is losing a huge amount of money to lack of value-addition. The same is applicable to the petroleum sector and all other raw materials. For example, from our farm records, it takes two days for a smallholder farmer to get cassava planted on half hectare cassava farm (**Fig. 2**). The same will take 30 minutes for a mechanical planter to do. In a similar analogy, it takes a whole day for a smallholder farmer to harvest 1 ton of cassava tuber. It takes 30 minutes for a mechanical harvester to do the same amount of work.

There are 10 products already discovered in cassava today, ranging from cassava flour, fufu, chips, glucose, starch gel, animal feeds, etc. But in its crude state, a ton of cassava can only be sold for N15,000.00, where even the peels can be sold for N70,000.00 per ton.

Approaches to Effective Mechanization and Value-Addition

Scalability

Economic growth can be jump-started; however, a particular scale must be maintained to enable for growth to be measured. Economies do not grow overnight. It takes consistency and commitment. One of the major challenges in our nation quest for industrialization is inappropriate startups – large scale facility without sustainability measures. Therefore, when challenges of this nature arise, it is difficult to maintain or sustain progress. At Niji Group, our progress has been consistent for the past 27 years. Until we identify a pertinent need for expansion we are satisfied where we are. The company began with manufacturing of local agricultural machineries and agro processing equipment (**Fig. 3**). From there, there was opportunity to add value to local products, the company identified cassava as one of the most consumed local staple food, and thus food processing became part of it. However, the availability of raw materials was a major concern, thus the company entered into farming and has been able to grow from 20 acres of farmland to over 5,000 acres of farmland today, which is also expanding to another 10,000 acres of farmland reputed as the largest most efficient cassava farm in Africa. Mechanization is doing much for the farm. The company has 1 bulldozer, 1 pay loader and 6 tractors with their complete implements.

Local Ingenuity

Niji-Lukas Nigeria Limited, a subsidiary of Niji Group fabricates over 90% of Niji Foods' entire integrated cassava processing plants that have a processing capacity of 100 tons per day. Niji Foods is also a subsidiary of Niji Group. It is good enough to establish that no nation can grow beyond the inputs of its local ingenuity.

India imports less than 5% of all the components that goes into the production of its tractors. Majority of the work is locally done and sourced locally.

Industrialization is fuelled locally. Local ingenuity must be encouraged. Every nation builds technologies based on their local demands. Where the needs of the people had been satisfied, they make room for a secondary market – exports. For instance, engines are climate sensitive and the same goes with the performance of tractors.

This is the reason why appropriate technological adaptation is very important where adoption is necessary.

Appropriate Technological Adoption (ATA)

Straight copy will do more harm than good. Technological adaptation demands proper study of the components that have gone into the building of the technology and why it was designed that way and also how has geography influenced the design.

Fig. 2 Niji Farms (Subsidiary of Niji Group) Cassava Plantation

Fig. 3 ITL Sonalika Brand of SKD Tractors assembled by Niji Tractors (Subsidiary of Niji Group)

Fig. 4 Niji Institute of Sustainable Agriculture (Subsidiary of Niji Group) Campus

This is the pathway to China's fastest economic growth. China engages in technology remodeling, which is a fast way to development. They study and copy the principles, use their own designs and methods.

For instance, over 90% of Nigerian factories failed and shutdown after 3 years of operation. The reason according to the survey exercise carried out was that these factories were always too bulky for operation and there were no appropriate considerations for local power and maintenance, both the operating and maintenance costs were high which will always require the inputs of expatriate to resolve such crisis.

Niji Group in its wisdom of mechanization has entered an agreement with an Indian Tractor company, SONALIKA. A fully semi knocked down (SKD) assembly plant has been built in Ilero, Oyo State of Nigeria. The design of the tractor makes and models were shared-intelligence between Niji Tractors Limited which is also a subsidiary of Niji Group and the International Tractors Limited (Sonalika Group) with much consideration for the specialty of the Nigerian vegetation. Thus the tractors deliver optimum performance.

Niji Group in 2016 established the Niji Institute of Sustainable Agriculture (NISA), Africa's premier Agribusiness Institute with a commitment to empower Africans through effective engagement in Agribusiness (**Fig. 4**). The campus located in a 5,000 hectare Sustainable City in Ilero, Oyo state of Nigeria, fully boarded with pilot farms, innovation laboratory and executive class rooms. Well proven with capacity to deliver NISA's Programmes uncover the huge prospect in agriculture, exploring the entire value chain, in addition to stimulating business models that delivers sustainable entrepreneurs and secure investments - The Future Enterprise Fellows Programme (FEF) {6 months}, The Enterprise Fellows Programme (EFP) {3 months}, The Global Executive Fellows Programme (GEF) {2 months}, and Specialized Courses Rack (SCR){2 weeks}. With audacious goal of turning villages into cities and advocating for enterprise driven economy is currently pioneering an Africa premier Agricity, taking advantage of the shared-opportunities to create business and good lifestyle in rural communities. The project has kick-started on a 10,000 hectares facility in Ipapo, Oyo State of Nigeria with major real estate and food processing companies already signed stake.

Conclusions

Saudi Arabia, which lies to the west of India, which is a typical desert region, has succeeded in turning a desert into a fruitful land. Crops are currently grown on mountain tops. Mechanization has aided the process. Indeed: they are no economic strongholds. Nigeria has one of the most productive soils and humid climate for crops germination. With appropriate mechanization procedures, it is valid that the nation will overtake most of the nations that have gone ahead of her. This means that smallholder farmers will be more productive, the nation will grow capacity to feed herself, reduce importation of food produce and increase her export base. Mechanization and value-addition are critical ingredients in transforming the agricultural sector.

REFERENCES

Ashaye. 1983. Suitability of Nigerian soils to mechanical cultivation. Proceedings of the First National Tillage Symposium of the NSAE, Pp 57-69.

EEPC. 2003. Agricultural machinery, parts and tractors market in Nigeria EEPC, Lagos, Nigeria. Sept. 17, 2003.

FMA. 2001. Land use in Nigeria. Fed. Min. of Agric. & Rural Dev. Diary 2003, Abuja, Nigeria.

https://www.dailytrust.com.ng/news/business/nigeria-beans-imports-hit-n10bn-annually nabda/184344.html. Accessed 02/02/2018.

http://wdi.worldbank.org/table/4.2#. Accessed 02/02/2018.

Oni, K. C. 1996. Effective management and maintenance of agricultural equipment in Nigeria. Lead Paper In: Proceedings of the Annual Conf. of NSAE, 18: 343-354.

■■

Effective Use of Indigenous Farm Machinery and Implements in Soil Tilling, Planting and Weeding in Nigeria

by
S. N. Asoegwu
Professor
Dept. of Agricultural and Bioresources Engineering
Federal University of Technology
P.M.B. 1526, Owerri
NIGERIA

N. R. Nwakuba
Lecturer 1
Dept. of Agricultural and Bioresources Engineering
Michael Okpara University of Agriculture
Umudike, P.M.B. 7267, Umuahia
NIGERIA
nrnwakuba@gmail.com

S. O. Ohanyere
Lecturer 1
Dept. of Agricultural and Bioresources Engineering
Federal University of Technology
P.M.B. 1526, Owerri
NIGERIA

Abstract

In Nigeria, there is a high demand of agricultural products for food, feed, fur, fuel and fibre for both internal consumption and export. Can this high demand of agricultural products be met by the almost non-existent of indigenous agricultural machines? In order to meet with the present challenge of ensuring food security in the country, the Federal Government of Nigeria realized the need to make use of appropriate indigenous farm implements to improve soil tilling, planting and weeding operations. This paper presents the case of indigenous farm machines in Nigeria and the sources of power for their effective use. The nation should embark on policies that would enhance the development, marketing and maintenance of indigenous farm machines to make them readily available to the farmers. Engineers, agricultural extension workers and technicians in the country are encouraged to extend the technology of indigenous machines to the beneficiaries for their effective use. The importance of maintaining these machines for their effective use was also highlighted.

Keywords: Indigenous farm machinery, soil tilling, planting, weeding, maintenance

Introduction

Soil tilling, planting and weeding are some of the first cultural practices required for agricultural crop production. Nigeria is an agricultural country with predominantly rural agricultural activities. The Nigerian small-scale farmers are estimated to account for the cultivation of about 90% of the total cultivated land area in Nigeria, producing nearly 90% of total agricultural output (Oni, 2011). The use of appropriate agricultural equipment and tools for small-scale intensive crop production contributes to the viability of the farm by enhancing production efficiency. Equipment and tools are necessary for soil preparation, planting and weed control, etc. Sustainable agriculture can be a labour-intensive business and by selecting the appropriate tool for the task at hand, farmers can increase profits by increasing crop yields, improving crop quality, and reducing expenses. Unfortunately, the present agricultural mechanization policies, strategies and schemes in Nigeria are not viable as these may not have impacted on the overall agricultural productivity of the country. Effective use of indigenous farm machinery/implements in soil tilling, planting and weeding has been considered most critical in evolving a sustainable food security in Nigeria (Kutte and Tya, 2001) and may perform the magic of improving agricultural productivity in Nigeria.

A Case of Indigenous Machines and Implements

Various programmes and strategies of government in the past to improve agriculture in Nigeria had not succeeded as a result of over-dependence on foreign systems, equipment and technology, i.e. dependence on imported food, agro-material input, raw materials and equipment; poor level of technological development for the efficient and effective operation and maintenance of these imported technologies. These afore-mentioned reasons caused the United Nations Industrial Development Organization (UNIDO) regional consultation meeting on agricultural machinery industry in Africa, held in Ethiopia in 1982, to state that agricultural mechanization in Africa should be based on machines and equipment, designed and manufactured within the region, especially for African farms and farmers (UNIDO, 1982). Before this meeting the Second National Development Plan (1970-1974) in Nigeria had stated that "no realistic change can be expected from the present nature of Nigerian agriculture, due to the drudgery attached to it, until the farmer finds an alternative to the hoe and cutlass technique of production. The clearing of bush, preparation of land, the sowing of seeds, the various post-planting operations are all processes in which the farmer's present tools can do little for high productivity per acre". Up till today in Nigeria, the situation has not improved considerably.

The Nigerian agriculture is still 80% dependent on small scale rural farmers who are in dire need of simple, cheap, labour saving and efficient tools and equipment. This is because tractors, combine harvesters and the other sophisticated, though efficient equipment, that could otherwise be used, are either too costly to acquire or too complex for farmers to use and maintain (Yiljep *et al*., 1995). A new approach to rural agriculture in Nigeria should be through improved design, manufacture and use of small farm machinery, especially for soil tilling, crop planting and weeding, geared towards the need of rural illiterate population, improved handy tools which can be operated by the simple farmers.

So it can be asserted that the mechanization of Nigerian agriculture must be based largely on indigenous engineering research to design, modify or otherwise develop and manufacture locally most of the needed machines, equipment and gadgets (Odigboh, 1985; Azogu, 2009). A number of equipment and tools for tillage, planting and weeding have been produced locally in Nigeria. These include hand plough (**Fig. 1**), big hoe, rake and matches (NAERLS, 1989).

Recently, the first made in Nigeria mini tricycle tractor (**Fig. 2**) for small scale farmers has been developed in collaboration with the National Center for Agricultural Mechanization (NCAM), Ilorin, Kwara State of Nigeria. However, this would go a long way to reduce over-dependence of Nigerian small-scale farmers on imported farm tractors, provide cost effective alternative to expensive conventional tractors, thereby resulting in gross improvement in their agricultural productivity as well as boosting the National Domestic Gross Product of the country if the federal government sponsors its commercial production.

Other simple farm equipment, designed and fabricated by various Universities, Polytechnics, Research Institutes, Private Individuals and other organizations have been found to be quite suitable for Nigerian farmers and could be mass-produced locally. Unfortunately, these later ones end up with the initiators either due to lack of funds to extend them to the public or that manufacturers are unwilling to venture into their mass production because of uncertainty of making profit. These should not be left at that, because the advantages of local manufacture of indigenous farm equipment are numerous. These include production of agricultural machines specifically designed to suit Nigerian crops and farmers, and ensure independence from imported and oftentimes inappropriate equipment; development of technological and industrial capability in Nigeria and encourage the development of ancillary industries for the nation's rapid industrialization; and formation of the elements of an agricultural mechanization technology which can qualify as both indigenous and appropriate (Odigboh, 1988). These equipment will be simple in design, easy to use and maintain by our local technology and farmers, and within the financial capacity of our farmers.

Fig. 1 Pictorial view of a hand plough

Fig. 2 First Nigerian mini tractor with its matching implement
Source: http://www.nigerianeye.com/2016/05/the-first-made-in-nigeria-tractor-for.html.

Fig. 3 Pictorial view of hoe blades of different sizes based on region
(**a**) Abakiliki hoe blades; (**b**) Keffi hoe blades; (**c**) Zaki Biam hoe blades
Source: Ohanyere *et al*. (2016).

Effective Use of Indigenous Farm Machines and Implements

The few of the indigenous farm equipment in Nigeria have proven that these fulfill a need and are found sustainable in terms of their use ability. However, to effectively use these, there is need to have an overview of the farming system, the cropping cycles, and the purpose for which the implement will be used. This would help in getting the right equipment of the appropriate size to do the job.

Soil Tilling

This is the preparation of the seedbed to provide enough loose soil of appropriate clod size, to sow seeds or plant crops. The other objectives may include control of weeds, incorporation of trash or manure, and the control of drainage or the adverse effect of erosion and to increase infiltration rates. Soil tilling disrupts the soil structure and soil life (Schonbeck, 2007). Maintaining and enhancing the life of the soil is the farmer's responsibility and depends on the farmer's ability to select and use the right implements and practices to till the soil for crop production. However, there is a range of indigenous equipment used to achieve these aforementioned objectives. These include hoes, traditional plough, harrows, cultivators, etc.

