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A Continental Overview on Patterns and Dynamics

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A Continental Overview on Patterns and Dynamics

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Abstract

This study provides an overview on the patterns and dynamics of mechanization in African agriculture over the 10 year period (2005-2014). Farm level and value chain related mechanization are considered. This study looks in to pattern of agricultural mechanization along the entire value chain (production, post-harvest, processing, transport and storage) and compares it with the annual average agricultural output over the same time period. Clusters of countries are identified by grouping countries into those that have simultaneously experienced high growth rate in agricultural machinery and also in agricultural output, including; Angola, Botswana, Ethiopia, Malawi, Mali, Morocco, Niger, Rwanda, Tanzania, Togo, and Zambia. On the opposite side of the spectrum are countries with low growth in machinery and in agricultural output, and include for instance Madagascar, Zimbabwe, Uganda, and Egypt. In general, there is a positive correlation (of 0.52) between agricultural machinery growth and agricultural output growth in Africa, which is a classical two – way relationship, not to be interpreted as a causal one.

Keywords: Agricultural mechanization, machinery, patterns, agri-food system, value chains, agricultural growth, Africa

JEL Codes: Q01; Q18; D20; L64

List of Abbreviations

2WTs	Two-Wheeled Tractors
4WTs	Four-Wheeled Tractors
ACT	African Conservation Tillage network
AGS	Rural Infrastructure and Agro-industries Division (FAO)
AUC	Africa Union Commission
BMZ	German Federal Ministry for Economic Cooperation and Development
	“Bundesministerium für wirtschafliche Zusammenarbeit und Entwicklung”
CIMMYT	International Maize and Wheat Improvement Center
	“Centro Internacional de Mejoramiento de Maíz y Trigo”
CV	*Cheval Vapeur* (Metric Horsepower)
FAO	Food and Agriculture Organization of the United Nations
GCS	Gross Agricultural Capital Stocks
ha	Hectare
IFPRI	International Food Policy Research Institute
IPAR	Institute of Policy Analysis and Research
kW	kilowatt
kW/ha	kilowatt per hectare
NCS	Net Agricultural Capital Stocks
OECD	Organization for Economic Co-operation and Development
PQI	Paasche Quantity Index
R&D	Research and Development
SDGs	Sustainable Development Goals
SIMLESA	Sustainable Intensification of Maize-Legume cropping systems in Eastern and Southern Africa
USDA	United States Department of Agriculture
ZEF	Center for Development Research “Zentrum für Entwicklungsforschung”

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1 Introduction

Agricultural mechanization has been defined in a number of ways. Perhaps the most comprehensive and appropriate definition is that it entails all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment (FAO, 2016). It includes all tools, implements and machinery and can use human, animal or motorized power sources. Mechanization eases and reduces hard labor (drudgery), relieves labor shortages, improve farm labor productivity, improves productivity and timeliness of agricultural operations, improves the efficient use of resources, enhances market access and contributes to mitigating climate related hazards (Sims and Kienzle, 2017).

Increased accessibility and effectiveness of agricultural mechanization can contribute to Africa's agricultural and economic transformation (IFPRI, 2016). Farm mechanization is essential in increasing land and labor productivity. Without proper mechanization, agricultural productivity in the smallholder sector will continue to stagnate, or even decline especially due to increasing labor constraints (FAO, 2006). The process of agricultural mechanization involves many aspects. From identifying farm operations that should be mechanized, and identifying, adapting and/or producing suitable machinery, to providing enabling and supporting environment and policies (such as markets, finance, capacity building) along the entire value chain (Baudron et al., 2015).

This study provides an assessment of the patterns of mechanization in agricultural value chains in Africa over the 10 year period (2005-2014). This study proposes a clustering criteria that is relevant for comparing agricultural mechanization growth across countries. This is particularly significant because it looks in to pattern of agricultural mechanization along the entire value chain (production, post-harvest, processing, transport and storage) and compares it with the annual average agricultural output over the same time period. The rest of this paper is organized as follows: section two provides a brief overview of research on mechanization in Africa; section three discusses previous approaches to measuring agricultural mechanization; section 4 describes data, proposes agricultural mechanization clustering criteria, and also presents the results of agricultural mechanization patterns in Africa; while conclusions and implications of the study are presented in section 5.

