Paradigm Shifts and the Development of Agricultural Mechanization in Sub Saharan Africa: A Case Study of Farm Power.

By Geoffrey C. Mrema

EXECUTIVE SUMMARY

The development of agriculture in Sub-Saharan Africa [SSA] using higher levels of farm power has had a chequered history over the seven decades from 1945 to 2015. Agricultural mechanization has been widely [and still is] supported in SSA by farmers, local leaders, policy makers and politicians. It has, however, been a controversial issue in some circles including among external experts and commentators. The objective of this paper is to provide a summary background review of the paradigm shifts which have occurred concerning the role of farm power in SSA agriculture over the period 1945-2015.

The mechanization paradigm of the 1950s & 60s did postulate that the provision of farm power, for field operations like land preparation, would be through mechanical technologies like tractors, without necessarily evolving through a transitional stage of using draft animals. This was seen then [in the 1950s and early 1960s] as a feasible option given the land abundance status of many countries in SSA and the difficulties of finding alternative sources of farm power - low population made the hand tool technology not a viable option and prevalence of the tsesse fly making use of draft animals difficult in large areas of SSA. The development programs of most countries in SSA in the 1950s & 1960s crafted by the departing colonial authorities with the assistance of major multilateral development agencies like the FAO, World Bank etc., were based on this paradigm.

From mid 1960s, there were, however, concerns raised by several influential experts and organizations on the impact and efficacy of the tractorization paradigm in mechanization programs in developing countries. These included the intermediate technology movement which advocated for a more evolutionary approach through the so called intermediate or appropriate technologies; the International Labour Organization [ILO] whose concern was the effect the use of tractors had on employment of rural labourers and the environmental movement concerned with the impact on the environment. A global expert consultation was convened by FAO and OECD in Rome in February 1975 to resolve the issues involved. The consultation recommended selective or appropriate mechanization, which combines hand tool, animal and mechanically powered agricultural implements and equipment suited to the physical, cultural, economic, and technological environment of the country concerned. A consensus was also reached on the manpower requirements for mechanization and the need to treat farm power as an input in agricultural production just like fertilizers, seeds etc. FAO was requested to develop guidelines to help member countries in developing their agricultural mechanization strategies [AMS]. The AMS guidelines were developed by FAO through wide consultation and released in 1981 which has been implemented by several countries since then.

A new paradigm was proposed in 1987, specifically linking the development of agricultural mechanization in SSA to the evolution of the farming systems as they intensify from shifting cultivation to more permanent production systems. This paradigm attributed the lack of progress in mechanization in SSA to, inter alia the public sector dominated tractorization programs of the 1960s & 70s. A study published by the World Bank in 1987 recommended a shift of assistance from tractors to draft animal power [DAP]. There followed then a wave of relatively well funded DAP programs and networks throughout SSA implemented for much of the 1990s. However, by 2005 it became apparent that the DAP programs and networks were not the panaceas to the mechanization problem in SSA while tractor imports had significantly declined in all countries. A re-examination of the whole process of agricultural mechanization development then commenced which culminated in the approval, in 2018, of the Framework for Sustainable Agricultural Mechanization in Africa F-SAMA with its ten priority elements.

The priority element no. 1 of F-SAMA is therefore: Boosting farm power through innovative business models. The goal is to ubiquitously provide mechanization services including farm power as an input in agricultural production through commercially sustainable enterprises. It is posited that development of the innovative business models and systems through which the enterprises are enabled to offer mechanization services such as primary land preparation for a significant part of the year and across countries and sub regions is the sure way to efficiently and effectively, boost the availability of farm power to all the farming groups be they small, medium, or large scale through environmentally and socio-economically sustainable mechanisms. Highlights of other key issues like size of tractors, impact on the environment, human resources and the institutional framework required for successful implementation of this element of F-SAMA are discussed. The SSA countries need to remain focused on the long-term goal as well as exchange information and experience through the Africa-Mechanize platform if they are to succeed in implementing this element of F-SAMA.

******************************************
INTRODUCTION

1. THE DEVELOPMENT OF MECHANIZED AGRICULTURE USING HIGHER LEVELS OF FARM POWER IN SUB SAHARAN AFRICA [SSA] HAS HAD A CHEQUERED HISTORY OVER THE SEVEN DECADES PERIOD FROM 1945 TO 2015 [AUC/FAO, 2018]. DURING THIS PERIOD, SIGNIFICANT EFFORTS HAVE BEEN DIRECTED AT IMPLEMENTING PROGRAMS WITH THE OBJECTIVE OF IMPROVING THE UTILIZATION OF FARM POWER AS AN INDISPENSABLE INPUT IN INCREASING AGRICULTURAL PRODUCTIVITY AND OVERALL PRODUCTION [SEE FIG 1]. THIS HAS INVOLVED IMPROVED HAND TOOLS POWERED BY HUMAN MUSCLES, THROUGH TO IMPLEMENTS USING DRAFT ANIMAL POWER [DAP] TO MACHINERY & IMPLEMENTS POWERED BY INTERNAL COMBUSTION ENGINES AND/OR ELECTRIC MOTORS SUCH AS IN TRACTORS, COMBINE HARVESTERS, HAMMER MILLS ETC. [SEE BOX 1 FOR STAGES IN AGRICULTURAL MECHANIZATION DEVELOPMENT]

2. Agricultural mechanization has been widely [and still is] supported in SSA by farmers, local leaders, policy makers and politicians. It has, however, been a controversial subject in some circles including among external experts and commentators [Dumont, 1966; de Wilde, 1967; Kline et al 1969; ILO, 1973; Pingali et al, 1987; IBRD, 1987; FAO,2008; FAO & UNIDO, 2009; FAO, 2013a&b]. During the 20th Century, the SSA region was land surplus, [and still is in some parts in the 21st century considered to be a land surplus region] with comparatively low population density and in most countries, wages remain relatively low (Binswanger, 1986; IBRD, 1987; FAO, 2015).

3. SSA is also the continent which is located almost entirely in the tropics thus making any farm work, relying entirely on human muscles, to be ergonomically quite difficult and arduous [Passmore & Durnin, 1955; Boshoff & Minto,1974]. This is particularly the case for the power intensive field operations like primary land preparation using the hand hoe and hence the call by African Union Commission [AUC] to confine the hand-hoe to the museum and relieve the farmer of the drudgery associated with hand hoe tillage common on over 60% of the cultivated land as of 2015 [AUC/FAO, 2016]. The AUC also acknowledges the fact that if mechanization is to succeed in SSA then it must be sustainable – commercially, environmentally, and socio-economically [See Box 2 for the Ten Elements of F-SAMA- Framework for Sustainable Agricultural Mechanization in Africa].

4. Reflecting widespread acceptance that mechanization is desirable, the agricultural development plans of many governments in the emerging independent African nations in the 1950s and 1960s [and indeed even in Asia and Latin America], emphasized transforming the agriculture sector through mechanization based on tractorization, among other things. These plans included, for example, the Swynnerton plan in Kenya of 1954 as well as plans developed by the World Bank in Tanzania [then known as Tanganyika] (IBRD, 1960), FAO in Nigeria (FAO, 1966) and national experts in Ghana (Ghana, 1962), among others.