Indigenous hoes are major hand tools in Nigerian agriculture used for land clearing, soil tilling, planting and harvesting (Oluka and Akubuo, 1997; Oni, 2011). It is generally characterized by its low productivity and high energy demand. Nigerian indigenous hoes are of various types and bear the names of the locations where these are prevalent (Ohanyere *et al*., 2016). According to Oni (2011), cultural diversities govern Nigerian indigenous hoes, such that the type of hoe used in most Northern parts of the country is radically different in structure with those in the other regions. There are generally three popular indigenous hoes in Nigeria developed to suit local farming conditions as shown in **Fig. 3**. These are: (i) Abakaliki hoe used mostly in Abakaliki area of Ebonyi State in South Eastern part of Nigeria; (ii) Keffi hoe used in Nasarrawa State in North Central part of Nigeria; and (iii) Zaki Biam hoe used in Benue State in the middle-belt regions of Nigeria (Ohanyere *et al*., 2016).

Other types of hoes are the Katuna and the carving (Gizadeo) hoes. These hoe designs are broad-bladed, narrow-bladed and tined with forged metal blades and long and short wooden handles. Little work has been done to improve on the existing type of Nigerian indigenous hoes. According to Oni (2011), documented studies by Nwuba and Kaul (1986), Bassi (1992; 1997) and Oluka and Akubuo (1997) were more of the ergonomic considerations than their design considerations. Interestingly, a recent design on weeding hoe has emerged for rice farm weeding as shown in **Fig. 4**. Their use has shown that about 50 percent reduction in labour input can be achieved for upland and lowland rice field weeding operations.

The traditional plough is the main implement for primary tillage. In Nigeria, these traditional ploughs are mainly animal-drawn and predominantly found in the Northern part of the country. The emcot, arara, and the ariana multipurpose toolbar (consisting of plough and ridger units, as well as cultivator tines, groundnut lifter, weeders and harrows), which are the most prominent tillage equipment in Nigeria (Starkey, 1989; Oni, 2011). These are made of wood with sometimes a metal share point. The wooden pole is attached to the hitch at the front and carries the soil engaging parts with a handle at the rear. The farmers use the handle to guide the plough. There is also an animal-drawn mouldboard plough usually of one or two furrows. These traditional ploughs and other soil tillage engaging implements have been modified by Nigerian agricultural engineers, technicians, artisan and blacksmiths to suit Nigerian farm-

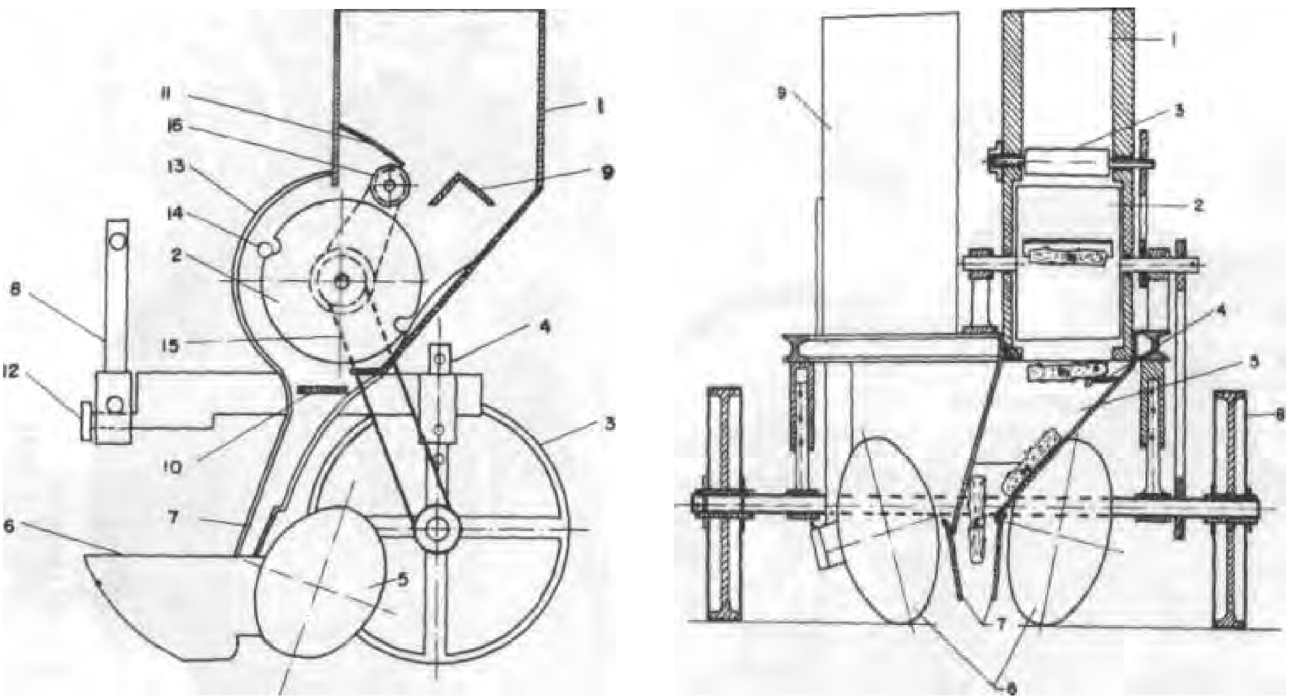
Fig. 4 Straight-spike rice field weeder

ing system.

Harrows and cultivators are secondary tillage implements for breaking up and smoothing out the surface of a ploughed field, and for stirring and pulverizing the soil, either before planting or after the crop has begun growing respectively. Animal drawn powered harrows and cultivators have been imported from India and other countries but are seldomly used due to the challenges associated with animal draft technology in Nigeria. Inter-row and intra-row rolling cultivators have been developed by the Institute of Agricultural Research (IAR). John Holt Agricultural Engineers, manufacturers of animal drawn equipment located in Zaria, Nigeria also developed “Strad” with a fixed tool bar and a pair of rotary hoes that straddle the ridge for weeding and for ridge remolding (Oni, 2011). Apart from the animal drawn harrows, the tractor-mounted types abound in the country; either trailed after the tractor by a draw-bar or mounted on the three-point hitch, whilst cultivators are usually either self-propelled or drawn as an attachment behind either a two-wheel tractor or four-wheel tractor. For two-wheel tractors; these are usually rigidly fixed and powered through couplings to the tractors' transmission.

Planting Machines

Farmers take several factors into consideration when choosing how best to establish a crop for production. Local soil and growing conditions, market considerations, and production resources affect whether a crop should be direct seeded or transplanted. How a crop is planted will affect its performance in establishment, earliness, quality and yield (NCAT, 2011). Seeding depth and spacing are important in order to achieve good yields because these factors lead to better germination and uniform crop stands. These should be uniform and optimal for the given growing condition. Precision seeding results in an optimum plant population and reduce seed consumption (Munzinger, 1992). Various designs of hand-operated, animal-drawn and tractor mounted seeders and planters have been developed to control plant density. The introduction of mechanical planters and seeders where the area to be sown is large or has proven difficult may displace labour. However, more labour-intensive methods of planting are still the commonest methods used by poor smallholders without undermining the quality of planting. All that is needed is sufficient care and the time of skilled operators. However, mechanical planters for cassava stems have been success-



(**a**) Side view
1. Hopper, 2. Metering drum, 3. Traction/Mechanism drive Wheel, 4. Wheel-depth adjuster, 5. Disc ridger, 6. Furrower, 7. Delivery chute, 8. Three-point hitch, 9. Load relief roof, 10. Cutting fall breaker/guide, 11. Rubber shield, 12. Hitch float pin, 13. Metering drum shield, 14. Cassava cutting about to drop into delivery.

(**b**) Front view (section) of planter Prototype illustrating progression of Fall of Cassava Stake (S) into Furrower
1. Hopper, 2. Metering drum, 3. Foam roller, 4. Fall breaker/guide, 5. Delivery Chute, 6. Disc ridger, 7. Furrower, 8. Drive wheel, 9. Auxiliary hopper

Fig. 5 Schematics of an indigenous cassava stem planter
Source: Odigboh (1985)

fully developed for rural farmers (**Fig. 5**). Other various designs for other crops are also in existence.

Locally-made hand-operated broadcasters have been manufacture for subsistent farming. These consist of a leather thong of a bow-like stick passing round a bobbin attached to a ribbed spinner. As the bow moves from left to right, the spinner rotates, scattering the seed which falls on to it from the canvas seed bag. Also, fabricated are hand-pushed/rotary injection jab-planters (with hoppers from which seeds are picked by the feed roller which contain pockets of suitable sizes for the crop concerned). The seeds then fall into the jabbing device which opens only just before withdrawing from the soil, allowing the seeds to be dropped into the hole at the pre-determined depth. There are other manually operated "walking stick" planters used in placing planting materials in holes in the soil. These dibblers could be steel tipped with wooden handles or all steel.

There are also locally made hand-pushed single row type row seeders (consisting of a plough or other furrow-making tools and seeds dropped in the furrow at appropriate intervals). There is also in existence, the animal-drawn type (one-row or two-row); an operator is sometimes required to feed the planting material manually through a sowing tube or directly into the furrow. A metal chain, ring or other small harrow trails it to cover the seed properly. Use of row seeders/planters allow for easier weeding and other cultural operations as well as contour planting which may help reduce erosion.

Apart from the imported tractor-mounted seeders (seed drills), there also exist locally manufactured seed drills that are hand-pushed and animal-drawn. These consist of seed-metering mechanisms driven by the land wheels which ensure that the rate of seeding, at a predetermined spacing in a row, is directly related to the distance travelled. The metering device, which takes the seed from the hopper, uses the chain driven by a sprocket mounted on the land wheel axle. The hopper is carried between a pair of iron land wheels, and a rear furrow press-wheel, a row-marker and two steering handles.

Weeders

Weed is one of the pests that interfere and compete with crops for plant food (light, water and nutrients), growth, development and yield of a crop and affect farm's economic bottom line. Weeds are referred to as robbers as these rob the farmer of their profits by reducing yields, lowering the quality of the crops, habouring insects that damage the crop and reducing the land value. The weeds may become so thick to the extent that the crop has to be abandoned thereby robbing the farmer's home. Therefore, the farmer must fight to control weed with every control measures. Even though chemical herbicides are popular worldwide, the majority of smallholder farmers control weeds by cultural methods through manual cultivation (cutting, uprooting, burying, burning, and smothering). The weeding control strategies include: hand-weeding or inter-row cultivation of the standing crop; mixed cropping; crop rotations; minimizing initial weed infestation by: sanitation (using clean seed and clean tools); prevention of seeds entering the field from field boundaries or in irrigation water (using weed seed traps); post-harvest grazing by livestock; post-harvest cultivation; and post-harvest burning of stubble.

Most seed bed preparation equipment are used for weeding (as earlier discussed). These include hoes (digging, rotary, chopping and pulling and pushing hoes); wheeled cultivators, ploughs and harrows. The indigenous ones are either manually-operated or animal-operated. When using chemical pesticides, it must be kept in mind that the chemicals involved are also poisonous to humans and must be used with great caution. Protective clothing and equipment must be used but these clothing and equipment may be uncomfortable when used in tropical areas. Some protective clothing and equipment include gloves and gauntlets, coveralls, head coverings, footwear, aprons, face shield and goggles as well as respirators. There is small-scale application equipment including knapsack and pressure cylinder sprayers. These may be hand-operated or motorized.

Traditional methods of pest and weed control by smallholder farmers are often most effective and economical and should be used whenever possible. Chemical pest control methods are widely used and sometimes abused. The information on the risks of using them, personal protective measures and safer methods of control are provided to the user, farmer or operator.

Selection of Power Source And Equipment

Selection of an appropriate power source and the matching equipment for tilling, planting and weeding is specific to local circumstances and must be accessible, available, affordable, and acceptable. Consideration is also given to the fact that the power source and the equipment should be user-friendly (i.e. compatible with the knowledge, skill and experience of the user), sufficiently available to complete operations on time, and should be operationally and financially sustainable. These equipment should be kept in efficient working condition, used to the best advantage (using skilful operators) and used within a system which is profitable to the farmer.

Having decided on the particular type of equipment required, consideration is given to the robustness of the machine, its ease of maintenance and availability of spare parts as well as its versatility. Choosing the right size of machines at purchase prevents a lot of problems because too small ones break down easily and too large ones cost more, are under-used, wear fast and cause extra maintenance problems. For effective use of a viable purchased farm equipment, consideration should be given to the machine's functional requirements according to the intended job to be done; machine's quality requirements to ensure reliability and minimize maintenance costs for high performance through good design and use of high quality materials for strength and wear resistance; and the availability of good after-sales services using local dealers or local artisan knowledgeable on the repair of the equipment.

Maintenance of Indigenous Farm Machines and Implements for Effective Use

The failure of mechanization in developing countries like Nigeria has been explained by many as a result of shortcomings in the area of tools, machines and equipment maintenance. These include: difficulties in finding spare parts; lack of competent technicians to repair machines; and shortage or complete lack of minimum maintenance (oil, grease, changing worn parts).

With indigenous farm equipment designed based on the concept of appropriate technology, the problem of maintenance is reduced as farmers or operators can maintain their equipment, have sufficient spare parts and not depend on supplies from outside. Policies which favour heavy tractorization and importation of animal-drawn equipment cause failures in mechanization, because of farmers' inability to purchase these imported equipment.

It is suggested that government should encourage the local fabrication of farm equipment together with the hundreds of parts needed to maintain them during their down time. This will encourage the development of a protected local agricultural engineering industry in which there will be a close and responsive relationship between local, usually small, artisanal workshops (such as blacksmiths, etc.) and the users. This will favour low price and good quality of service including spare parts for the effective use of the farm machines.