2 Brief Overview of Research on Mechanization in Africa

Mechanization is a key investment in any farming system. However, for decades, mechanization remained a neglected element of agricultural and rural development polices in Africa. Only limited progress in agricultural mechanization has been achieved in terms of increased number of machines and market expansion in post-independence Africa. Consequently, for decades, farm based mechanization in most African countries has relied to an overwhelming extent on human muscle, based on operations that depend on the hoe and other hand tools. Such tools have implicit limitations in terms of energy and operational output. These methods also place severe limitations on the amount of land that a family can cultivated. Further, they reduce the timeliness of farm operations and limit the efficacy of essential activities such as cultivation and weeding, thereby reducing crop yields.

Recent estimates show that African farming systems remain the least mechanized of all continents – 70% of the farmers cultivate parcels of less than two hectares by hand hoe (Pingali, 2007). Further, estimates from the Food and Agricultural Organization (FAO) show that Africa has less than two tractors per 1000 ha of arable land. In 2012, average tractor use in Sub-Saharan Africa was around 1.3 per 1000 hectares of cultivated land, compared to around 9.1 and 10.4 tractors in South Asia and Latin America respectively, for the same period (FAO, 2012). In fact, tractor use in Sub-Saharan Africa peaked at 1.9 per 1000 hectares in 1986 and has gradually declined since then (FAO, 2011; FAO, 2012). Several factors have been attributed to limit mechanization and to hinder government and private sector investment in mechanization among smallholder farmers in Africa. They include (i) thin markets that limit access to machinery and spare-parts supplies, (ii) missing institutions especially those that would be required to ensure adequate technicians and skilled personnel to operate and repair farm machinery, (iii) governance challenges such as political interest, elite capture, ineptness and corruption that constraint the government and hinder private sector's involvement in machinery importation, among others (see Daum and Birner, 2017 for a recent review).

Mechanization is an essential input not only for crop production, but it also has a crucial role to play along the entire value chain (FAO, 2007; Breuer, 2015). For example, mechanization is needed at different stages as follows:

(i) Production: for land preparation, crop establishment, weeding, fertilization, irrigation, crop protection, harvesting

(ii) Post-harvest/storage: for drying, grading, winnowing, cleaning, storage

(iii) Processing: for chopping, milling, grinding, pressing

(iv) Marketing: for packaging, transport

Most of the Research and Development (R&D) programs have placed much emphasis on increasing the efficiency with which land, water and nutrients are used, however farm mechanization appears to be an overlooked resource. The changing agricultural sector and the challenges faced by smallholders call for the need for farm mechanization suited to smallholder farming. Recent studies (such as Baudron et al., 2015; FAO, 2016) find that the rural area and smallholder farming conditions have changed tremendously in the last decade or two and seem to favor a shift to appropriate mechanization. This shift is expedited by a combination of many factors: agriculture is relatively getting more commercially-oriented and is characterized by seasonal labor shortages, the number of draught animals is declining in many parts of SSA, fuel is relatively more available in rural areas than before due to proliferation of small engines (especially moto bicycles) (ibid).

The demand for agricultural mechanization depends on several factors, such as; the intensity farming operations, market access for the agricultural products, labor market situations, capacity to utilize machines, and availability of complementary technologies (IFPRI, 2016). However, the benefits of mechanization also rely on the availability and the use of other complementary inputs such as improved seeds, fertilizers and water. Further, sustainable agriculture intensification will succeed where there is sufficient supply of farm machinery (Mrema et al., 2018).

Recent evidence (Diao et al., 2014) underline the importance of supply side factors in constraining successful mechanization among smallholder farmers. This is marked by the increased demand for some mechanized farming operations like ploughing and harvesting. However in many countries, Ghana for instance, the agricultural mechanization strategies are dominated by state-led mechanization program (Diao et al., 2014). This strategy is inherently weak in that the government-run agricultural mechanization service centers are inefficiently operated, and the direct importation of heavy machinery by the state inhibits private sector from importing appropriate and affordable machinery. Indeed, some assessments have found that that several previous government subsidized large tractor imports were not only ineffective and inefficient, but also adversely affected the private supply chain development (IFPRI, 2016). Similarly, many international aid programs for mechanization also continue to import many equipment that are unsuitable for specific SSA circumstances (FAO, 2006).

A promising supply model would entail development of market for hiring mechanized service. This involves private ownership of machinery by medium and large scale farmers who would in turn hire-out services to small-scale farmers. Government can then play a more supportive and complementary role by creating an enabling environment for private-sector-driven mechanization supply chains to thrive as opposed to direct government involvement in importation and distribution of machinery or in subsidized programs (IFPRI, 2016). Other areas that government has an immense role to play include providing R&D on locally appropriate and adaptable machinery (such as tractors suitable for small-scale farms, and multifunctional tractors), and providing skill development and vocational and technical training on machinery use and repairs (Kirui & Kozicka, 2018). It has been noted that most of these past initiatives promoting mechanization failed because of lack of supporting infrastructure (Baudron et al., 2015).