5. The objective of this paper is to provide a summary background review of the issues covered during the development of the ten elements of the F-SAMA focusing specifically on the priority element no 1: Boosting farm power through innovative business models. The paper provides an analysis of the paradigm shifts which have occurred over the past several decades in the process of assisting SSA countries in increasing the availability of farm power as an important component of the agricultural mechanization inputs necessary for increasing agricultural productivity and overall production in the region. The impact of these paradigm shifts on the quest of the SSA region to attain progress in agricultural mechanization is discussed. The paper has been specifically prepared to facilitate the discussions during the AfricaMechanize Webinar 3 session on the priority element no 1 of F-SAMA.
6. The first mechanization paradigm was the one, which advocated for the provision of farm power, for field operations like land preparation, through mechanical technologies like tractors, without necessarily evolving through a transitional stage of using draft animals i.e., direct tractorization. This was seen then [in 1950s and early 1960s] as a feasible option given the land abundance status of many countries in SSA and the difficulties of finding alternative sources of farm power - low population made the hand tool technology not a viable option and prevalence of the tsetse fly making use of draft animals difficult in large areas of SSA.

7. The tractorization paradigm was justified and supported then, notwithstanding the failure of one of the largest mechanized agriculture projects ever attempted in the world which was implemented in SSA – the Groundnut Scheme in Tanganyika [GST] in 1946-52 [Wood, 1950; Lord, 1963; Johnson & Ruttan, 1994; Rizo, 2004; and Esselborn, 2013]. This failure was attributed to, among other things, poor planning coupled with the use of inappropriate mechanical technologies and implements as well as biological and agronomical constraints. The successful adoption of tractors by the European settler farmers in eastern and southern Africa during 1945-65 reinforced the case for the tractorization paradigm. Also, early indications of success in commercial agricultural production by indigenous African small and medium scale farmers [SSFs & MSFs] in several settlement schemes which had been established in parts of eastern, southern, and west Africa during the 1950s & 60s reinforced the case for the tractorization approach [Mayne (1954, 1955 &1956); deWilde, 1967; Kates et al 1969; Kline et al, 1969; Anthony, 1970; Maina & MacArthur,1970; Bunting, 1970; Gemiill & Eicher, 1973].

**Figure 1. The four phases of Africa’s agricultural mechanization evolution**
Box 1. Stages in agricultural mechanization development

Stage 01
- Power Substitution: Draught animal power substituting human power or mechanical power substituting human and/or draught animal power.

Stage 02
- Mechanization of the Human Control Functions: Hand weeding replaced by mechanized weeding; manual cotton picking to mechanized cotton harvesting, etc.

Stage 03
- Adaptation of the Cropping System to the Machine: Examples include changing from broadcasting of seeds to row planting because of difficulties of weeding with machine in the later.

Stage 04
- Adaptation of the Farming System and Production Environment to Facilitate Mechanization: Intensive poul and livestock production; minimum and zero tillage systems; land clearance for mechanization, etc.

Stage 05
- Automation of Agricultural Production: Higher levels of mechanization where many production operations are automated – feeding systems in livestock production; precision application of fertilizers, herbicides, etc.

Stage 06
- Adaptation of crops/livestock to the mechanization system: Plant/animal breeding to facilitate mechanization of production activities e.g., harvesting; lodging; thresh-ability; or processing – ease of peeling.

Box 2. The ten priority elements of the Framework for SAMA [F-SAMA]

The framework for SAMA has ten priority elements with - eight of them clustered around three sustainability pillars [Commercial, Environmental and Socio-economic] and two elements are overarching and cut across. Each element has several options, and it is up to countries and sub-regions to decide on which one to pursue depending on prevailing local conditions.

The ten elements are:

A. UNDER THE COMMERCIAL SUSTAINABILITY PILLAR:
- Element 1: Boosting farm power through appropriate technologies and innovative business models.
- Element 2: Promoting innovative financing mechanisms for agricultural mechanization.
- Element 3: Building sustainable systems for manufacture and distribution of agricultural mechanization inputs.
- Element 4: Sustainable mechanization across agri-food value chains.
- Element 5: Innovative systems for sustainable technology development and transfer.

B. UNDER THE ENVIRONMENTAL SUSTAINABILITY PILLAR:
- Element 6: Sustainable transformation of land preparation and crop/animal husbandry practices.

C. UNDER SOCIO-ECONOMIC SUSTAINABILITY
- Element 7: Social sustainability and the roles of small-scale farmers, women and youth.
- Element 8: Human resources development and capacity building for SAMA.

D. OVERARCHING ELEMENTS FOR SAMA:
- Element 10: Creating sustainable institutions for regional cooperation and networking.

[From pg. 82-83 of FAO & AUC, 2018.]
8. The tractors and implements were supplied through the private sector with the main global manufacturers establishing their own franchises of dealers etc. throughout the SSA countries and the local financial institutions were actively involved in providing credit. Government managed and operated Tractor Hire Schemes [THS] were established in areas where the private sector was not strong and in several countries state farms were established to produce cereal grains. The tractors were used in the production of many commodities - maize, rice, wheat, sorghum and millets, pulses as well as cash crops like cotton, sisal, sugar cane, tea, and coffee. In most cases the tractors were used for primary land ploughing and harrowing with, in many cases, subsequent operations like planting and weeding being done by a combination of hand tools and/ or draft animals [deWilde, 1967; Anthony, 1970; Bunting, 1970; Gordon, 1970; Lele, 1976; Gohlich, 1984].

9. Tractor numbers in use in SSA increased from 1945 and by 1960 SSA had more tractors in use than any of the other developing country regions/continents [Fig 2]. Most of the tractors were privately and/or cooperatively owned and managed with those under government THS being less than 10% of the national fleet [Kolawole, 1972; Muchiri & Mbara, 1991, Kaul, 1991; Mrema, 1991].

Figure 2. Tractor use by region, 1961–2000.

THE INTERMEDIATE TECHNOLOGY PARADIGM

10. There were, however, concerns raised by several influential experts and organizations, from mid-1960s, on the impact and efficacy of the tractorization paradigm in mechanization programs in the developing countries. These concerns were raised mostly for programs in Asia but also on those in SSA and Latin America. They included:

- A prominent French rural development expert and politician, Professor Rene Dumont, in his famous 1996 book, *False Start in Africa* stated: ‘The problem of mechanization is crucial because African elites are seduced by the idea of modern machines. It is difficult to convince them that agricultural progress does not depend on immediate and complete mechanization…. It is not that mechanization is
impossible on African soil. Machines will be in wide use in the future, but there are still too many obstacles……” [Dumont, 1966]. The ideas propounded by Professor Dumont, where he was critical of the rapid tractorization policies promoted in some African countries in the 1960s, epitomized the framework for agricultural mechanization then advocated by the French Colonial and post-colonial systems. This was based on an evolutionary approach whereby the farm power situation was expected to evolve gradually from the hand tool technology through animal powered implements to mechanically powered machinery and equipment over several decades if not centuries [Dumont, 1966; Carrilon & LeMoigne, 1975; Mazoyer & Roidart, 2006].