Even where machines are to be imported, there should be a realistic assessment of user need (technical and economic benefits and burdens) and effective organization for training in their use and maintenance. There should be a network of spare parts dealers and dealer workshops for efficient repair and maintenance services. The workshops should aim at self-sufficiency in the spare parts it stocks. These spare parts could be categorized as consumables (for routine servicing like soil-engaging parts of tillers, planters and weeders, grease, tyres, etc.), predictables (which need replacement some time during the life of the equipment e.g. chain, drive belt, etc.) and erratic (which should last the lifetime of the equipment but fail in random manner e.g. sprocket, gear, gearbox, bearing, etc.).

Conclusions

This paper gives an overview of the effective use of indigenous farm machinery and equipment for soil tilling, planting and weeding operations in Nigerian agriculture. Sustainable food security as well as enhanced agricultural productivity in Nigeria has been found to be dependent on the effective use of indigenous farm machineries and implements. Over reliance on foreign systems, equipment and technology, poor level of technological development for efficient and effective operation and maintenance of these imported technologies amongst other factors in preference for locally designed and developed farm equipment have toughened the development of agricultural mechanization in Nigeria.

Selection of appropriate power source and equipment compatibility for tilling, planting and weeding operations are specific to local circumstances and must be accessible, available, affordable, and acceptable. Power source and the equipment should be user-friendly, sufficiently available for timeliness operations, and should be physically, operationally and financially sustainable. The following actions are considered necessary for effective use of indigenous farm machinery for tilling, planting and weeding and any other operations:

Regular maintenance especially with regards to routine checks, adjustment and replacements, together with frequency of lubrication and the quality of oils and greases used;

Replacement of worn out parts in good time in order to reduce damage to neighbouring components;

Employ or use competent craftsmen/machines since unskilled repairs or incorrect spare parts can only lead to more trouble and expense;

Think ahead by planning for the maintenance of the equipment to be done in good time and purchasing consumable parts and replacements for wearing parts in advance;

Most importantly, selecting the right type of farm equipment to do the right job at a profitable price because if a machine is fundamentally unprofitable; no amount of good maintenance can keep it going.

REFERENCES

Azogu, I. I. 2009. Promoting appropriate mechanization technologies for improved agricultural productivity in Nigeria: the role of the National Centre for Agricultural Mechanization. Journal of Agricultural Engineering and Technology, 17(2):1-10.

Bassi, S. Y. 1992. Soil cutting forces during hand-hoeing. In: Tillage Research and Agricultural Development in Sub-Saharan Africa. Proceedings of the Nigerian Branch of ISTRO (1997): Pp. 121-136.

http://www.nigerianeye.com/2016/05/the-first-made-in-nigeria-tractor-for.html.

Kutte, M. T. and Tya, T. S. K. 2001. Mechanization strategies for sustainable agricultural production in Nigeria. Proceedings of the International Conference and Annual General Meeting of the Nigerian Institution of Agricultural Engineers, 23:27-33.

Munzinger, P. 1992. Wowing, Planting and Fertilizer Distribution. In: Tools for Agriculture. 4th Ed. Intermediate Technology Publications in association with CTA and GRET.

National Agricultural Extension and Research Liaison Services (NAERLS) 1989. Report on Survey and Identification of Local Smiths with Potential for Simple Oil Extraction Equipment Fabrication. NAERLS/ABU, Zaria.

Nation Centre for Appropriate Technology (NCAT). 2011. Equipment and tools for small-scale intensive crop production. www.attra.ncat.org/sarc_current.php.

Nwuba, E. I. and R. N. Kaul. 1986. The effect of working posture on the Nigerian hoe farmer. Journal of Agricultural Engineering Research, 33:79-85.

Odigboh, E. U. 1985. Mechanization of Cassava Production and Processing: a Decade of Design and Development. University of Nigeria Inaugural Lecture Series No. 8 Published by University of Nigeria Press UNN, Nsukka.

Odigboh, E. U. 1988. Indigenous Technology and Human resources Development for Enhancing Agricultural Productivity. Proceedings of the Nigerian Society of Agricultural Engineers, 12:43-55.

Ohanyere, S. O., K. N. Nwaigwe, S. N. Asoegwu and C. I. Ijioma. 2016. Analysis of deflection characteristics of selected cultivation hoes used in mechanized tillage within West Africa. ASABE Annual International Meeting, Orlando, U.S.A, Pp. 1-7.

Oluka, S. I. and C. O. Akubuo 1997. Mechanical strength of the Nigerian tillage hoe. In: Tillage Research and Agricultural Development in Sub-Saharan Africa. Proceedings of the Nigerian Branch of ISTRO, (1997), 137-143.

Oni, K. C. 2011. Tillage in Nigerian agriculture. Proceedings of the Nigerian-Branch of International Soil Tillage Research Organization (ISTRO-Nigeria) Symposium. University of Ilorin, Nigeria, 21st -24th February, 2011, Pp. 12-23.

Schonbeck, M. 2007. Beating the weeds with low-cost cover crops, intercropping and steel. The Virginia Biological Farmer, 30:7-8.

Starkey, P. 1989. Harnessing and Implements for Animal Traction. An Animal Resources Handbook for Africa. GTZ Publications, GMbH, Pp. 180-192.

UNIDO. 1982. Regional Consultation Meeting on Agricultural Machinery Industry held in Addis Ababa, Ethiopia, 5-9 April, 1982.

Yiljep, Y. D., A. N. Jibril and A. O. Lawal 1995. Sustaining Agricultural Equipment Production in Nigeria: Potentials and laminations of Blacksmiths. Proceedings of the Nigerian Society of Agricultural Engineers, 17:320-325.

■■

EVENT CALENDAR

2018

◆ Autonomous Trucks—2nd International VDI Conference—
April 10-11, Dusseldorf, GERMANY
https://www.vdi-wissensforum.de/en/event/autonomous-trucks/

◆ XIX. World Congress of CIGR
April 22-25, Kyneria, TURKEY
http://www.cigr2018.org/

◆ NAMPO Harvest Day
May 15-18, Bothaville, SOUTH AFRICA
http://www.grainsa.co.za/pages/nampo/exhibitors

◆ Caspian Agro 2018—12th Azerbaijan International Agriculture Exhibition—
May 16-18, Baku, AZERBAIJAN
http://caspianagro.az/en-main/

◆ SIMA ASEAN
June 6-8, Bangkok, THAILAND
http://www.sima-asean.com/en/

◆ GreenTech
June 12-14, Amsterdam, NETHERLANDS
http://www.greentech.nl/amsterdam/

◆ Asia Agri-tech Expo & Forum
July 26-28, Taipei, TAIWAN
http://www.agritechtaiwan.com/en-us/

◆ EURAGENG 2018 Conference
July 8-12, Wageningen, THE NETHERLANDS
http://ageng2018.com/

◆ 2018 ASABE Annual International Meeting
July 29-August 1, Detroit, USA
https://www.asabe.org/meetings-events/2018/07/2018-asabe-annual-international-meeting.aspx

◆ Agritechnica Asia 2018
August 22-24, Bangkok, THAILANS
http://www.agritechnica-asia.com/

◆ Global Wter Security for Agriculture and Natural Resources
October 3-6, Hyderabad, INDIA
http://asabewater.org/

◆ Agrosalon
October 9-12, Moscow, RUSSIA
http://www.agrosalon.com/Visitor/VisitorsInfo/

◆ KIEMSTA 2018
October 31-November 3, Cheonan, KOREA
http://kamico.or.kr:8001/KIEMSTA/e-main.html

◆ EIMA 2018
November 7-11, Bologna, ITALY
https://www.eima.it/en/index.php

◆ EuroTier
November 13-16, Hanover, GERMANY
https://www.eurotier.com/

◆ Nebraska Power Farming Show
December 4-6, Nebraska, USA
https://nebraskapowershow.com/

2019

◆ SIMA
February 24-28, Paris, FRANCE
https://en.simaonline.com/

◆ Agritechnica
November 10-16, Hanover, GERMANY
https://www.agritechnica.com/en/

■■

NEWS

CLUB OF BOLOGNA

strategies for the development of agricultural mechanisation

http://www.clubofbologna.org

GIUSEPPE PELLIZZI PRIZE 2018

The Club of Bologna (www.clubofbologna.org) in collaboration with the Accademia dei Georgofili organizes the third edition of the "Giuseppe Pellizzi Prize", an international competition reserved to PhD Theses devoted to Farm Machinery and Mechanization topics. The prize is awarded concurrently with the agricultural machinery exhibition EIMA International, held in Bologna (Italy) every two years.

Applicants must have achieved a PhD with specific reference to the sector of "Agricultural Machines and Mechanization" under the following specific headings: (i) Tractors and Engines; (ii) Agricultural Machines and Mechanization; (iii) Components and Materials; (iv) Automation and Electronics.

To be eligible the Applicants must: (i) be born after the 31st December 1981, (ii) have obtained the PhD title not before the 1st January 2016, and (iii) be presented by a Full Member of the Club of Bologna, who will act as Tutor.

The application should be submitted exclusively by e-mail to the Club of Bologna Secretary General (Prof. Marco Fiala; marco.fiala@unimi.it) using the Forms download from the Club web site *http://www.clubofbologna.org*. The submission deadline is 30th June 2018.

The Management Committee of Club of Bologna will assess the presented PhD Theses and will select the three best ones. Winners will receive from FEDERUNACOMA a cash prize of 1200, 800 and 500 Euro, for 1st, 2nd and 3rd place, respectively. During the "Giuseppe Pellizzi Prize 2018" award ceremony—organized in a special session of the 28th Club of Bologna Members Meeting (10-11 November 2018)—the three winners will be asked for a short lecture on their PhD Thesis results. Finally they will be invited to attend—as guest experts, hosted by FEDERUNACOMA—to the Club Members' Meetings for a period of five years (up to 2023).

Club of Bologna Secretary General
Marco Fiala

Promoted by FEDERUNACOMA Italian Agricultural Machinery Manufacturers Association (www.federunacoma.it)

PRESIDENT	Paolo Balsari (Italy): paolo.balsari@unito.it; Tel: + 39 011 6708587
SECRETARY GENERAL	Marco Fiala (Italy): marco.fiala@unimi.it; Tel: +39 02 50316868
FEDERUNACOMA REPRESENTATIVE	Marco Pezzini: marco.pezzini@federunacoma.it; FederUnacoma – Italy
MANAGEMENT COMMITTEE MEMBERS	Ulrich Adam (CEMA); El Houssine Bartali (Morocco); Yoshisuke Kishida (Japan); Oleg Marchenko (Russia); Emilio Gil (Spain); Danilo Monarca (Italy); Axel Munack (Germany); Peter Pickel (Germany); John Posselius (USA); Alain Savary (France); John Schueller (USA); Gajendra Singh (India); Bassam Snobar (Jordan); Karl Renius (Germany).
PAST PRESIDENTS	Luigi Bodria (Italy); Ettore Gasparetto (Italy)
ADMINISTRATIVE SECRETARIAT	Patrizia Menicucci – FederUnacoma, ufficio.stampa@federunacoma.it; Tel: +39 06 43298253

■■

Co-operating Editors


B Kayombo


M F Fonteh


S A Ndindeng


S E Abdallah


A A K El Behery


Ahmad Addo


R J Bani


I K Djokoto


A N GITAU


D K Some


K Houmy


O A Oyelade


Umar B Bindir


J C Igbeka


E U-Odigboh


K C Oni


U L Opara


N G Kuyembeh


A H Abdoun


A B Saeed

-AFRICA-

Benedict Kayombo
Assoc. Prof. of Soil and Water Eng., Dept. of Agric. Eng. and Land Planning, Botswana College of Agric., Univ. of Botswana, Private Bag 0027, Gaborone, BOTSWANA. TEL+267-3650125, bkayombo@bca.bw

Mathias Fru Fonteh
Assoc. Prof. and Head, Dept. of Agril. Eng., Faculty of Agronomy and Agril. Sciences, Univ. of Dschang, P.O. Box 447, Dschang, West Region, CAMEROON. TEL+237-7774-0863, matfonteh@yahoo.com

Sali Atanga Ndindeng
Dr., Rice Processing and Value-Addition Specialist, Africa Rice Center (AfricaRice), Sustainable Productivity Enhancement, M' bé Research Station, 01 B. P. 2551, Bouaké 01, COTE D' IVOIRE, S.Ndindeng@cgiar.org

Said Elshahat Abdallah
Dr., Prof. of Agricultural Process Engineering Department of Agricultural Engineering, Faculty of Agriculture Kafrelsheikh University, Kafr Elsheikh 33516, EGYPT. TEL+20473148949, saidelshahat@agr.kfs.edu.eg; dr.selshahat@gmail.com

Ahmed Abdel Khalek El Behery
Agric Eng. Research Institute, Agril. Research Center, Nadi El-Said St. P.O. Box 256, Dokki 12311, Giza, EGYPT. behery28@yahoo.com

Ahmad Addo
Assoc. Prof., Department of Agril. Engg, Kwame Nkrumah Univ. of Sci. and Tech. (KNUST) Kumasi, GHANA. TEL+233-3220-60242, aaddo.coe@knust.edu.gh

Richard Jinks Bani
Lecturer & Co-ordinator, Agric. Eng. Div., Faculty of Agric., Univ. of Ghana, Legon, GHANA

Israel Kofi Djokoto
Prof., Israel Kofi Djokoto, Associate Prof. Univ. of Science and Technology, P.O.Box 420 ust, Kumasi, GHANA, profdjokoto@yahoo.com

Ayub N. Gitau
Chairman and Associate Prof., Dept. of Environmental and Biosystems Engineering, University of Nairobi, P.O Box 30197, Nairobi, KENYA, ayub.gitau@uonbi.ac.ke; gitauan@yahoo.co.uk

David Kimutaiarap Some
Eng. Prof. Dept. of Agril & Biosystems Eng., School of Engg Chepkoilel University College of Moi Univ., P.O. Box: 2405-30100, Eldoret, KENYA, dkimutaisome2@gmail.com