The private sector may benefit even more where there is good effective demand for machinery, and economic use rates, and where there is efficient machinery and equipment supply chains and services (Mrema et al., 2018). Recently, private importers have been found to be able to import lower-cost machinery and the brands preferred by farmers, which can be easily and cheaply repaired (IFPRI, 2016). While assessing the economics of tractor ownership by Ghanaian farmers, IFPRI (2014) found that tractor service provision is profitable when tractors owners take advantage of timely access of the tractors in their own farms and provide numerous services such as ploughing, and maize-shelling to other farmers. Locally manufactured tractor mountable implements such as seeders and shellers are affordable and would guarantee quick returns in the short to medium term. In the face of small and insignificant markets for farm machinery, it might be worthwhile to consider exploiting economies of scale through inter-country or regional manufacturing and/or supply hubs.

The Sustainable Development Goals (SDGs) in goal number twelve – SDG12: ensuring sustainable consumption and production patterns – provides a strong case for sustainable crop production intensification that will protect natural resources while producing food for the global growing population (Le Blanc, 2015; UN, 2015). In order to achieve this, there is need to sharply improve labor and land productivity in the smallholder farming sector which produces up to 80% of the food in developing countries. This would not only require improved access to essential crop production inputs including quality seed, fertilizer and irrigation water, but also would necessitate increased access to machinery.

The changing agricultural sector and the challenges faced by smallholders in developing countries, especially in Africa, call for the need for farm mechanization suited to smallholder farming. For example, conventional four-wheeled tractors (4WTs) may not feasible for many smallholders owing to their high capital costs, unsuitability for fragmented holdings as well as farm topography and slope. More appropriate technologies such as two-wheeled tractors (2WTs) and their requisite accessories may be needed. Indeed, 2WTs are becoming more available in the SSA as reflected by increasing imported units in several countries especially in Eastern and Southern Africa, such as Tanzania and Ethiopia where about 6,000 and 4,100 units were in use as of 2014 (Baudron et al., 2015).

As smallholder agriculture become more commercial and modern, and agricultural value chains get more intricate, there is need for strategies to promote diverse types of mechanization technologies along these value chains (Mrema et al., 2018). Vast mechanization opportunities for small to medium scale farmers and other entrepreneurs lie in agro-processing, transport or other off-farm activities. In identifying farm operations that should be mechanized, priority ought to be given to tasks where labor productivity is low and/or where labor drudgery is high (Baudron et al., 2015).

The collapse of virtually all the government-run tractor schemes demonstrates the need for a new approach to mechanization that involves the private sector. Sustainability of such new approaches should ensure the profitability for farmers, private sector actors, and other service providers in the supply chain. The growing shortage and deteriorating quality of human labor in most countries is as a result of ageing farmer population and rural–urban migration of the able youth (Proctor and Lucchesi, 2012; Filmer and Fox, 2014; IPAR, 2014; Mekuria et al., 2014; FAO, 2015). For decades, the low levels of farm mechanization has been linked to labor drudgery which makes farming unattractive to the youth and to disproportionally affect women – youth opt for alternative urban livelihoods, favoring non-farm over on-farm activities (Diao et al. 2012). Further, the decline in number of draught animals and diseases outbreaks (such as Trypanosomiasis) cannot be under estimated.

Addressing declining farm power (agricultural mechanization) can be achieved by decreasing power demand through power saving technologies or/and by increasing farm power supply through appropriate mechanization. Earlier studies have shown that land preparation is the most energy-demanding farming operation in rain-fed agriculture (Lal 2004). Thus simplification of this soil inversion operation either by reduced or no tillage would highly reduce the amount of power needed. It is estimated that reduced or no till would cut energy requirements by about half compared to mouldboard or disc ploughing (Lal 2004). Reduced or no tillage would also make it possible to use low powered, affordable and easy to maintain 2WTs (Singh 2006; Singh, 2013). However, that the African Conservation Tillage (ACT) Network documents that conservation agriculture practices have largely been adopted by large scale farms (ACT, 2017). In 2016 for instance, 68% (that is, 1.835 million ha out of a total of 2.679 million hectares) of land area under conservation agriculture were in large scale farms especially in South Africa, Zambia, Mozambique, Malawi and Zimbabwe (ibid).