- The intermediate technology movement which was becoming an influential voice in forums on the development agenda also opposed the tractorization paradigm citing several reasons – balance of payments, creating unemployment and other social concerns. They therefore advocated for more intermediate technologies such as improved hand tools, DAP etc. as an alternative to tractorization both in the short and medium term. The book Small is Beautiful by renowned economist Dr. A. Schumacher, which advocated for intermediate technologies, was highly influential especially to those in developed countries who advocated for the intermediate technology paradigm in agricultural development. Many Intermediate/Appropriate Technology [IT/AT] centers were established throughout SSA and in Asia to develop and transfer such technologies during 1970 to 2000. [Eicher & Baker, 1982; IRRI, 1983; Moens & Siepmann, 1984; Starkey, 1988; FAO, 2008].

- During 1970–1973, the International Labor Organization (ILO) of the United Nations [UN] undertook several case studies on mechanization in the developing world – the reports of which had a major impact on policy debates on tractorization. The ILO studies supported the concerns expressed by, among others, the intermediate technology movement, that introduction of tractors and other mechanically powered machinery and implements was leading to serious unemployment of farm laborers and workers in all the four continents of the developing world (ILO, 1973). These studies reinforced the case of those who were questioning the rationale of development strategies that emphasized mechanization and advanced mechanical technologies in agriculture.

- The first global oil price hikes of 1973, which ostensibly made use of tractors appear even more uneconomical in the developing world, especially for the smallholder sector [Makhijani & Poole, 1975; Fluck & Baird, 1979; Stout, 1979] strengthened the case against the tractorization paradigm. This did significantly strengthen the case in support of the use of improved hand tools, draught animal technology and other renewable forms of energy. The poor performance of government-sponsored and operated tractor hire schemes [THS] in several developing countries further weakened the arguments for the tractorization paradigm [Seager & Fieldson, 1984]. This is notwithstanding the fact that number of tractors in Government operated THS was less than 10% of the total number in use in the national tractor fleets in most SSA countries [Kaul, 1991].

11. In response to the growing criticism of tractorization paradigm, supporters of mechanization scorned the opponents who especially feared creation of unemployment and compared them to the Luddites in England in the nineteenth century, who smashed textile machinery for fear it would create unemployment. They argued that if agriculture in developing countries is perceived as a “gigantic programme” for relieving unemployment, then these countries would continuously face hunger and massive starvation. On the issue of the high amount of energy required for operating these tractors, the proponents of mechanization argued that the fossil fuels used in agricultural machinery, even in the most advanced countries, accounted for less than 5 percent of the total energy used in agricultural production [Kline et al. 1969; Esmay and Faidley, 1972; Khan, 1972; Stout, 1974; Fluck & Baird, 1979, Adams,1988].
Towards a Consensus – Selective /Appropriate Mechanization Paradigm

12. By 1970, it was apparent that the role of modern mechanization technologies in agricultural development in the developing countries, was in many cases, a controversial issue. This was particularly the case on the role of farm power in agricultural development. The controversy was such that conflicting advice was being proffered to developing countries with, at times, two UN technical agencies [e.g., FAO and ILO] taking diametrically opposite views on the ubiquitous use of tractors.

13. To bridge the gap between the two viewpoints among policy makers and development specialists, FAO and the OECD convened an Expert Consultation on the Effects of Farm Mechanization on Production and Employment in February 1975 in Rome, Italy to discuss the issues involved (FAO, 1975). The experts at the consultation agreed that:

- Farm mechanization should lead to increased production while reducing the drudgery associated with performing agricultural tasks using hand tool technology. With respect to its unemployment effects, however, the experts noted that there were so many variables that could affect employment in agriculture that it was extremely difficult to isolate the effects of farm mechanization. They concluded that urgent action was required to determine whether continued growth in farm mechanization was “socially desirable”, which could only be done by conducting field studies in the countries concerned.

- The consultation then recommended appropriate mechanization, which combines hand tool, animal and mechanically powered agricultural implements and equipment suited to the physical, cultural, economic, and technological environment of the country concerned.

- Further, the need to train manpower for all aspects of agricultural mechanization programmes was highlighted, noting specifically that “manpower training requirements for extension in the use, or introduction of farm mechanization based on animal power were considerable, particularly if attempts are made to introduce draught animals in areas where there was no tradition of animal husbandry and use of draught animals.”

- There were also recommendations for developing countries to formulate agricultural mechanization policies and develop strategies for their implementation, and for carrying out research in agricultural mechanization within the national agricultural research systems.

- Finally, there were specific recommendations to FAO, particularly on the need for developing guidelines for determining and evaluating appropriate forms and levels of farm mechanization to suit different ecological, social, and economic conditions of the developing countries.

- It was suggested that FAO provide support to governments in setting up advisory services in this field, strengthening its information services to provide multidisciplinary information on agricultural mechanization.

14. Following this 1975 Rome Expert Consultation, FAO did convene several other technical consultations and meetings to reach a consensus on the role of mechanization [specifically farm power] as an input in agricultural and rural development. These consultations did culminate in the fifth meeting of the Committee on Agriculture [COAG] of the FAO Council held in April 1979 where a consensus was reached that agricultural mechanization was an indispensable input to rural development. This therefore led to the second major Paradigm as defined by the 1975 Consultation: Selective or Appropriate Mechanization based on the level of power input per hectare, be it from the muscles of humans and/or draft animals OR from mechanical technologies. Thus, progress in mechanization thereafter has been measured in terms of available total power per hectare [hp/acre or kW/ha].

15. Papers by Professor Giles of North Carolina University [Giles (1966 & 1975)] did provide the conceptual framework and justification for inclusion of farm power together with the biochemical
inputs [fertilizers, improved seeds, and crop protection pesticides] as being a ‘first-generation’ factor in the process of transformation of farming and agriculture in general through the green revolution. [Mellor, 1998; Ruttan, 1998; and Reardon, 1998]. The concept of minimum power per hectare became the norm in agricultural mechanization strategy formulation - in his 1975 paper Giles recommended a minimum of 0.5hp/ha from different sources [human; draft animals and mechanical power]. [See Table 1 for Projections 2005 to 2050 of kW/ha for India]

16. The Guidelines for agricultural mechanization strategy [AMS] were developed by FAO and were technically reviewed extensively and subsequently approved by the Committee on Agriculture [COAG] of the FAO Conference in 1981. They were released as FAO Agricultural Services Bulletin No. 45 entitled Agricultural Mechanization in Development: Guidelines for Strategy Formulation [FAO, 1981]. The main objective of these AMS guidelines was to define and put in proper perspective the relationship between agricultural mechanization and overall national development objectives in the developing countries and to provide technical guidelines for appropriate mechanization strategy formulation.

17. While these guidelines were not meant to provide a ‘cookbook’ recipe that could be applied to every development situation pertaining to agricultural mechanization, it nevertheless has remained the main basic reference document for technical guidance in mechanization strategy formulation over the past four decades. It was extensively used in Asia region during 1975-2015 under the Regional Network for Agricultural Mechanization [RNAM] now CSAM [FAO-RAP, 2014]. During the three decades, 1985-2015, FAO has provided technical support to many countries in Africa and elsewhere helping them to develop their AMSs.