Karim Houmy
Dr., International Consultant on Agricultural Mechanization, 2 Rue Ali Al Haddani, Route Akrach, Souissi, Rabat, MOROCCO. TEL+212-7-680512, houmy@maghrebnet.net.ma

O. A. Oyelade
Dr., Farm Power and Machinery Dept., National Centre for Agril. Mechanization (NCAM), P.M.B. 1525, Ilorin, Kwara State, NIGERIA. TEL+2348069030588, yemibamigbedjdoyelade@gmail.com

Umar Buba Bindir
Director General/CEO, National Office for Technology Acquisition and Promotion, No 4. Blantyre Street, Wuse II PMB 5074, Abuja, FCT Federal Republic of NIGERIA. TEL+234-9461-1183, ubindir@yahoo.com

Joseph Chukwugotium Igbeka
Prof., Dept. of Agril. Eng., Univ. of Ibadan,, Ibadan, NIGERIA. TEL+234-2-810-1100-4, Library@Ibadan.ac.ng

Emmanuel Uche Odigboh
Prof., Agril. Engg Dept., Faculty of Eng., Univ. of Nigeria, Nsukka, Enugu state, NIGERIA. TEL+234-042-771676, MISUNN@aol.com

Kayode C. Oni
Dept. of Agril. & Biosystems Eng., Faculty of Eng. & Technology, Univ. of Ilorin, PMB 1515, Ilorin, NIGERIA. TEL+234-803-5724708, kayoroll@gmail.com

Umezuruike L. Opara
Research Prof., S. Africa Research Chair in Postharvest Technology, Faculty of AgriSciences, Stellenbosch Univ., Private Bag X1, Stellenbosch 7602, SOUTH AFRICA. TEL+27-21-808-4604, opara@sun.ac.za

Nathaniel Gbahama Kuyembeh
Assoc. Prof., Njala Univ. Colle, Univ. of Sierra Leone, Private Mail Bag, Free Town, SIERRA LEONE. TEL+249-11-778620/780045

Abdien Hassan Abdoun
Member of Board, Amin Enterprises Ltd., P.O. Box 1333, Khartoum, SUDAN.

Amir Bakheit Saeed
Assoc. Prof., Dept. of Agric. Eng., Faculty of Agric., Univ. of Khartoum, 310131 Shambat, SUDAN. TEL+249-11-310131, absaeed5@yahoo.com

Abdisalam I. Khatibu
P. O. Box 2138, Zanzibar, TANZANIA. khatibu@zansec.com

Solomon Tembo
52 Goodrington Drive, PO Mabelreign, Sunridge, Harare, ZIMBABWE.

-AMERICAS-

Hugo Alfredo Cetrangolo
Full Prof. and Director of Food and Agribusiness Program Agronomy College Buenos Aires Univ., Av. San Martin4453, (1417) Capital Federal, ARGENTINA. TEL+54-11-4524-8041/93, cetrango@agro.uba.ar

Irenilza de Alencar Nääs
Prof., Agril. Eng. College, UNICAMP, Agril. Construction Dept.,P.O. Box 6011, 13081 -Campinas-S.P.,BRAZIL. TEL+55-19-788-1039, irenilza@agr.unicamp.br

Abdelkader E. Ghaly
Prof., Emeritus of Biological & Environmental Eng. Dalhousie Univ., P.O. Box 1500, 1360 Barrington St., Halifax, Nova Scotia, B3H 4R2, CANADA. Abdel.Ghaly@Dal.Ca

Edmundo J. Hetz
Prof., Dept. of Agric. Eng. Univ. of Concepcion, Av. V. Mendez 595, P.O. Box 537, Chillan, CHILE. TEL+56-42-216333, ehetz@udec.cl


A I Khatibu


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


M A L Roudergue


R Aguirre


O Ulloa-Torres


Y M Mesa


P P Rondon

S G C Magaña

H Ortiz-Laurel

A I Luna Maldonado

G C Bora

M R Goyal

A K Mahapatra

S M Farouk

Daulat Hussain

M A Mazed

R Ali

Chetem Wangchen

M A Basunia

Xiwen Luo

S M Ilyas

Surya Nath

Indra Mani

C R Mehta

A M Michael

B S Pathak

Marco A. L. Roudergue
Mechanization and Energy Dept., Agril. Eng. Faculty, Campus Chillan, Univ. of Concepcion, Chile. Vicente Mendez #595, CHILE. TEL+56-42-2208709, malopez@udec.cl

Roberto Aguirre
Assoc. Prof., National Univ. of Colombia, A.A. 237, Palmira, COLOMBIA. TEL+57-572-271-7000, ra@palmira.unal.edu.co

Omar Ulloa-Torres
Prof., Escuela de Agricultura de la Region, Tropical Humeda(EARTH), Apdo. 4442- 1000, San Jose, COSTA RICA. TEL+506-255-2000, o-ulloa@ns.earth.ac.cr

Yanoy Morejón Mesa
Agril. Engineer Univ. Agraria de La Habana, Facultad de Ciencias Técnicas Autopista Nacional y Carretera de Tapaste Apartado, 18-19 San José de las Lajas, Mayabeque, CP 32700 CUBA. ymm@unah.edu.cu

Pedro Paneque Rondon
Assoc. Prof., Universidad Agraria de La Habana, Facultad de Ciencias Técnicas, Autopista Nacional y Carretera de Tapaste, Apartado 18-19, San José de las Lajas, Mayabeque, CP 32700 CUBA. paneque@unah.edu.cu

S. G. Campos Magaña
PhD. and Prof., Paseo de los Claveles #398, Colonia Parques de la Cañada. CP 25080, Saltillo, Coahuila, MEXICO. camposg_1999@yahoo.com

Hipolito Ortiz-Laurel
Head of Agric. Eng. and Mechanization Dept./ Postgraduate College, Iturbide 73, Salinas de Hgo, S.L.P., C.P. 78600, MEXICO. TEL+52-496-30448

Alejandro Isabel Luna Maldonado
Prof. and Head of the Dept. of Agricultural and Food Engineering, Autonomous University of Nuevo Leon, Nuevo León, MEXICO. alejandro.lunaml@uanl.edu.mx; alejlun@yahoo.com

Ganesh C. Bora
Associate Prof., Dept. of Agricultural and Biological Engineering, Mississippi State Univ., 130 Creelman St., Room 242, P.O. Box 9632, MS 39762, U.S.A. gcbora@abe.msstate.edu

Megh R. Goyal
Senior Acquisitions Editor, Agric. & Biomedical Eng. and Retired Professor in Agric. & Biomedical Eng. Univ. of Puerto Rico, Mayaguez P.O. BOX 86, Rincon, PR-00677, U.S.A. goyalmegh@gmail.com

Ajit K. Mahapatra
Agric. & Biosystems Eng. Dept., South Dakota State Univ., P.O. Box 2120 Brookings, SD 57007-1496, U.S.A. TEL+1-605-688-5291, mahapata@sdstate.edu

-ASIA and OCEANIA-

Shah M. Farouk
Prof. (Retd.), Farm Power & Machinery Dept., Bangladesh Agril. Univ., Mymensingh 2202, BANGLADESH. TEL+880-1711-801923, smf1941@yahoo.com

Daulat Hussain
Dean, Faculty of Agric. Eng. and Technology, Bangladesh Agril. Univ., Mymensingh-2202, BANGLADESH. TEL+880-91-52245

Mohammed A. Mazed
Member-Director, Bangladesh Agri. Res. Council, Farmgate, Dhaka, BANGLADESH. mamazed@barcbgd.org

Rostom Ali
Prof., Dept. of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh-2202, BANGLADESH. rostomfpm@bau.edu.bd

Chetem Wangchen
Programme Director Agril. Machinery Centre Ministry of Agric. Royal Government of Bhutan, Bondey Paro Bhutan 1228, BHUTAN. krtamc@druknet.bt

Mohammad Ali Basunia
Associate Prof., Mechanical Engineering Programme, Institute Teknologi Brunei (ITB), Jalan Tungku Link, Gadong BE 1410, BRUNEI DARUSSALAM. ali.basunia@itb.edu.bn

Xiwen Luo
Prof. of South China Agricultural University; Academician of Chinese Academy of Engineering, Wushan, Guangzhou, 510642, CHINA. xwluo@scau.edu.cn

S. M. Ilyas
Prof. Green View Apartment, Flat-699; Pocket-2; Sector-19; Dwarka, NEW DELHI-110 075, INDIA. Tel+91-95608 48971, smilyas15@gmail.com

Surya Nath
c/o R.K. Univ., School of Eng. Rajkot-Bharnagar Highway, KASTURBADHAM, RAJKOT,360020, Gujrat, INDIA. drnath.surya@gmail.com

Indra Mani
Prof., Head of Division of Agril. Eng. IARI, New Delhi-110012, INDIA. maniindra99@gmail.com

C. R. Mehta
Project Coordinator, AICRP on Farm Implements and Machinery, ICAR - Central Institute of Agricultural Engineering, Nabi-bagh, Berasia Road, Bhopal - 462 038, INDIA. crmehta65@yahoo.co.in

A. M. Michael
1/64, Vattekunnam, Methanam Road, Edappally North P.O., Cochin, 682024, Kerala State, INDIA. kmichael65@eth.net

B. S. Pathak
Adjunct Prof., Indian Agril. Research Institute, KC5, Kavi Nagar, Ghaziabad- 201002, INDIA. bspathakprof@gmail.com

Vilas M. Salokhe
Prof., Flat B-1, Royal Gateway Apartment Near Yallama Temple, Main Road Kasaba Bawada Kolhapur - 416006, INDIA. vsalokhe@yahoo.com

Gajendra Singh
Adjunct Professor, Indian Agricultural Research Institute (IARI), 86-C, Millennium Apartments, Sector-61, NOIDA, U. P. 201301, INDIA. TEL+91-99-71087591, prof.gsingh@gmail.com

Sitaram Dagdupant Kulkarni
Dr., Flat No. 105, Guruprasad Apptts., Plot No. 85 & 86, Survey No. 78, Left Bhusari Colony, Kothrud, Pune - 411038, INDIA. sdkulkarnispu@gmail.com

S. R. Verma
Ex-Dean & Prof. of Agr. Eng., H. No. 14, Good Friends Colony, Barewal Road, Ludhiana 141012. Punjab, INDIA. TEL+91-161-2551096, srverma10@yahoo.com

Kamaruddin Abdullah
The Graduate School/Renewable Energy, Darma Persada University, JI. Radin Inten II, Pondok Kelapa, East Jakarta, 13450, INDONESIA. TEL+64-21-8649051, kabdullah0997@yahoo.com

Mansoor Behroozi-Lar
Prof., Emeritus Tehran Uni. Agr. Eng., Ph. D., Jalal All


V M Salokhe

G Singh

S D Kulkarni

S R Verma

Kamaruddin Abdullah

M Behroozi-Lar

Saeid Minaei

A Mahdavian

A M Abdul-Munaim

H Hasegawa


B A Snobar


J H Chung


In-Bok Lee


M Z Bardaie


Enkhbayar Gonchigdorj


M P Pariyar


H P W Jayasuriya


Alamgir A Khan


A Q A Mughal


M S Mirjat


N A Abu-Khalaf


R M Lantin


R P Venturina


S A Al-Suhaibani


A M S Al-Amri


S G Illangantileke


S F Chang


Suming Chen


S Krishnasreni


S Phong-supasamit

Ahmad Nasim St. Nasim Danesh Complex Block #35, second floor Tehran, IRAN. Behroozil@Yahoo.com

Saeid Minaei
Assoc. Prof., Dept. of Agr. Machinery Eng., Tarbiat Modarres Univ., P.O.Box 14115-336, Tehran, IRAN. TEL+9821-44180537, minaee@modares.ac.ir

Alireza Mahdavian
Assistance Prof., Department of Biosystems Engineering, Tarbiat Modares Univ., P.o.Box 14115-336, Tehran -14977-13111, IRAN. TEL +98-912-3346506, al.mahdavian@gmail.com; a.mahdavian@modares.ac.ir

Ali Mazin Abdul-Munaim
Assistant Prof., Dept. of Agril. Machines and Equipments, College of Agric., Univ. of Baghdad, IRAQ. TEL+964-778-4561, old2a3y@yahoo.com

Hideo Hasegawa
Assoc. Prof., Institute of Science and Technology, Niigata University, 8050 Ikarashi 2-no-cho, Nishi-ku, Niigata 950-2181 JAPAN. +81-25-262-6690, hsgw@agr.niigata-u.ac.jp

Bassam A. Snobar
Prof., Univ. of Jordan, Faculty of Agriculture, Amman 11492, JORDAN. snobar@ju.edu.jo

Jong Hoon Chung
Prof., Dept. of Biosystems & Biomaterials Science and Eng., College of Agril. and Life Sciences, Seoul National Univ., Bldg 200 Rm 2216 1 Gwanangno, Gwanak-Gu, Seoul, 151-742, KOREA. TEL+82-2-880-4601, jchung@snu.ac.kr

In-Bok Lee
Prof., Laboratory of Aero-Environmental & Energy Engineering (A3EL), Dept. of Rural Systems Eng., College of Agril. & Life Sciences, Seoul National Univ., San 56-1, Shillim-dong, Gwanak-gu, Seoul-city, KOREA. TEL+82-2-880-4586, iblee@snu.ac.kr

Muhamad Zohadie Bardaie
Prof., Dept. of Agril. and Biosystems Eng., Univ. Putra Malaysia, 43400 upm, Serdang, Selangor, MALAYSIA. TEL+60-3-8946-6410

Enkhbayar Gonchigdorj
Director, School of Eng. & Technology, Mongolian University of Life Sciences, Ulaanbaatar, Zaisan, 17024, MONGOLIA. TEL+60-976-11-341554 enkhbayar@muls.edu.mn

Madan P. Pariyar
Consultant, Rural Development through Selfhelp Promotion Lamjung Project, German Technical Cooperation. P.O. Box 1457, Kathmandu, NEPAL.