Table 1: Projections for mechanization in India (Singh, 2013)

<table>
<thead>
<tr>
<th>Item</th>
<th>2005</th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural workers (millions)</td>
<td>230</td>
<td>280</td>
<td>340</td>
<td>350</td>
</tr>
<tr>
<td>Draught animals (millions)</td>
<td>53</td>
<td>37</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>Tractors (millions)</td>
<td>3.0</td>
<td>4.5</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Power tillers (thousands)</td>
<td>152</td>
<td>250</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Diesel engines (millions)</td>
<td>6.4</td>
<td>7.3</td>
<td>7.8</td>
<td>8.5</td>
</tr>
<tr>
<td>Electric motors (millions)</td>
<td>17</td>
<td>25</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>Power (kW/ha)</td>
<td>1.5</td>
<td>2.2</td>
<td>3.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

NEW IDEAS AND PARADIGM DURING 1985-2005


19. The IBRD (1987) report as well as the Pingali et al (1987) book, had several recommendations which appear to have inordinately influenced the policies and priorities on agricultural mechanization of the World Bank and several other development and donor agencies during the two decades period from 1987 to 2007. Both the Pingali et al 1987 and IBRD (1987) reports were particularly critical of encouraging increased use of tractors in agriculture in SSA and the developing countries in general and instead recommended use of what they called appropriate technologies such as DAP.

20. The conceptual framework for the Pingali et al 1987 was anchored on the assumption that the increase in overall demand for mechanization in SSA was likely to have been driven by the
intensification of farming systems and by broader economic transformation. From the literature on farming systems evolution (Boserup 1965; Ruthernberg 1980) they then suggest that the demand for mechanization is linked to the process of intensification of the farming systems—characterized by more frequent land preparation and a shortened fallow period—driven by population growth and market development.

21. Pingali et al 1987 recommended that the indicator of the level of farming system intensification is the “R-value,” which was proposed by Ruthernberg (1980), and which measures the share of cultivated area in a particular year to total agricultural land. Countries or areas with a high R value, they posited indicated that they have increasing farming system intensity and hence higher demand for overall farm power inputs, which could be supplied by human, animal, or mechanical powers. However, this process is also accompanied by economic transformation, which raises the relative price of rural labor, leading to an increased demand for mechanical technologies that can substitute for labour.

22. However, other socio-economists such as Darrity 1980 has suggested that, the Boserup, 1965 and Ruthernberg, 1980 analysis of farming systems, as interpreted by Pingali et al 1987, for mechanization in SSA, is more suitable for analysis of farming systems which are still at the exceedingly early stages of development and which are still practising shifting agriculture [or ‘primitive agriculture’ in 18th & 19th century as Darrity, 1980 defines it]. Morrison 2006 compares the Boserup, 1965 analysis to what pertained in India during pre-colonial times in the 18th century. The Boserup, 1965 analysis may thus not be that relevant in defining the process of mechanization in farming systems which are evolving to higher levels of mechanized agriculture involving internal combustion engines as it is occurring in SSA during the 4th quarter of 20th century and 1st quarter of 21st Century.

23. Further, to be able to plan and formulate mechanization strategies and projects for a specific area/district/country one would have to be able to compute the ‘R’ – Ruthernberg values. Given the paucity of data in most SSA countries it would be quite difficult to get these R values. It is also important to note that the Pingali et al (1987) study was undertaken during the early part of the third quarter of the 20th Century when the farming systems [FS] as well as the intermediate technology [IT] movements & paradigms were in vogue in the agricultural development arena [Eicher & Baker, 1982; Collinson, 2001]. Further, at that time there were no Divisions of Agricultural Mechanization & Engineering Services [DAMES] operating in most of the countries in the SSA region. As a follow up to the FAO (1981) recommendations and guidelines on agricultural mechanization strategy, the DAMES were established in most SSA countries during the period 1990 to 2010 and they are staffed mostly by agricultural engineers who are more conversant with kW/ha rather than the ‘R’ values.

**RESPONSE OF SSA TO THE NEW IDEAS & PARADIGM**

24. FAO and other technical agencies such as the Commonwealth Secretariat [COMSEC] in London both of which had provided technical support to agricultural mechanization programs [including for tractor projects] implemented by Ministries of Agriculture [MoAs] in most African countries in 1960-80 were particularly put in an invidious position by the IBRD (1987) and Pingali et al 1987 papers. Likewise, the MoAs were in a quandary as the recommendations of Pingali et al (1987) on tractor mechanization were against the advice they had received over a long period from the international technical agencies like FAO & COMSEC and even the World Bank itself [IBRD, 1960, 1981 & 1989].

25. FAO had weathered an earlier thrust against use of the tractor in Third World agriculture [due to its, allegedly, unemployment effects] which was led by a sister UN agency [ILO - the International Labour Organization] in the early 1970s [Clayton, 1973, ILO, 1973] as explained above. FAO had
done this through organizing a ‘global expert consultation’ on ‘Mechanization and Employment’ in Rome in 1975 [FAO/OECD, 1975] where a consensus was reached that the use of tractors did not necessarily lead to increased unemployment overall and the need for member countries to be provided with technical guidelines to facilitate the formulation of agricultural mechanization strategies. FAO had by 1980, developed these technical guidelines and was in the process of piloting their implementation in several countries in Asia and Africa [FAO, 1981]. Surprisingly to FAO, neither the proceedings of the global expert panel consultation [FAO/OECD, 1975] nor the guidelines developed for strategy formulation [FAO, 1981] were even cited in the Binswanger, [1978]; IBRD (1987) and Pingali et al, 1987 reports/publications.

26. When the Pingali et al (1987) document as well as the IBRD 1987 one, were released, it took some time before their impact was felt in the operational side on implementation of mechanization programs. The ideas in Pingali et al (1987) were quite new especially to those who were responsible for policy and strategy for agricultural mechanization including project implementation. These were largely agricultural engineers newly graduated from universities in Europe and North America and were not that familiar with the theories of Boserup and Rutherford which were based on what Professor Darrity of Duke University has characterized as ‘Anthropological Economics’ [Darrity, 1980]. Even the farming systems approach was then, in mid 1980s quite new in SSA and pilot projects were being implemented by research divisions of the Ministries of Agriculture with donor assistance in some countries in SSA [Eicher & Baker, 1982; Collinson, 2001].

27. It is also important to recognize that many of the mechanization policies and as well as programs/projects implemented in the 1960s by most SSA countries had been formulated with technical support from the main international development agencies such as FAO; ILO; UNDP; World Bank etc. as part of the rolling five-year national development programs [deWilde, 1967; Bunting, 1970; FAO, 1975 & 1981; COMSEC, 1990]. Technical guidance was therefore being provided to member countries in accordance with what was then accepted development paradigms for agricultural mechanization. ****Much of the technical knowledge on mechanization was a carry-over of what had been developed during the last years of colonial rule in the 1950s & 60s as well as experience gained in implementation of similar programs in other parts of the World after the Second World War [Mayne, 1954; 1955 & 1956; deWilde, 1967; Hall, 1968; Kline et al 1969; Bunting, 1970; Oluwasami, 1975; Eicher & Baker, 1982; Crossley & Kilgour, 1983; Seager et al 1984, Gibb, 1988].