Hemanatha P. W. Jayasuriya
College of Agril. and Marine Sciences, P.O. Box 34, PC 123Al-khod, Muscat Sultanate, OMAN. TEL+968-2414-1223, hemjay@squ.edu.om

Alamgir A. Khan
Research Engineer, Agricultural Mechanization Research Institute, Multan, PAKISTAN. alamgirakhtar@hotmail.com

A. Q. A. Mughal
Research Professor, Greenwich Univ., DK-10, Street 38t, Darakshan, DHA Phase-6, Karachi-75500, PAKISTAN. dr.aqmughal@greenwich.edu.pk

Muhammad Saffar Mirjat
Dean, Faculty of Agril. Eng., Sindh Agriculture Univ. Tandojam, PAKISTAN. TEL+92-221653160, drmirjat@hotmail.com

Nawaf A. Abu-Khalaf
Assistant Prof., Palestine Technical Univ. -Kadoorie (PTUK), P.O.Box 405, Hebron, West Bank, PALESTINE. TEL+972-2-2227-846/7, nawafu@hotmail.com

Reynaldo M. Lantin
Retired Professor, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Banos, College, Laguna 4031, PHILIPPINES. TEL+63-49-536-2792, reylantin@gmail.com

Ricardo P. Venturina
PHILIPPINES.

Saleh Abdulrahman Al-suhaibani
Prof., Agril. Eng. Dept.,College of Agric., King Saud Univ., P.O. Box 2460 Riyadh 11451, SAUDI ARABIA. salsuhaibani@gmail.com

Ali Mufarreh Saleh Al-Amri
Prof., Dept. of Agril. Systems Eng., College of Agril. Sciences & Food, King Faisal Univ., P.O.Box 55035, Al-Ahsa, 31982 SAUDI ARABIA. aamri@kfu.edu.sa

Sarath G. Illangantileke
Prof., Sarath Ilangantileke, Consultant in Agric Engineering, Mechanization and Education, 4/567 Victoria Range Bungalows, Kengalla, SRI LANKA. sageilan@gmail.com

Sen-Fuh Chang
Adjunct Prof., Dept. of Bio-Industrial Mechatronics Eng., National Taiwan Univ., 136 choushan Road, Taipei, 106. TAIWAN. sfchang@ntu.edu.tw

Suming Chen
Prof., Dept. of Bio-Industrial Mechatronics Eng., National Taiwan Univ., 1, Section 4, Roosevelt Road, Taipei, TAIWAN. TEL+886-2-33665350, schen@ntu.edu.tw

Suraweth Krishnasreni
Emeritus Prof. 24/77 Baan Kasemsan 1, Soi Kasemsan 1 Rama 1 Rd., Wangmai, Pathumwan, Bangkok 10330, THAILA, surawethk@gmail.com

Surin Phongsupasamit
President, Institute for Promotion of Teaching Science and Technology, 924 Sukumit Rd. Klong Toey Bangkok, THAILAND, surin1950@hotmail.com

Akkapol Senanarong
Agricultural Engineering Research Institue Department of Agriculture, 50 Phaholyothin Rd., Jatuchak Bangkok 10900, THAILAND, akkapol@ksc.th.com

Peeyush Soni
Associate Professor & Coordinator, Agril. Systems and Eng., School of Environment, Resources and Development; Asian Institute of Technology; 12120 THAILAND, soni.ait@gmail.com

Can Ertekin
Prof., Dpt. of Farm Machinery and Technologies Eng., Faculty of Agril., Akdeniz University, 07070, Antalya, TURKEY. ertekin@akdeniz.edu.tr

Imad Haffar
Managing Director, Palm Water Jumeirah Village (Slte Office Gate #10) Al Khail Road, P.O. Box 215122, Dubai, U.A.E. Tel+971-4-375-1196, imad.haffar@palmwater.ae

Nguyen Hay
Prof., President of Nong Lam Univ., Linh Trung Ward, Thu Duc District, Ho Chi Minh City, VIET NAM. nguyenhay@gmail.com

Pham Van Lang
VIET NAM. langvcd@yahoo.com


A Senanarong


P Soni


C Ertekin


I Haffar


N Hay


P V Lang


T H Katardjiev


P Kic


J Müller


K P Ferentinos


Nick Sigrimis


E Gasparetto


W B Hoogmoed


Jan Pawlak


O S Marchenko


M Martinov


J Ortiz-Cañavate


Brian G Sims

-EUROPE-

Tihomir Hristov Katardjiev
General Manager at Yogurtson Trade Ltd., Omachi 216-74, Ichikawa-shi, Chiba-ken 272-0801, Japan (BULGARIA). miro@yogurtson.com

Pavel Kic
Professor, Czech Univ. of Life Sciences Prague, Faculty of Eng. 16521 Prague 6-Suchdol, CZECH REPUBLIC. TEL+420-2-2438314 kic@tf.czu.cz

Joachim Müller
Prof. of the Univ. Hohenheim, Institute of Agril. Eng., Head of Agric.l Eng. in the Tropics and Subtropics, Univ. of Hohenheim, 70593 Stuttgart, GERMANY. TEL+49-711-459-22490, Joachim.mueller@uni-hohenheim.de

Konstantinos P. Ferentinos
Researcher, Dept. of Agricultural Engineering, Institute of Soil & Water Resources, Hellenic Agricultural Organization "Demeter" , Ministry of Agriculture and Food of Greece, 61 Dimokratias Av., Athens 13561, GREECE. kpf3@cornell.edu

Nick Sigrimis
Prof., Agricultural University of Athens, Iera Odos 75, Athina 118 55, GREECE. TEL +30-6940940885, ns@aua.gr

Ettore Gasparetto
Former Professor of Agril. Mechanization, Dept. Agril. Eng., Univ. of Milano, Via Galileo Galilei 17, I-35121 Padova, ITALY. TEL+39-0250316619, ettore.gasparetto@unimi.it

W. B. Hoogmoed
Univ. Lecturer, Wageningen Univ., Farm Technology Group, P.O.Box 317, 6708 AA Wageningen NETHERLAND. willem.hoogmoed@wur.nl

Jan Pawlak
Institute for Technology and Life Sciences, Branch in Warsaw, Poland, ul. Rakowiecka 32, 02-532 Warsaw, POLAND. j.pawlak@itp.edu.pl

Oleg S. Marchenko
Prof. and Agril. Engineer, Dept. Head in All-Russia Research Institute for Mechanization in Agric. (VIM), 1st Institutsky proezd, 5, Moscow 109428, RUSSIA. TEL+7-926-492-1207, oleg072000@mail.ru

Milan Martinov
Prof., Faculty of Technical Sciences, Chair for Biosystems Eng., Novi Sad, SERBIA. TEL+ 381-21-485-2369, MilanMartinov@uns.ac.rs

Jaime Ortiz-Cañavate Puig-Mauri
Dpto. Ingenieria Rural Universidad Politécnica de Madrid, Esc. T. S. Ing. Agrónomos 28040-Madrid SPAIN. TEL+34-91-336-5852, jaime.ortizcanavate@upm.es

Brian G. Sims
FAO Agricultural Mechanization Consultant. 3 Bourneside Bedford MK41 7EG, U.K. BrianGSims@aol.com

Retirement Co-editors' Name List

Co-editor's name	Nationality	Inaugural year	Retired year
Adrian Moens	Netherlands	1972	1989
Bala Krishna Shrestha	Nepal	1972	1991
Chul Choo Lee	Korea	1972	2014
Chau Van Khe	Vietnam	1972	1980
Manbahadur Gurung	Bhutan	1972	2006
Merle L. Esmay	U. S. A.	1972	1990
Giuseppe Pellizzi	Italy	1973	2012
Mohamed A. Bedri	Sudan	1973	1987
Shahansha-Uddin Choudhury	Bangladesh	1973	1991
T. B. Muckle	U. K.	1973	1978
Chang Joo Chung	Korea	1975	2014
T. Touggaard Pedersen	Denmark	1975	1990
Bilash Kanti Bala	Bangladesh	1976	1982
George B. Hanna	Egypt	1976	1988
Jun Sakai	Japan	1976	2015
Siswadhi Soepardjo	Indonesia	1976	1985
Tieng-Song Peng Taiwan	Taiwan	1976	2015
Mohammad Ilyas	Pakistan	1977	1981
Amala Prasad Sharma	Fiji	1978	1981
Arumugam Kandiah	Ethiopia	1978	1989
Bherulal T. Devrajani	Pakistan	1978	2004
John Kilgour	U.K.	1978	2014
Satish Chandra	Fiji	1979	1990
Jitendra P. Mittal	Nigeria	1980	1993
Naresh Chandra Saxena	India	1980	1988
Paris Andereou	Lebanon	1980	1984
Wang Wanjun	China	1981	2012
Allah Ditta Chaudhry	Pakistan	1981	2015
Allan L. Phillips	U. S. A.	1981	2004
Julien G. Van Lancker	Brundi	1981	1989
Suppiah Kathirkamathamby	Sri Lanka	1981	1991
Armed Hossain Mirdha	Mexico	1982	1991
A. A. Valenzuela	Chile	1982	2013
David Boakye Ampratwum	Ghana	1982	2011
Kshirode Chandra Roy	Bangladesh	1982	1985
M. H. Abdel Aziz	Saudi Arabia	1982	1991
Krishna Prakash Srivastava	Ethiopia	1983	1989
Muhammad Siddique Chaudhry	U. S. A.	1983	1991
Wimala Tissa Weerakoon	Zambia	1983	1985
Harry D. Henderson	Lebanon	1984	1985
Mohammad Afzal	Pakistan	1984	1994
A. P. Kaloyanov	Bulgaria	1985	2013
Soedjatmiko	Indonesia	1986	2014
Aalbert Anne Wanders	Netherlands	1988	2007
Ali Mahmoud El Hossary	Egypt	1988	2010
Chanchai Rojanasaroj	Thailand	1988	2011
Edward A. Baryeh	Zimbabwe	1988	2014
T. P. Ojha	India	1988	2015
Eltag S. Eldin Mahmoud	Sudan	1990	2011
Henrik Have	Denmark	1990	2009
Graeme Ross Quick	Australia	1995	2015
Rafiq ur Rehman	Pakistan	1995	2015
Abdulsamad Abdulmalik Hazza'a	Yemen	1999	2014
Yunus Pinar	Turkey	1983	2016
William J. Chancellor	U.S.A	1972	2017
Kunihiro Tokida	Japan	2016	2017
Shujun Li	China	2012	2018

Back Issues

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol.47, No.3, Summer, 2016-)

◇ ◇ ◇

Vol.47, No.3, Summer 2016

Grain Recovery Efficiency of a Developed Rice Stripper Harvester for Rural Use in Nigeria (Adisa A. F.) 7
Development of Low Cost Plastic Evaporative Cooling Storage Structure (V. K. Chandegara, Sachin C. Sureja, Suman B. Vamja, Kajal R. Vaghela) 14
Effect of Mechanical Planting on Grain and Straw Yields, Water Use Efficiency and Profitability of Rice Cultivation (P. C. Mohapatra, M. Din, S. P. Patel, P. Mishra) 23
Design of Nitrogen (Liquid Urea) Metering Mechanism for Point Injection in Straw Mulched Fields (Jagvir Dixit, J. S. Mahal, G. S. Manes) 28
Evaluation of Tractor Drawn Potato Planter in West Bengal State of India (Subrata Karmakar, Subhajit Roy, Prasenjit Mandal, Rahul Majumder) 36
Design and Development of a Power Operated Tamarind Huller Cum Deseeder (Jansi Sheeba Rani, J, P. Rajkumar, R. Kailappan) 41
Energy Use for Wheat Cultivation in Southeast Anatolia Region of Turkey (H. Huseyin Ozturk) 47
Design and Development of Cup in Cup Feed Metering Seed Drill for Seed Pattern Characteristics Study of Paddy Seeds (M. K. Ghosal, M. Din) 54
Development and Evaluation of Aloe Vera Gel Expulsion Machine (V. K. Chandegara, A. K. Varshney) 60
A Review on Status of Gum Tapping and Scope for Improvement (S. C. Sharma, N. Prasad, S. K. Pandey, S. K. Giri) 68
Design, Manufacturing and Field Test of Animal-drawn Ground Nuts planting Machine for Rural Farming in Northern Kordofan (Sudan) (Mohamed H. Dahab, Moayed M. Balal, Rafie M. Ali) 76
Research and Application of Osmotic Dehydration Technique in Preservation of Fresh Guavas (Psidium guajava L.) (Wael Mohamed Elmessery, Said Elshahat Abdallah) 82

◇ ◇ ◇

Vol.47, No.4, Autumn 2016

Investigation on Possibilities for Sustainable Provision of Corn Stover as an Energy Source: Case Study for Vojvodina (Marko Golub, M. Martinov, S. Bojic M. Viskovic, M. Martinov, D. Djatkov, G. Dragutinovic, J. F. Dallemand) 7
Design and Evaluation of Biomass Combustor and Solar Dryer for Turmeric Processing (H. Sanchavat, S. Kothari) 16
Effect of Conservation Agricultural Practice on Energy Consumption in Crop Production System in India (K. P. Singh, C. R. Mehta, M. K. Singh H. Tripathi, R. S. Singh) 21
Moisture Dependent Dimensional and Physical Properties of Re-Fabricated Rice (Syed Zameer Hussain, Baljit Singh) 27
Design of Rotary Weeder Blade (S. P. Modak, Baldev Dogra, Ritu Dogra, Dinesh Kumar) 32
Selected Anthropometric Study and Energy Required for Grading Tomatoes by Farmers using Hoes in Zaria (A. Afolabi, M. Abubakar, O. T. Oriolowo) 41
Low Cost Fermenter for Ethanol Production from Rice Straw in Egypt (Mohamed A. A. A., R. K. Ibrahim, M. A. M. Elesaily) 47
Development and Evaluation of a Pneumatic Dibble Punch Planter for Precision Planting (Majid Dowlati, Moslem Namjoo) 53
Development and Evaluation of Improved TNAU Mini Dhal Mill (P. Rajkumar, C. Indu Rani, R. Visvanathan) 60
Development of Three-Dimensional Force Measurement Instrument for Plough in Mountain Region (Karma Thinley, M. Ueno, K. Saengprachatanarug, E. Taira) ... 66
Energy use Pattern and Economic Analysis of Jute Fibre Production in India a case study for West Bengal (V. B. Shambhu) 74
Animal Drawn Improved Sowing Equipment for Mustard in Terraces of Sikkim in India (R. K. Tiwari, S. K. Chauhan) 82
A Tractor Drawn Vegetable Transplanter for Handling Paper Pot Seedlings (B. M. Nandede, H. Raheman) 87

◇ ◇ ◇

Vol.48, No.1, Winter 2017

Low Cost Fermenter for Ethanol Production from Rice Straw in Egypt (Mohamed A. A. A., R. K. Ibrahim, M. A. M. Elesaily) 7
Shearing Characteristics of Sorghum Stalk (Mrudulata Deshmukh, S. K. Thakare S. W. Jahagirdar) 13
Design of a Portable Dates Cluster Harvesting Machin (Ahmed Nourani, F. Kaci, F. G. Pegna, A. Kadri) 18
Development of a Paddle Wheel Aerator for Small and Medium Fish Farmers in Nigeria (Omofunmi O. E., Adewumi J. K., Adisa A. F., Alegbeleye S. O.) 22
Determination of Residue, Drift and Biological Efficacy of Different Spray Methods Against Flower Thrips (Frankliniella spp.) (Thys., Thripidae) in Strawberries (N. Yarpuz-Bozdogan, E. Atakan, A. M. Bozdogan, T. Erdem, N. Daglioglu, E. Kafkas) 27
Determination of Dermal Exposure of Operator in Greenhouse Spraying (N. Yarpuz-Bozdogan, A. M. Bozdogan, N. Daglioglu, T. Erdem) 33
Regional Distribution of the World's Tractor Stock (Jan Pawlak) 39
Storage and Handling Engineering of Sugarbeet Pulp as a Feedstuff for Animal Feeding (Said Elshahat Abdallah, Wael Mohamed Elmessery) 45
Promoting Agricultural Productivity in Nigeria − The Case of the Agricultural Credit Guarantee Scheme Fund (ACGSF): 1981 to 2014 (M. A. Olaitan, B. O. Ogunlaja, L. Juma, M. A. Olasupo, J. Yusuf, O. A. Oyelade) 59
Farm Mechanization Strategy for Promotion of Improved Equipment Under Animal Based Farming in Nagaland-India (R. K. Tiwari) 71
Performance Evaluation of Self-Propelled Groundnut Combine (T. Senthilkumar, D. M. Jesudas, D. Asokan) 76
Prototype: A Ridge Profile Mechanical Power Weeder (D. S. Thorat, P. K. Sahoo, Dipankar De, Mir Asif Iquebal) 81

◇ ◇ ◇

Vol.48, No.2, Spring 2017

Present Status and Future Trends of Engineering Science in Mongolian Agriculture (G. Enkhbayar, C. Byambadorj, B. Hymgerel, D. Baatarkhyy) 13
Agricultural Machinery in Kyrgyz Republic (Kunio Nishizaki) 17
Agricultural Machinery Market of the Russian Federation (N. Sandakova, H. Hasegawa, T. Sandakov, E. Kolesnikova) 22
Government Policy of Agricultural Machinery in the Russian Federation (E. Kolesnikova, H. Hasegawa, S. Sidorenko, N. Sandakova, A. Melnikov) 27
Current Situation, Issues and Trends of Mechanization for Grain Harvesting in the Russian Federation (S. Sidorenko, E. Trubilin, E. Kolesnikova, H. Hasegawa) 31
Role of Agricultural Education for the Development of Agro-Industrial Complex in Primorsky Krai, Russian Federation (K. Andrei, Z. Dmitrii, H. Hasegawa) 36
Present Situation and Future Prospect for Farm Mechanization in Bhutan (Kinga Norbu) 40
Rice Mechanization in Laos and Its Current Issues (Hiroshi Akutsu) 44
Trends of Tractorization in Indian Agriculture (T. Senthilkumar, N. S. Chandel, C. R. Mehta, B. S. Gholap) 50
Present Status and Future Prospects of Agricultural Machinery Industry in Iran (Behroozi Lar) 60
Farming Systems in Oman and Mechanization Potentials (H. P. W. Jayasuriya, A. M. Al-Ismaili, T. Al-Shukaili) 66
Controlled Environment Agriculture in Oman: Facts and Mechanization Potentials (A. M. Al-Ismaili, N. K. Al-Mezeini, H. P. Jayasuriya) 75
Agricultural Mechanization in Jordan (Bassam A. Snobar) 82
Japanese Agricultural Machinery Situation and the Role of Institute of Agricultural Machinery (Hiroshi Fujimura) 88

◇ ◇ ◇

Vol.48, No.3, Summer 2017

Design, Development and Evaluation of Whole Cane Combine Harvester (Joby Bastian, P. K. Sureshkumar, B. Shridar, D. Manohar Yesudas) 7
Detaching of Saffron Flower Parts Based on

Aerodynamic Properties (Abbas Moghanizadeh) 14
Design, Development and Evaluation of Manually Operated Seabuckthorn Fruit Harvesting Tools (D. K. Vatsa, Virendra Singh) 20
Design and Development of Groundnut planter for Power Weeder (A. Ashok Kumar, A. Anil Kumar, V. Vidhyadhar, K. Mohan, Ch. Suresh, A. Srinivasa Rao, M. V. Ramana) 25
Assessment of Design Variations in Tractor-Trailer Systems on Indian Farm for Safe Haulage (Satish Devram Lande, Indra Mani, Adarsh Kumar, Tapan Kumar Khura) 31
Effect of Mulches and Drip Irrigation Management on the Quality and Yield of Potato Relating Hydro-Thermal Regime of Soil (Kamal G. Singh, Amanpreet Kaur, R. P. Rudra, Alamgir A. Khan) 37
Design and Development of a Digital Dynamometer for Manually Operated Agricultural Implements (Rohul Amin, Murshed Alam, Md. Rostom Ali) 44
Development and Evaluation of Impact and Shear Type Tamarind Deseeder (Karpoora Sundara Pandian N., Rajkumar P., Visvanathan R.) 52
Effect of Plant Crushing by Machine Traffic on Re-Generation of Multi-Cut Berseem Fodder (C. S. Sahay, P. K. Pathak, P. N. Dwivedi) 58
Design, Fabrication and Drying Performance of Flash Dryer for High Quality Cassava Flour (A. Kuye, A. O. Raji, O. O. Otuu, E. I. Kwaya, W. B. Asiru, I. B. AbdulKareem, B. Alenkhe, D. B. Ayo, Sanni L. O.) 63
Effect of Planting of Onion Sets in Different Orientations on Crop Growth for Development of Onion Set Planter (A. C. Rathinakumari, D. M. Jesudas) 71
A Contribution of Foam Separation Technique and Electro-Coagulation for Dairy By-Products Treatment (Said Elshahat Abdallah, Wael Mohamed Elmessery) 77
Development of a Damping System for Reversible Mouldboard Plows Using Multiple-Criteria Decision Analysis (A. Mahdavian, H. Aghel, S. Minaei, G. H. Najafi, H. Zareiforoush) 88

◇ ◇ ◇

Vol.48, No.4, Autumn 2017

Farm Mechanization Strategy for Promotion of Animal Drawn Improved Farm Equipment in Nagaland State of India (R. K. Tiwari, S. K. Chauhan) 7
Available Resources for Farm Mechanization in Two Urban Areas of Enugu State of Nigeria (J. C. Adama) 13
A Cost Analysis Model for Agricultural Bush Clearing Machinery (J. C. Adama, C. O. Akubuo) 18
Effect of Moisture Content on Physical Properties of Finger (Eleusine coracana) Millet (K. P. Singh, R. R. Potdar, K. N. Agrawal, P. S. Tiwari, S. Hota) 24
An Innovative Versatile Multi-crop Planter for Crop Establishment Using Two-wheel Tractors (ME Haque, RW Bell, AKMS Islam, KD Sayre, MM Hossain) 33
Development of Pneumatic Assisted Electronically Controlled Automatic Custard Apple Pulper (V. Eyarkai Nambi, R.K.Gupta, R. K. Viswakarma, R. A. Kausik) 38
Design, Development and Evaluation of Neem Depulper (R. C. Solanki, S. N. Naik, S. Santosh, A. P. Srivastava, S. P. Singh) 45
Development of A Hydro-Separating Cowpea Dehuller (J. O. Olaoye, F. B. Olotu) 52
Effect of Conservation Tillage and Crop Residue Management on Soil Physical Properties and Crop Productivity of Wheat (V. P. Chaudhary, M. Parmanik) 62
Design and Development of Pedal Operated Ragi Thresher for Tribal Region of Odisha, India (S. Hota, J. N. Mishra, S. K. Mohanty, A. Khadatkar) 71
Performance Evaluation of Power Weeders for Paddy Cultivation in South India (T. Seerangurayar, B. Shridar, R. Kavitha, A. Manickavasagan) 76
Design and Development of A Pull Type Four Row Urea Super Granule Applicator (M. Alam, A. Kundu, M. A. Haque, M. S. Huda) 82

◇ ◇ ◇

Vol.49, No.1, Winter 2018

Agricultural Mechanization in Southwestern China during Transitional Period: A Case Study (C. Jian) 7
Development and Performance Evaluation of a Hydraulic Press for Animal Feed Blocks Formation (M. A. Basiouny) 11
Development of a Sorting System for Fruits and Vegetables Based on Acoustic Resonance Technique (Karthickumar P., Sinija V. R., Alagusundaram K., Yadav B. K.) 22
Promotion of Self-propelled Rice Transplanters in Odisha State of India (P. Samal, M. Din, B. Mondal, B. N. Sadangi) 28
The Influence of the Ginning Process on Seed Cotton Properties (S. A. Marey, A. E. El-Yamani, I. F. Sayed-Ahmed) 36
Design Analysis and Optimization of Rotary Tiller Blades Using Computer Software (G. M. Vegad, R. Yadav) 43
Electronic Hitch Control Valve for Massey Ferguson 285 Tractors (N. Moradinejad) ... 50
Utilization Pattern of Power Tillers in Shivalik Hills of India—A Case Study (S. Singh, D. K. Vatsa) 57
Trend Analysis of Vegetation Indices Using Spectroradiometer at Different Growth Stages of Cotton (K. A. Gautam, V. Bector, V. Singh, M. Singh) 63
Research on A Method to Measure and Calculate Tillage Resistance of Tractor Mounted Plough (H. Jiangyi, L. Cunhao) 67
Outline to the Ukrainian Market of Agricultural Tractors in 2016 (K. Syera, G. Golub, H. Hasegawa) 74
Power Tiller Operated Zero-till Planter for Pea Planting in Rice Fallow of North East India (S. Mandal, A. Kumar, C. R. Mehta, R. K. Singh) 79

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

Criteria for Article Selection

Priority in the selection of article for publication is given to those that –

a. are written in the English language;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written in MS DOS format.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. The AMA does not pay for articles published.
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article needs to be sent to Co-operating Editor in the writer's neighboring country. Please note that it is AMA Chief Editor that decide whether publish each submitted paper on AMA or not. Even if Co-operating Editor found your manuscript suitable for publication on AMA, it can not the case with AMA Chief Editor.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent by E-mail with Word File and PDF File attached.
b. The data for graphs and photographs must be saved into piecemeal data and enclosed (attached) with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
(i) brief and appropriate title;
(ii) the writer(s) name, designation/title, office/organization; and mailing address;
(iii) an abstract following ii) above;
(iv) body proper (text/discussion);
(v) conclusion/recommendation; and a
(vi) bibliography
d. Tables, graphs and diagrams must be numbered. Table numbers must precede table titles, e.g., "Table 1 Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Fig. 1 View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies **in US dollars** and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

SUBSCRIPTION/ORDER FORM

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (AMA)

Issued Quarterly

AMA has Achieved an IMPACT FACTOR!!

AMA has been read by those involved in agricultural machinery and industry all over the world since the first publishment in 1971. Thanks to many contributions from both the readers and writers, in 2012, we have achieved an Impact Factor, established by Thomson Reuters in U.S.A. AMA is the only Japanese agricultural machinery and industry related magazine which achieved an Impact Factor.

Subscription Rate (includes surface mail postage)

Annual (4 issues).......................... ￥8,000
Single copy...................................... ￥2,500

(Check one)
☐ Please send me/us an invoice
☐ I/We enclose remittance for ￥__________________
☐ Please charge my/our credit card
　☐ VISA
　☐ MASTER　Card. No. ______________________________

Exp. date ______________________________

Signature ______________________________

We deeply appreciate your payment by credit card (NO EXTRA CHARGE NEEDED).
We charge you extra 4,000 JPY when paid by check or wire transfer.