28. What was being proposed under the Pingali et al (1987) framework was, therefore, a new way of thinking about agricultural mechanization and had not been part of the knowledge and advice provided by the technical agencies. Indeed, the Pingali et al 1987 paradigm and framework were in many instances contradicting what FAO had just published, in 1981, as a guideline to its member countries on Agricultural Mechanization strategy formulation and the content of its technical advice to member countries in developing their strategies. These FAO Guidelines [FAO, 1981] had been developed following the consensus reached at the Global Consultation on Agricultural Mechanization and Employment which FAO & OECD had organized in 1975 in Rome, [FAO/OECD, 1975] as explained above.

29. It is also important to recognize that agricultural mechanization policies and strategies were and are still being handled in most SSA countries by agricultural engineering/mechanization [DAMES] divisions in collaboration with the planning divisions of the ministries of agriculture. These DAMES were mostly then and are still staffed by agricultural engineers who would have found it difficult to follow the proposals by Pingali et al as it was contrary to their basic training. The Ministries of Agriculture requested for clarifications from the World Bank as well as from the technical agencies on what they should follow between the two options. Further, even in the main donor agencies there was confusion on what was the best approach in this regard [COMSEC, 1990].
30. Ministers of Agriculture of the countries in the Commonwealth of Nations requested the Commonwealth Secretariat to convene an expert consultation to discuss the contradictions on the technical advice being provided by the leading agencies [COMSEC, 1990]. An important point here is that eight of the eleven countries covered in the Pingali et al (1987) field survey were English speaking and/or members of the Commonwealth of Nations [Ethiopia; Botswana; Kenya; Tanzania; Zambia; Nigeria and India as well as Cameroon which is partially English speaking]. The Commonwealth Secretariat convened such a consultation workshop at the Ahmadu Bello University in the northern Nigerian city of Zaria on 13-17 August 1990. This workshop was attended by 60 senior experts from 9 African countries [Botswana; Gambia; Ghana; Kenya; Lesotho; Nigeria; Swaziland; Tanzania and Zambia] as well as representatives of GTZ; UK; UN-ECA/FAO and India.

31. Resource persons had been commissioned to prepare overview papers and each country representative was required to prepare a paper on the status of agricultural mechanization in their respective countries focusing on success cases as well as failure ones. The resource papers included those from FAO on Agricultural Mechanization Strategy Formulation: Procedures and Issues; India – on Formulation and Implementation of Mechanization Policies in India; from GTZ on Small four-wheel tractors for the tropics and sub tropics as well as an overview paper on the main issues on agricultural mechanization in Africa specifically focusing on what was in the PBB framework.

32. Professor R. N. Kaul – an Indian National with long experience of agricultural mechanization programs in SSA and Asia and who was then working [as an expatriate] as Professor of Agricultural Engineering and Programme Leader of the Agricultural Mechanization Programme at the Institute of Agricultural Research of the Ahmadu Bello University in Samaru, Zaria, Nigeria was assigned the task of preparing the overview resource paper entitled: Agricultural Mechanization in Africa: An Overview of Main Issues [Kaul 1991]. On the Pingali et al (1987) report, Prof Kaul had the following remarks:

‘….. Pingali et al (1987) in a study of 30 tractor projects in Sub-Saharan Africa from 1945 – 1980 (7 small-holder; 13 Government Tractor hire schemes and 10 block cultivation schemes) concluded “In many tractor project areas no tractors can be found today. Where any tractors are still being used, their use is inevitably associated with rice cultivation. But even these surviving tractors today are privately owned. The transition from the hand hoe to animal-draft power, where its use is appropriate, continued to be made despite the emphasis on tractors. Of the seventeen attempts to bypass animal traction for tractorization only three succeeded, all of them associated with low-land rice cultivation schemes” Pingali et al 1987.’.

Thirty tractor schemes (with less than 3000 tractors total), spanning over a period of 35 years (1945-1980) and covering the entire SSA region is just a small sample for one to conclude with such a blanket prescription. In addition, animal traction has been even less successful despite over 80 years of extension effort.........’ Kaul, 1991.

33. Eight case studies on status of agricultural mechanization were presented from seven African countries [Botswana; Ghana; Kenya; Nigeria; Swaziland; Tanzania and Zambia] as well as from India. Five of the 7 case studies were from countries which were covered in the Pingali et al 1987 rapid field survey. These papers gave a different picture of the status of agricultural mechanization in those seven countries – being more objective and unbiased in contrast to the perspective presented in Pingali et al, 1987. As an example, is the status of Government operated tractor hire services – while these were operational in 1960s [and even then, had less than 10% of the tractor fleets in all the countries], by mid 1980s most of them had been privatized with the tractors thereafter being operated by the private sector. The case study from India presented by Dr S. K. Misra – The Joint Commissioner in-charge of Agricultural Engineering Services at headquarters of the All-India Ministry of Agriculture in New Delhi gave a different perspective of the agricultural


35. In addition to endorsing the comments by Professor Kaul on the prescriptions of Pingali et al 1987 as summarized above, the workshop also, among other things, noted that:

- “……Too often in SSA failed agricultural mechanization schemes have been subjected to cursory economic review, without the required detailed technical analysis, whilst success cases have not been adequately analysed and publicised.
- Too often blanket prescriptions have been made based on very rudimentary data and flawed methodology. There should not be blanket prescriptions to the African agricultural mechanization problem – the heterogeneity of the agricultural systems must be appreciated, and this should be built in the process of agricultural mechanization policy and strategy formulation……” [COMSEC, 1990 & 1991].

36. The workshop did recommend the need to facilitate more information exchange on both failed and successful mechanization projects as earlier recommended in the 1967 World Bank study led by Dr de Wilde [de Wilde, 1967; COMSEC,1990]. Further, the Workshop noted the cautious approach and recommendations on tractorization made during the deWilde mission in 1967 when public sector operated THS were more common as compared to the prescriptive and negative recommendations made by the Pingali et al team in 1987 when most public sector THS had been privatized [COMSEC, 1991].

**IMPACT OF THE NEW PARADIGM ON AGRICULTURAL MECHANIZATION DEVELOPMENT IN SSA**

37. The net result of this new paradigm and the corresponding policies implemented, was a stagnation and/or decline in numbers of tractors imported into the region. As reported in FAO, 2008 while in 1961 through to 1970 SSA had more tractors in use than Brazil, China, India, and Thailand by the year 2000 India, China and Brazil had 6.9, 4.4, and 3.7 times the number of tractors in use in SSA [including South Africa] [see Fig 3]. In 1998, the hand tool technology dominates land preparation in 65% of the cultivated land in SSA compared to 20, 25, 30, and 40% in the Near East, Latin America; South Asia; East Asia regions respectively [see Fig 4]. The number of tractors in use in 2000 in all SSA countries was almost equal to the number in Thailand which in 1990 had less than 20% of the number in SSA then. Annual imports of tractors in all the SSA declined from an average of over 10,000 units in the early 1980s to under 3000 units by 1995. [See Fig 5]. This is particularly important as the massive increase in the use of tractors in Asian agriculture which occurred during the period 1975-2015 had disproved the findings of the Binswanger 1978 report on the economics of tractor use in Asian agriculture [Singh, (2001; 2013); Verma, 2006; FAO-RAP, 2015]. [see fig 6 for increases in tractor imports in Thailand, Pakistan; and tractors in use in India].

38. The IBRD (1987) report made specific recommendations to the World Bank and other donors to discourage assistance for mechanization projects with tractor components and instead they should focus their assistance to draft animal power and implements as well as the intermediate technologies. Thereafter, during the period 1985 to 2005, there was active and large donor supported programs of promoting DAP and other appropriate technologies in agriculture throughout SSA [ Starkey, (1986); IBRD (1987 & 1989)]. National and regional animal traction
networks were established throughout SSA and heavily supported by donor agencies [Starkey, 1988 & 1998]. This was accompanied by a corresponding decrease in donor support to mechanization programs with tractor components. Most countries in SSA were then implementing the Economic Structural Adjustment Programs [ESAPs] with the support of the World Bank and IMF and they were discouraged from investing in programs with tractor mechanization components [IBRD, 1987 & 1989].

39. This new paradigm appears to have significantly influenced policy options of the major donors on assistance for agricultural mechanization programs with tractor components in SSA. This is exemplified by, among others, the increased emphasis and funding for Draft Animal Power [DAP] projects/programs during the period 1985 to 2005; Regional and sub-regional as well as national networks on animal traction technology were established throughout SSA, donors provided support to establish DAP research and extension programs and centres, several large workshops and seminars on DAP were organized [WATNES; ATNES etc] as well as publications were published during the period [Kjoerby, 1983; Starkey and associates, 1985; 1986; 1989; Nwuba & Kaul, 1986]. Funding for projects with tractor components was reduced significantly.

![Fig. 3. Tractors in use in Africa compared in other developing countries.](image)

40. Also, the Appropriate Technology/Intermediate Technology [AT/IT] movement became prominent in the mechanization debate and activities in SSA. Many AT/IT centres and programs
funded by donors and national governments were established at national /regional levels throughout SSA during the period 1975 to 2000 developing several types of prototypes [e.g., FMDU in Botswana; RTDU in Kenya; AATP in Tanzania etc.]. The CGIAR system reduced its involvement in agricultural engineering & mechanization research and the units for research in these area at the founding IARCs [IRRI, IITA, ICRISAT etc] were phased out in the 1990s. These had been quite active in the earlier years and were the ‘unsung heroes’ in terms of their contribution to the success of the green revolution especially in Asia [Khan, 1972; Brader, 1994; Bell et al 1998; Okali et al 1997; White, 2000; FAO,2008; Lantin, 2013; FAO-RAP (2014 & 2015)].

Figure 5. Imports of Tractors in SSA Countries [FAO/AGST2008]

Figure 6. Tractors in use in different Asian Countries [FAO/AGST-2008]
41. There has always been a concern on the impact of increased mechanization on the environment in Africa. As Colin Maher, a leading soil scientist in Eastern Africa noted in 1950; ‘……the grave erosion which occurs on ploughland from time to time has often induced an ‘old timer’ to say ruefully that we should never have put a plough into Africa’ [Maher, 1950]. Also, the environmental field in Africa as often inspired by counter parts in Europe is particularly prone to passions as Anderson & Groove (1987) noted ‘ …Much of the emotional as distinct from the economic investment which Europe made in Africa has manifested itself in a wish to protect the natural environment as a special kind of ‘Eden’ for the purposes of European psyche rather than a complex and changing environment in which people have had actually to live…’. During the colonial period the conservation movement was split between those who focused on erosion problems on the lands farmed by indigenous natives and those who focused on erosion issues on the large-scale commercial farms operated mostly by European settler farmers [Tiffen et al 1994; Rowland (1974 & 1994); Kayombo & Mrema, 1998].

42. As noted in AUC/FAO, 2018, the conservation tillage technology has been adopted mostly by large scale farmers in Eastern and Southern Africa [ACT, 2015 & 2017]. Also, the Conservation Agriculture [CA] movement is gaining traction in SSA and has particularly strong views on tillage/plowing of land which may influence policy on agricultural mechanization. The current thrust is to convert from conventional tillage [CT] [practiced on 97% of cultivated land] to conservation agriculture practiced on about 3% of cultivated land in SSA. The issue therefore is more of the type of implements used rather than the power source. Several of the IARCs have programs on CA in eastern and southern Africa even though there are divided opinions, among key stakeholders of the CGIAR system, on extent of adoption and suitability of CA techniques to small holder farmers in Africa and Asia as evidenced by the Nebraska Declaration of 2014 ([Baker et al, (2006); Friedrich & Kassam, 2012; Friedrich, (2013), CGIAR (2013); Corbeels et al, (2014); Stevenson et al (2014)]. These issues and concerns should be considered in agricultural mechanization policies and strategies in Africa especially as they tend to impact on the type of farm power used as well as human health issues [FAO-AUC, 2018].

43. The key environmental issue as related to sustainable agricultural mechanization in SSA is concerned is to recognize the fact that all over the world conservation agriculture [CA] and specifically conservation tillage [CT] has been successfully adopted where the farm power problem has been solved. So far in SSA large scale farmers [LSFs] who have largely tackled the farm power problem are increasingly adopting CT & CA because it makes economic sense for them to do so. Medium Scale Farmers [MSFs] who in several countries are acquiring their own powered machinery for their own farms and are offering mechanization hire services to other farmers [both small and other medium] are likely to be the next adopters of CT and CA practices provided the R & D system comes up with the required appropriate implements. As noted in Element 6 of F-SAMA enhanced adoption of CA requires sustainable provision of minimum levels of farm power. Tackling the farm power constraint is therefore critical for environmental sustainability. This is particularly the case in those sub-regions of SSA where land preparation in over 80% of the cultivated land is still done by the hand tool technology [Fig 7].

Small and Large Tractors Paradigm

44. Another issue which is being repeatedly stated by external actors as a fact is that African countries use high horse-power tractors compared to Asia where, it is indicated that small tractors dominate. There is a need to first define what are small tractors and what are large. Holtkamp (1989 & 1990) defines small tractors as those under 26kW and they come either with one axle [hence 2 wheel-tractor (2WT) or power tiller] or with two axles [hence small 4 wheel-tractor (4WT)] and the medium and large 4-wheel tractors (4WT) with engines of over 26kW. The small 2WT or power...
tillers have been tried in SSA in two waves, first in the 1960s when they failed miserably and the second wave from 2005 with over 80% of them imported in to four African countries [Madagascar; South Africa, Nigeria and Tanzania] where they appear to be successful in tillage of wetlands [either irrigated or in floodplains] for paddy production and in general transportation in rural areas with poor road infrastructure [IRRI, 1983; FACASI, 2015; Baudron et al, 2015, IFPRI, 2020]. On the other hand, there were 45 prototypes of the small 4WT developed in the 1960s-80s all over the World including the Kabanyolo [Uganda] and Tinkabi [Swaziland], Bouyer [France] and Multitrac [Germany]. Only the Tinkabi and Bouyer reached a production level of about 1000 units by mid 1980s [Gohlich, 1984; Holtkamp, 1989 & 1991].