****

Name: ______________________________

Firm: ______________________________

Position: ______________________________

Address: ______________________________
(block letters)

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
1-12-3 Kanda-Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Tel. +81-3-3291-3674, Fax. +81-3-3291-5717
URL: http://www.shin-norin.co.jp
E-Mail: ama@shin-norin.co.jp

We provide a series of machines from nursery cabinet to conveyor and try to help farmers for more efficient farm work.

container

- For conveying rough rice from field
- Fit for compact tractors
- With optional caster and rough rice conveyance hose, you can easily set it up and take out rough rice in a short time

capacity
1500 - 4900 L
(GK11-BG)

nursery cabinet

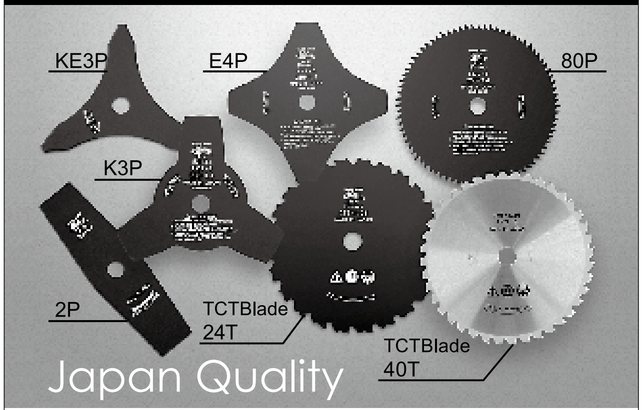
- For favorable growing of seedlings
- Keeping a fixed temperature in the range of 5℃ to 40℃
- Easily assembled and installed

(NK-240)

Ishii Factory Co., Ltd.

4-1-13 Kyoden, Sakata-shi, Yamagata-ken 998-0102, JAPAN
TEL: +81-234-28-8239 FAX: +81-234-28-8256
URL: http://isi-mfg.com/ E-mail: isi-support@isi-mfg.com

Japanese high quality cutting blades for agricultural



Stabilized quality by the start-to-finish production system

We especially have strength in manufacturing blades with high cutting edge and have excellent durability.

We have been supplying these blades to agricultural and gardening industries for more than 50 years in over 30 countries across the world.

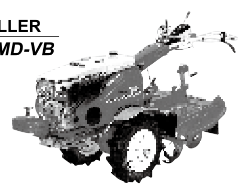
SANYO METAL WORKS Co., Ltd.

301-1, Torimachi, Miki, Hyogo, 673-0456, Japan
TEL : +81-794-82-0188 FAX : +81-794-83-6009
Mail : info@sanyo-mt.co.jp SANYO METAL website ▶

MAMETORA DEDICATES TO AGRICULTURE ALL OVER THE WORLD

With originality, reliability and passion, we fulfill the needs of our customers. We're always making efforts to manufacture products of high quality and are pleased to devote ourselves to the food industry in the world as well as that in Japan.

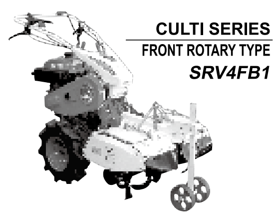
TILLER
HMD-VB



MAMETORA

CULTI SERIES
REAR ROTARY TYPE
MPC6XSB1

CULTI SERIES
FRONT ROTARY TYPE
SRV4FB1



MAMETORA AGRIC. MACHINERY CO., LTD.

HEAD OFFICE : 2-9-37, NISHI, OKEGAWA-SHI, SAITAMA-KEN 363-0017 JAPAN
TEL: +81-48-771-1181 FAX: +81-48-771-1529
URL: http://www.mametora.co.jp E-mail: info@mametora.co.jp

The next is on Latin America !

Will be out in spring, 2019

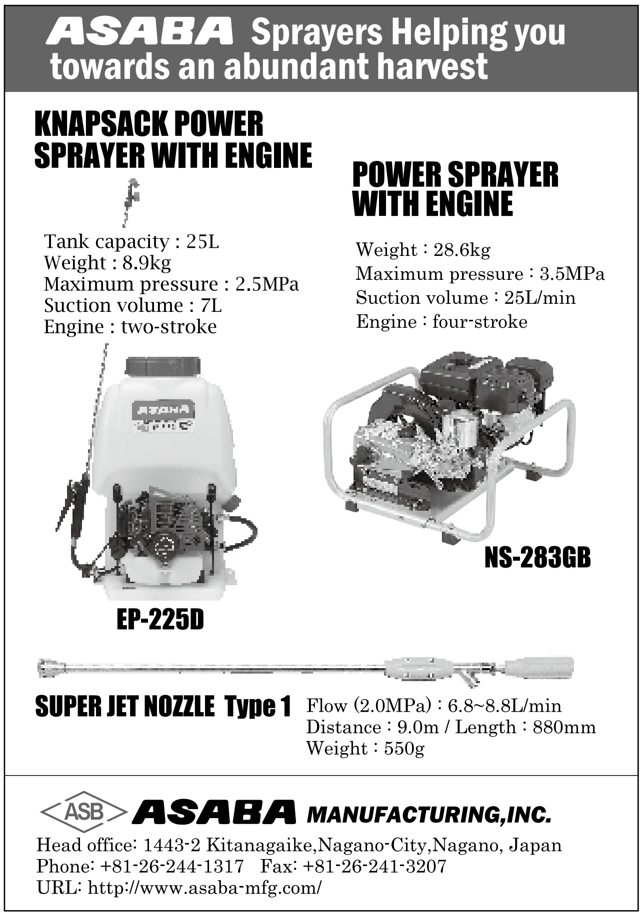
AMA Announcement

Hope you enjoyed this special issue.
We plan to feature African region again in smaller scale in autumn.
Still more excitement is coming soon after that.
We're publishing another special issue in spring, 2019 !
The next destination is Latin America.
What new discoveries will we make there ?

Wait and see !!

Farm Machinery Industrial Research Corp.

1-12-3 Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054 JAPAN
TEL: +81-3-3291-3674 FAX: +81-3-3291-5717 Email: ama@shin-norin.co.jp


Sanyokiki
Tractor Arm-type Grass Mower (Attachment)
Hammer Knife Mower
Hydraulic Shovel Grass Mower Attachment
(Power shovel / Excavator Grass Mower Attachment)
Hammer Knife Mower
Farm Tractor Cargo Work Machine (Attachment)
Front Loader
SANYO KIKI CO.,LTD.
Tel: +81-(0)865-64-2871 http://www.sanyokiki.co.jp/
Telefax: +81-(0)865-64-2874 E-mail san@sanyokiki.co.jp
3858,Shinjo,Satosho-cho,Asakuchi-gun,Okayama,719-0392 Japan
ISO 9001
ISO9001
JQA-QM4853

ASABA Sprayers Helping you towards an abundant harvest
KNAPSACK POWER SPRAYER WITH ENGINE
Tank capacity : 25L
Weight : 8.9kg
Maximum pressure : 2.5MPa
Suction volume : 7L
Engine : two-stroke
EP-225D
POWER SPRAYER WITH ENGINE
Weight : 28.6kg
Maximum pressure : 3.5MPa
Suction volume : 25L/min
Engine : four-stroke
NS-283GB
SUPER JET NOZZLE Type 1
Flow (2.0MPa) : 6.8~8.8L/min
Distance : 9.0m / Length : 880mm
Weight : 550g
ASB ASABA MANUFACTURING,INC.
Head office: 1443-2 Kitanagaike,Nagano-City,Nagano, Japan
Phone: +81-26-244-1317 Fax: +81-26-241-3207
URL: http://www.asaba-mfg.com/

JUA TECHNOLOGIES INTERNATIONAL
Klein E. Ileleji, PhD
Cofounder & CEO
Email: klein.ileleji@dehymeleon.com
Tel: +1(765) 490-2151
www.dehymeleon.com
USAID FROM THE AMERICAN PEOPLE
FPL
PURDUE FOUNDRY
elevate ventures

ものづくり日本大賞
優秀賞

Winners of the Sixth Monodzukuri Nippon Grand Award METI Excellence Prize

In Product And Engineering Division
"Canycom Masao Team"
The Prize To Be Presented By The Prime Minister.

4 Wheel Drive Brush Cutter MASAO

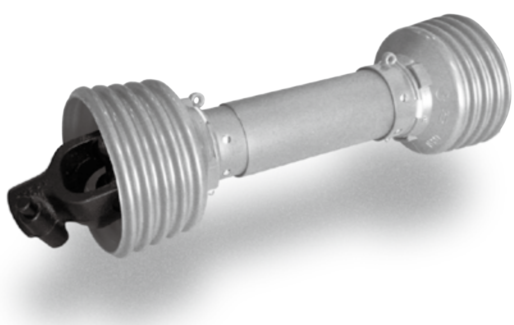
CANYCOM
CanyCom

Head Office／
90-1 Fukumasu, Yoshii-machi,Ukiha-city, Fukuoka 839-1396, Japan TEL+81-92-272-1104 ･FAX+81-92-272-1119 http://www.canycom.jp/eng/

MATSUI-W
MATSUI WALTERSCHEID LTD.
MATSUI GROUP
SINCE 1980

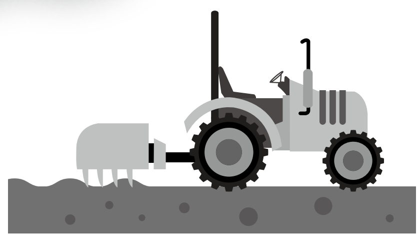
PTO Drive Shafts

Continuously seeking to provide customers with globally optimized products



High Durability for Muddy water

ISO 9001 / 14001 Certified



Expert of PTO Drive Shafts **MATSUI WALTERSCHEID LTD.**
937-5 Komagome, Koga-city, Ibaraki 306-0126 Japan TEL：+81-280-75-1321 FAX：+81-280-76-6700
URL：http://www.m-w.co.jp/ E-mail：info@m-w.co.jp

TAIYO

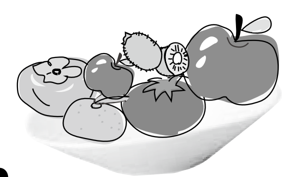
Rotary Tiller Blade

Born in Japan
Make in India
Now to the World

TAIYO Co., Ltd. www.k-taiyo.co.jp

TAIYO INDIA PVT. LTD. taiyoindia.com

CHIKUSHIGO Sorting Machine



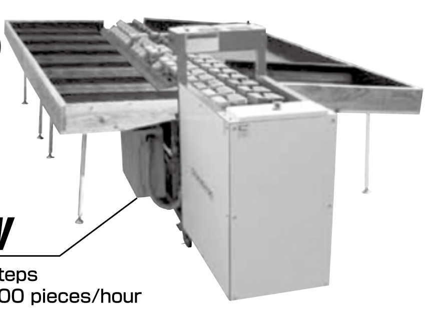
Long Awaited High Performance Labor Saving Machine !

Electronic Weight Sorting Machine

One row one way type

TZ5-477S

number of steps : 5 steps
Hourly capacity : 4,300 pieces/hour



Two row two way type

TZ5-477W

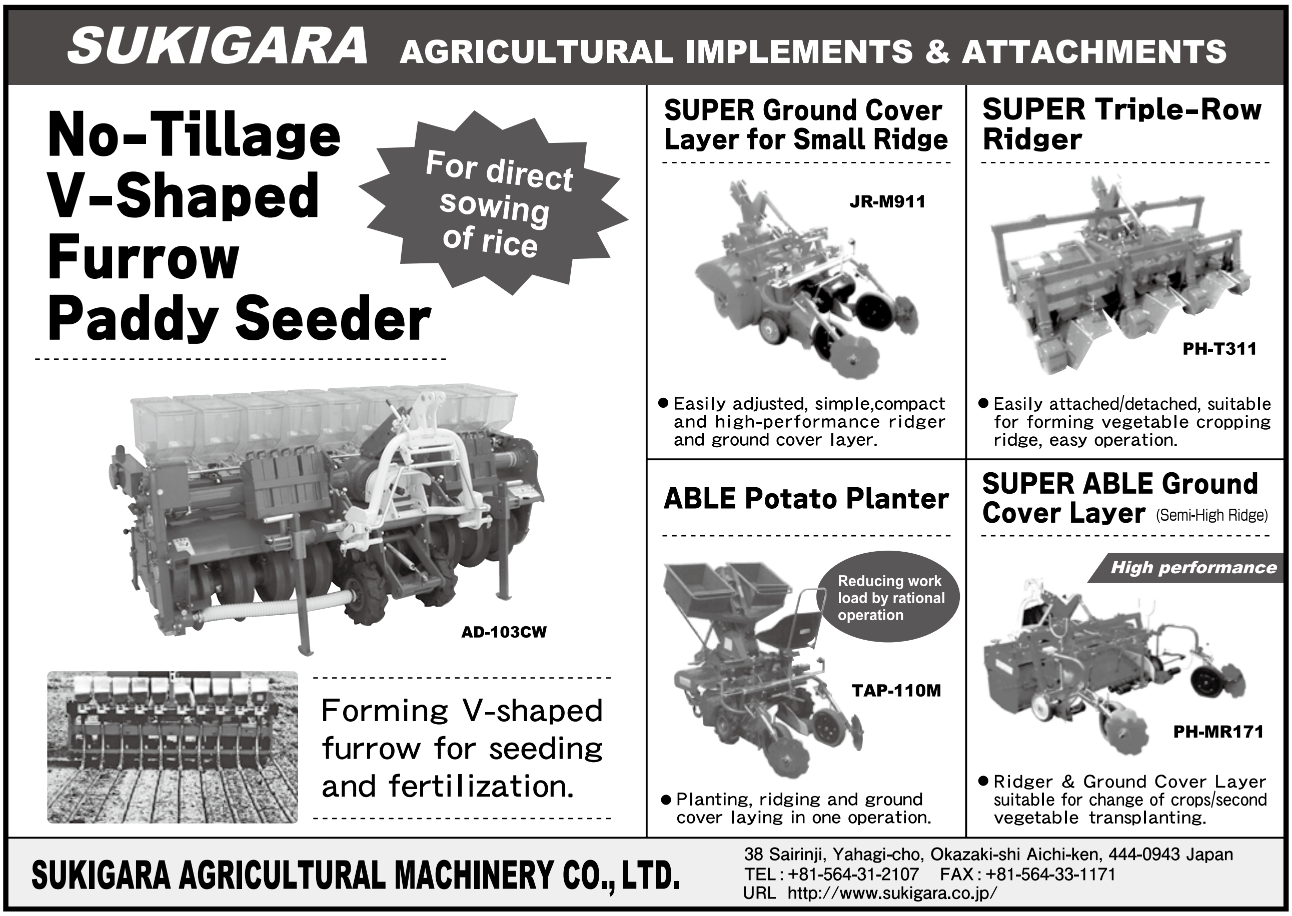
number of steps : 5 steps
Hourly capacity : 8,600 pieces/hour