45. In several recent papers & reports there are unverified and/or incorrect statements about these small tractors especially on their power capacity and comparison of their acceptability/adoption in Asia cf. their potential role and adoption in SSA [Diao et al, 2020]. There has been considerable research on soil mechanics and tillage related to, among other factors, the power requirements and testing of different tillage implements in Africa over the past five decades (Boshoff 1966; Boshoff & Minto, 1974; Willecocks & Twomlow, 1992; FACASI, 2015). Let us use these research findings which are based on fundamental principles of soil mechanics and engineering to decide on what type of tractors and implements are suitable for SSA as recommended in the F-SAMA document [AUC/FAO, 2018]. So far much of the advocacy for increased use of low horse-power tractors in SSA appears to be based largely on socio-economic reasons coupled with inappropriate comparison of the Asian and SSA situation and farming systems rather than on basic principles of soil mechanics and engineering [AUC/FAO, 2018]. Besides the different sub-regions of SSA have different power requirements given their soil conditions and level of development of the farm power sector [see fig. 7 Farm Power in different regions of SSA].

Figure 7. Primary land preparation in Africa (2006)

Institutions and organizations for boosting Farm Power in SSA

46. The issue of the institutions and organizations needed for addressing the organizational, logistical and managerial problems in the transition from essentially peasant and small scale dominated agriculture to mechanized agricultural systems is critical. The AGS45 on AMS of FAO (1981) in chapter 11 on pg. 55 to 58 offers different models on Systems for Machinery Use.’ [FAO,1981]. Countries in SSA have followed these guidelines to the extent possible. Recent research attention has been focused on the models being piloted in Ghana and Nigeria with the AMSECs and AEHE [IFPRI, 2020]. But these are basic units at district level which have been piloted in these two countries for less than a decade and from an institutional perspective are still work-in- progress. It may therefore be too early to draw lessons from them for scaling up elsewhere in SSA. Besides there are other institutional and
organizational models which have been tried elsewhere in SSA and/or Asia [e.g., block farms; cooperatives; machine-rings; mechanization clusters etc.] for a much longer period and key lessons could be drawn from them.

47. The key question, as noted in AUC/FAO, 2018, is what institutions and organizations would be catalytic to the development of agricultural mechanization at national, sub-regional and regional levels? What has worked elsewhere in SSA and Asia? Over the past 50 years several countries have established strong DAMES at national level – what has been their impact cf. similar institutions elsewhere [e.g. Asia]? What role did regional institutions in Asia such as RNAM/APCAEM/CSAM/APO/AsDB as well as the UN and donor agencies play in the Asia success cf. similar institutions in SSA [e.g., ARCT; ARCEDEM; AfDB]? The World Bank was in the 1980s pushing for the farming systems approach and/or Boserupian framework on evolution of mechanization in SSA while FAO/UNDP/UNIDO had a different approach of AMSs – how did this affect mechanization especially farm power in SSA? The CGIAR system has consistently been spending 40-50% of its budget in SSA over the past 60 years - what role has it played in mechanization of African agriculture cf. in Asia where there were strong programs for agricultural mechanization in the 1960s to 80s at IRRI and ICRISAT? On the other hand, IITA the main IARC in SSA phased out its agricultural engineering program from the 1980s – what impact has this had on mechanization in SSA.

48. There is no question that farm power is an indispensable input for increasing agricultural productivity and overall production. Studies by the Centre for Sustainable Agricultural Mechanization [CSAM] of the Asia Pacific region do show clearly that farm power was and remains a critical input in in increasing agricultural growth [FAO- RAP, 2015]. As Fan & Pardey, 1992 demonstrated in their seminal paper that farm power contributed 11.8% of growth in agricultural output of P.R of China which occurred between 1965 to 1989 grater even the contribution of irrigation which 3.3% [see Table2]. SSA needs to learn from such successful development models if it is to break out of the cycle of low agricultural productivity and food insecurity.

Table 2: Accounting for growth in agricultural output in China: 1965–1989 (Fan & Pardey, 1992)

<table>
<thead>
<tr>
<th>Factor</th>
<th>% Contribution to growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>-0.9</td>
</tr>
<tr>
<td>Irrigation</td>
<td>3.3</td>
</tr>
<tr>
<td>Labour</td>
<td>3.4</td>
</tr>
<tr>
<td>Farm power</td>
<td>11.8</td>
</tr>
<tr>
<td>Institutional change</td>
<td>13.8</td>
</tr>
<tr>
<td>Research</td>
<td>19.8</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>21.3</td>
</tr>
<tr>
<td>Other factors</td>
<td>27.6</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Farm Power & Sustainability Issues

49. The issue of sustainability is critical to the success of Element 1 of the F-SAMA is important due to the increasing global pressure for transformation of current agricultural production systems into more sustainable ones and the initiatives undertaken in both the Asia Pacific and Africa regions to develop frameworks for sustainable agricultural mechanization strategies over the past five years [SAMS & F-SAMA respectively]. The SAMS and F-SAMA provide a longer-term vision of how stakeholders see agricultural mechanization evolving in their respective regions whilst taking cognizance of progress and developments in the sub sector over the past fifty years [FAO/CSAM, 2014 and AUC/FAO, 2018]. Given the high investment costs for farm power assets, it is important
that the consideration of sustainability goes beyond environmental sustainability issues to include commercial and socio-economic sustainability.

50. The global experience on agricultural mechanization, shows that there are regions within countries which are early adopters [by several decades in some cases] while other regions are late adopters of mechanization technologies [e.g., Punjab in India with tractors and combine harvesters [Singh, 2013]; Mbeya Region in Tanzania with power tillers (Mrema et al 2020); Central Tanzania with 4WT (Shetto & Mkomwa, 2021) and Northern Ghana [IFPRI, 2020]. Such early adopter regions are likely to be able to support and commercially sustain agri-businesses specializing in the provision of mechanization services within and/or across the national boundaries [Mrema et al 2020]. Given the current low demand in the national markets, [for say tractors] in most countries in SSA, it may well be prudent to plan for mechanization services and franchises at sub regional level. As noted in FAO, 2008 of the 107,500 units of four-wheel tractors in use SSA [excluding South Africa] in 2000, about 72% of them were concentrated in six countries with the remaining 28% spread in over 40 countries. Indeed, in some sub-regions [e.g., the SACU – Southern Africa Customs Union] the franchises for agricultural machinery and implements are organized at sub-regional level to attain economies of scale and scope and hence create more viable and sustainable enterprises. Sub-regional markets may thus be the more sustainable option for agricultural mechanization supply chains using the regional economic blocks as recommended in the SAMA framework [AUC/FAO, 2018].

51. Also, countries in SSA should consider provision of other services like, research and development; testing of agricultural machinery and implements; setting of standards; as well as manufacturing and trade activities at the sub-regional level to attain economies of scale and scope as recommended in AUC/FAO, 2018. The experience of implementing such activities at the sub regional and regional levels in Asia region should be invaluable to SSA countries. These issues should be given more prominence as there are quite several national institutions in SSA which offer such services, and which lack the critical mass of experts to be effective and are inadequately funded and equipped. Highlights of lessons from Asia in operating such regional centres as APO; CSAM; testing and standards bodies like ANTAM would be invaluable to SSA [FAO/UNIDO, 2010]. Also, there are quite several pan-African institutions [such as the Inter-Africa Bureau of Animal Resources [AU-IBAR] which has been quite successful in eradicating several livestock diseases which could offer useful lessons on modalities of regional cooperation for solving development problems [FARA, 2014; AUC/FAO, 2018].

52. Over the past several decades the emphasis of governments, the international development fraternity as well as the R & D systems has been directed at facilitating ownership by the small farmer of farm power machinery and equipment. This has been done through designing, manufacturing and promotion of equipment which can be sustainably owned by the farmer. Further policy priority has been directed at provision of credit or other subsidies to enable the farmer to procure such machinery and equipment which in rainfed agriculture he/she hardly fully utilize throughout the year. The farmers are therefore forced to invest considerable resources on machinery which they use of one month and store it for the remaining 11 months.

53. Perhaps more could be achieved if the research and development as well as technology transfer agenda could be directed at creating entrepreneurs who are able to offer mechanization services throughout the year and are able to sustainably finance their enterprises in addition to offering the services at affordable and economic prices such as Mr. Kingangi in Kenya as explained in Box 3 Efficient Tractor Hire Services in Kenya. Such entrepreneurs are emerging in several parts of SSA – Southern Africa: Eastern Africa and West Africa. Research on their business models and facilitating their development and scaling up will do more to the mechanization efforts of SSA than spending a lot of resources on designing prototypes which never move beyond the research workshop or on testing new paradigms developed in far off places.
Box 3: Efficient Tractor Hire Service in Kenya

Mr. Gideon Gitungo Kingangi is a very talented provider of tractor hire services, and he is also a 9-seater van tour operator. His home is located in Kabete near Nairobi in Kenya where he owns a field of about 2 acres. He purchased a new 80 hp 4WD tractor with a disc plough (3 x 660 mm) and a harrow (24 x 560 mm) using credit provided by a tractor distributor in April 2009. The total cost was about 42 000 USD and a 30 percent down payment was required. The remainder to be paid back in 2 years at an annual interest rate of 15 percent.

The hiring service starts in Kabete to plough and harrow for maize from November to January the following year. The tractor then moves to Nyahururu, one of the granary areas in Kenya for wheat and maize. He needs to transport his tractor and equipment over 700 km by hiring a lorry to Lamu for the maize crop. Then he asks the operators to drive from Lamu to Taveta near Mt. Kilimanjaro for beans and maize. The harrow is pulled by the tractor and the disc plough is mounted on it. The tractor works continuously in Oloitokitok nearby Taveta from June to August. The long season is ended in Kabete in September for maintenance work.

The hire service is provided to farmers if they pay half of the service fee when signing the contract. The remaining 50 percent is collected on completion of the job. He charges 2 000Ksh (25USD)/acre for ploughing and 1000Ksh/acre for harrowing. He estimates that the capacity of the tractor is 10 acres/day for ploughing and 15 acres/day for disc harrowing. He employs two qualified (over 5-years’ experience) operators and pays them 10 percent of the hire service fee for their work. Additionally, he provides them with meals and accommodation during field trips.

He believes that he is able to pay back the credit with interest in 2 years. The critical issue is an incentive for operators to increase the volume of hiring work. There are no problems of spare parts supply and maintenance service, he says. He is willing to purchase a lorry to transport his machines as well as transport hay as a new business.

Estimated gross annual income 2,000,000 Ksh (25 600USD). 1 USD = 78Ksh (May 2010)
Sales: 20 000Ksh/day x 250 days/year = 5 000 000Ksh
Fuel cost: 80Ksh/litre x 8litre/acre x 10 acres x 250 = 1 600 000Ksh
R&M cost: 500 000Ksh. Operator cost: 750 000Ksh. Other costs: 250 000Ksh


CONCLUSIONS

54. The SSA region had more tractors in use in 1960 than all the other developing regions of the world as is evident from the preceding sections. By the end of the 20th century the hand tool technology, with entire reliance on human muscle power, still dominated land preparation on 65% of the cultivated land in SSA with the figure being over 85% of the cultivated land in Central Africa sub region [Fig. 7]. It is obvious that the SSA region is the least mechanized in the world. The tractor remains the most basic machinery for farming and it is unlikely there will be alternatives to it at least in the coming several decades. SSA needs to find ways of ensuring that majority of its farmers have access to mechanization services especially for tillage as other regions of the world have done. The region needs to remain focused and avoid the paradigm shifts which have characterized mechanization policies and strategies over the past seven decades.

55. An important lesson from the agricultural mechanization experience of other continents is the need to invest in the training of human resources for mechanization. The training needs to be not only in the technical and engineering fields but also in entrepreneurial skills. As noted by, among others, Singh, 2001, the first undergraduate degree program in agricultural engineering was started in 1942 in Allahabad University in India cf. in United Kingdom where the first such programs started in
1965 in Silsoe College and Newcastle University [Gibb,1988]. In addition, India transformed her educational system for the agricultural sector in the 1950s by establishing several state agricultural universities which played a pivotal role in the green revolution of the 1960s [Lele, 2012]. The same transformation occurred in the educational system of the other countries in the Asia region. It is no wonder therefore that India, is now the largest manufacturer of tractors in the World exporting the same to all continents [Singh,2013; FAO-RAP, 2014]. In SSA similar transformation of the educational system started only in the 1970s and a lot still needs to be done, in this regard, for the region to catch up.

56. During the 1960s and up to the 1990s the supply chain in SSA for tractors and other agricultural machinery and implements was dominated by European and North America companies [Kurdle, 1975; Burch, 1987]. However, since the turn of the 21st century new players have emerged from the newly industrialized countries who are now dominating the supply chains for agricultural machinery and implements in SSA [Agyei-Holmes, 2014; Cabral, 2019]. Countries in SSA may need to adjust their agricultural mechanization strategies to factor in this new situation. As noted in the F-SAMA report this may be difficult to many countries in SSA as, on a national basis, the current market for agricultural machinery and implements is quite small [AUC/FAO, 2018; Mrema et al 2019]. In this respect, to attain economies of scale and scope, a sub-regional approach may need to be adopted. In key areas like in testing of agricultural machinery and implements a regional approach may be necessary just as it has happened in Asia with the Asian Network for Testing of Agricultural Machinery [ANTAM] [FAO-RAP, 2014 & 2015].

57. As has been noted in AUC/FARA, 2018 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 efficiently 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. The research should focus both on the hardware [new equipment etc.] as well as the software – the business and institutional mechanisms which can facilitate optimal and commercial utilization of the hardware.

58. There has been quite some paradigm shift in the agricultural mechanization policies and strategies of most of the countries in the SSA region. In several cases these shifts have been inspired by writings and research by external experts. This is unlike in Asia where the capacity for analysis of the process of and technologies involved in agricultural mechanization development was built in the 1940s & 50 and hence, they have been able to engage and where necessary critically review and challenge/engage the external experts with local perspectives on the proposed different paradigms. With F-SAMA report and institutions such as ACT and AfricaMechanize Platform as well as PASAE being available to coordinate and facilitate joint research work and discussions on contemporary mechanization issues progress should be achieved during the coming two to three decades. There are signs of success in some parts/districts/regions of SSA countries where primary land preparation is being undertaken on up to 90% of cultivated land by tractors e.g., Northern Ghana, Central Tanzania the North Rift Districts of Kenya among other areas. These success cases should be analyzed and lessons drawn from the analysis used for scaling up in other areas. The AfricaMechanize platform should play a catalytic role in scaling up and propagating such successful models.
REFERENCES/BIBLIOGRAPHY


FAO, 2015


********************************************************************************
FIGURE 8: ‘R’-RUTHERNBERG NUMBER