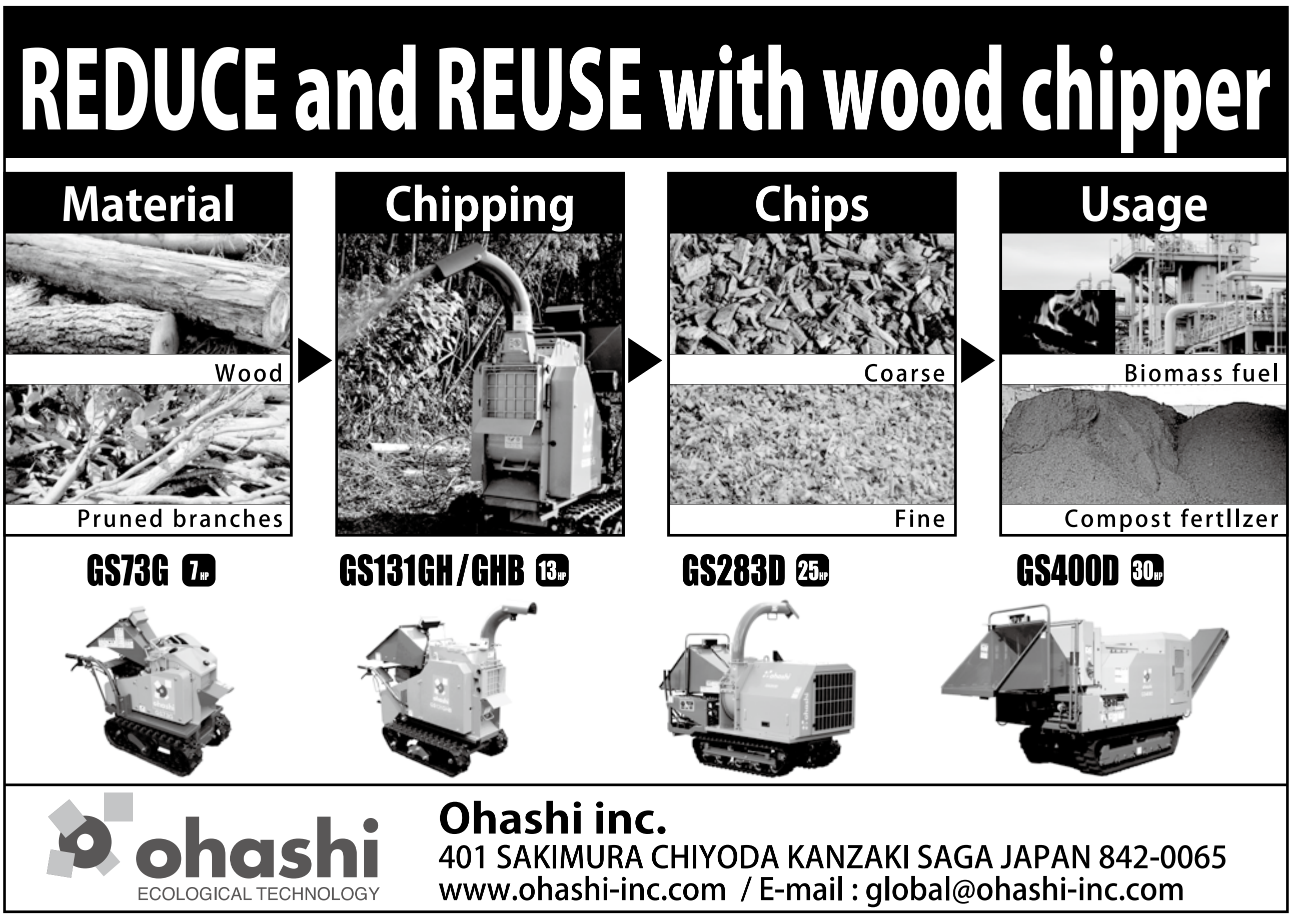
Instantly measure the weight and sort the products on moving tray

- Usable for sorting tomato, persimmon, pear, apple, orange, kiwi fruit and etc
- Five sorting steps equipped, sorting criteria is easily specified by 10 key
- Range of electronic sorting is 10g ~ 999g. With automatic control by computer, products are sorted within the range of specified criteria
- Large shoot makes it easy to pack the products in the case

CHIKUSHIGO CORPORATION
www.chikushigo.co.jp

29-3 Ino, Umimachi, Kasuya-gun,
Fukuoka-ken 811-2104 Japan
TEL: +81-92-932-1662 FAX: +81-92-933-5787


SUKIGARA AGRICULTURAL IMPLEMENTS & ATTACHMENTS
No-Tillage V-Shaped Furrow Paddy Seeder
For direct sowing of rice
AD-103CW
Forming V-shaped furrow for seeding and fertilization.
SUPER Ground Cover Layer for Small Ridge
JR-M911
● Easily adjusted, simple,compact and high-performance ridger and ground cover layer.
SUPER Triple-Row Ridger
PH-T311
● Easily attached/detached, suitable for forming vegetable cropping ridge, easy operation.
ABLE Potato Planter
Reducing work load by rational operation
TAP-110M
● Planting, ridging and ground cover laying in one operation.
SUPER ABLE Ground Cover Layer (Semi-High Ridge)
High performance
PH-MR171
● Ridger & Ground Cover Layer suitable for change of crops/second vegetable transplanting.
SUKIGARA AGRICULTURAL MACHINERY CO., LTD.
38 Sairinji, Yahagi-cho, Okazaki-shi Aichi-ken, 444-0943 Japan
TEL : +81-564-31-2107 FAX : +81-564-33-1171
URL http://www.sukigara.co.jp/


REDUCE and REUSE with wood chipper
Material
Wood
Pruned branches
Chipping
Chips
Coarse
Fine
Usage
Biomass fuel
Compost fertllzer
GS73G 7HP
GS131GH/GHB 13HP
GS283D 25HP
GS400D 30HP
ohashi
ECOLOGICAL TECHNOLOGY
Ohashi inc.
401 SAKIMURA CHIYODA KANZAKI SAGA JAPAN 842-0065
www.ohashi-inc.com / E-mail : global@ohashi-inc.com

Technology Inherited from the Past to the Present: Fearlessly Facing the Future.

Our goal for the future is to create an environment of balance between people,
agriculture and nature, and to this end, we intend to progress toward a secure future
with the trust and rich experiences, and to support a safe,
comfortable living environment for everyone while achieving harmony with the natural environment.

From October 1st, 2017, IHI STAR Machinery Corporation(IHI STAR)
& IHI Shibaura Machinery Corporation (ISM) has merged, forming IHI Agri-Tech Corporation (IAT).

SHIBAURA STAR

IHI Agri-Tech Corporation

http://www.ihi.co.jp/iat/en/

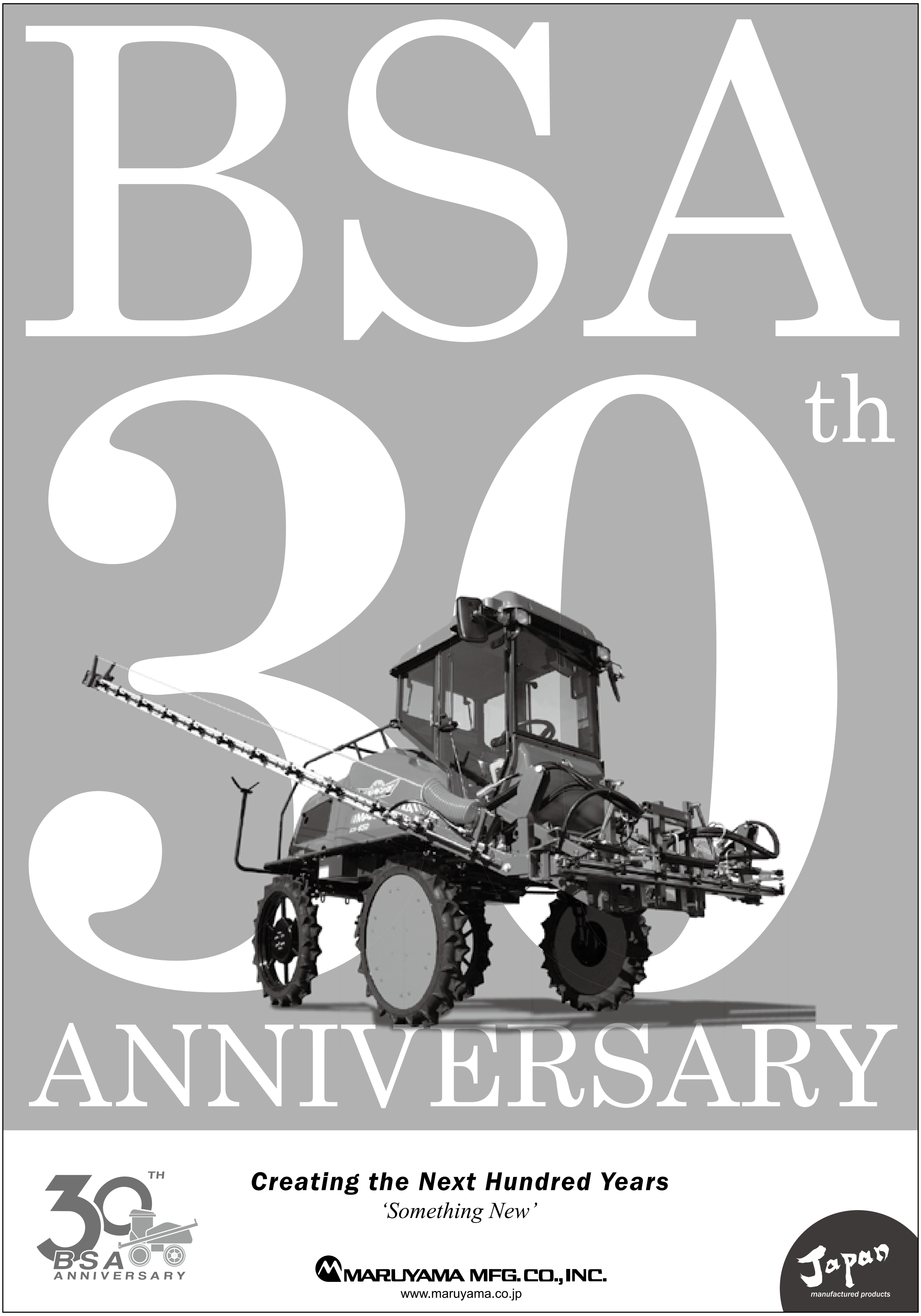
Hammer knife mower | Medium-sized cutting round baler | Rotary lawn mower | Fertilizer spreader

Maize baler wrapper | Wrapping machine | Square baler

IHI Realize your dreams

IHI Agri-Tech Corporation


MOROOKA TECHNOLOGY to WORLDWIDE JOBSITE
HST SYSTEM AND RUBBER CRAWLER
MOROOKA developed Rubber Crawler about 40 years ago with joint development with Bridgestone. Rubber Crawler provides high performance even on irregular ground, stable moving on the sloping ground or snowy land.
Team MOROOKA Helps You ! Here's Experts in Each Field !!
Best Buddy in Muddy Fields
Tough and stable Rubber Crawler Forklift
Powerful and Invinsible Hero
Carrier Dump for a large amount
For fertilizer transportation
For sugar cane plant transportation
For potato transportation
Specialties of MOROOKA Products
Pioneer of the rubber crawler
● Seamless and durable rubber crawler assures high performance movement with low ground pressure.
● Simple and compact design allows easy operation for everybody.
● Ship structure underbody and rotary bogie system absorb the impact and allow the stable movement.
● Rubber crawler is used as base body of wide range of industrial machines.
● Rubber crawler and HST (hydrostatic transmission) system enables easy control for smooth & stable movement and huge driving power.
For forestry
For agriculture and multipurpose
ROTARY SCREEN
FORWARDER
MOBILE WOOD CRUSHER
FORKLIFT
SHOVEL LOADER
CARRIER
MOROOKA
MOROOKA Co., Ltd.
358, Shoubeeshindenmachi, Ryugasaki city, Ibaraki Prefecture, 301-0031, Japan
TEL : +81-297-66-2111 FAX : +81-297-66-3110 E-mail : info@morooka.co.jp
URL : www.morooka.co.jp (Japanese) www.morooka.com (English)


BSA
30th
ANNIVERSARY
30TH BSA ANNIVERSARY
Creating the Next Hundred Years
'Something New'
MARUYAMA MFG.CO.,INC.
www.maruyama.co.jp
Japan
manufactured products


www.mahindrafarmequiment.com
NOT JUST PIONEERING FARM EQUIPMENTS,
BUT LEADING A REVOLUTION GLOBALLY TOO.
We offer products that are tough, reliable, technologically superior and work with you at every step
of farming to open new doors of possibilities for you. Come, rise with us.
*By Volume
TRACTORS
IMPLEMENTS &
FARM MACHINERIES
HARVESTERS
RICE VALUE CHAIN
SOLUTIONS
Mahindra
Rise.


GCR1380
MITSUBISHI
Mitsubishi Agricultural Machinery NEW DESIGN CONCEPT
EAGLE DESIGN
POWER AND PRIDE. GCR1380
MITSUBISHI MAHINDRA AGRICULTURAL MACHINERY CO., LTD.
2-133-4,Sakurada,Kuki,Saitama,340-0203 Japan
http://www.mam.co.jp