Successful promotion of conservation agriculture (reduced tillage practices) and its mechanization options will require proper policies, political will, incentives for private sector participation, and perhaps more importantly training for small-scale farmers (FAO, 2006; Collier and Deacon, 2009). Increasing motorized equipment if Africa, just like was achieved in some Asian countries during the ‘’Green Revolution’’ and in the course of the last three decades, can be achieved through three different approaches (see Diao et al. (2012) for detailed description):

(i) Medium to large scale farmers own medium-size machines and hire out their services to other farmers (the Indian model). This should be accompanied by high public support (subsidies) for the purchase of machines (tractors, combined harvesters, threshers, etc.) and large investment in infrastructure (Singh 2006; Hazell 2009).

(ii) Migration of specialized equipment like combine harvesters, threshers and tractors across regions (Chinese model). This model would require good quality rural road network and large agro-ecological areas with varying rainfall gradients and generally non-fragmented lands (Dixon et al. 2001) which presently is typically not the case in most African countries.

(iii) Purchase of small and affordable machines (such as multipurpose 2WTs) by many of small scale farmers who in turn become service providers to other smallholder farmers (Bangladeshi model). This model has not only worked in Bangladesh but in many other countries in Asia such as Thailand, Vietnam, and Sri Lanka. About 80 percent of cropland in Bangladesh is mechanically prepared – mainly by small machines such as 2WTs (Kulkarni 2009; Baudron et al., 2015) and nearly all Bangladeshi farmers have access to machinery though only about one in thirty farmers actually owns one (Justice and Biggs 2013). Besides, the 2WTs are used not only for land preparation but also for other purposes such as transport, post-harvest operations and water pumping which increases the rates of return on investment (Biggs et al. 2011).

3 Review of Measurements of Level of Agricultural Mechanization in Africa: Previous Approaches

Previous studies have considered the level of agricultural mechanization in different ways, namely:

(i) Number of tractors per arable land (tractors/1000ha or per 100 sq. km). This may include:
   - Number of tractors (with four wheels and two axles) – Mrema et al. (2008).
   - Tractors in use per 1 000 ha of agricultural land – FAO/AGS (2004); FAO (2008).
   - Amount of arable land area cultivated by different power sources (Hand, draught animal power, tractors) – Ozmerzi (1998); FAO (2001); Bishop-Sambrook (2003).

(ii) Farm power availability: This may include:
   - Power availability per hectare (kW/ha) – Ozmerzi (1998); Mrema et al. (2008); Olaoye & Rotimi (2010).
   - Mechanical and electrical power sources verses animate power (Human and animals) – FAOSTAT/AGS (2004); Mrema et al. (2008).
   - Different sources of power for primary land preparation in SSA – FAO (2008).

(iii) Level of mechanization in terms of mechanical power as a ratio of total farm power (tractor power and human power) – Olaoye & Rotimi (2010); Taiwo & Kumi (2015) or power intensity – (Pingali and Binswanger (1987); Pingali (2007). Furthermore, machination index has also been presented as the ratio of machine energy to total energy (machine, animal, and human energy) – Nowacki (1978); Hormozi et al. (2012); Zangenehet al. (2015); Ramirez et al. (2007); Abbas et al. (2017). There are various types of mechanically-powered technologies in agriculture in SSA (see Mrema et al. (2018) for a detailed description):
   a. Tractors including: Four-wheel tractors (4WT), Low horsepower four-wheel tractors specially designed for the developing countries, single axle tractor (power tiller or two-wheel tractor), and land clearing (crawler) tractors
   b. Motorized water pumps
   c. Motorized harvesting and postharvest handling technologies (such as combine harvesters, threshers, shellers);
   d. Milling technologies (especially for grains)

(iv) Ratio of machinery cost to the cost of labor force – Kislev & Peterson (1982); Pingali and Binswanger (1987); Ozmerzi (1998); Ji et al. (2017); Ashayeri et al. (2018).

(v) Machinery/equipment weight – such as tractors and disc harrows of varying weights (in tons) – Ozmerzi (1998); Ou et al. (2002). Machinery weights can also been presented as mechanization capacity ratio (that is, number of available machines multiplied by their annual potential working capacity as a ratio to total operation) – Paman et al., 2012.

(vi) Agricultural machinery import values – Epule & Bryant (2015); Hanlin & Kaplinsky (2016).

Previous indices described above are not without limitations. For example the most commonly used measure – number of tractors (4WTs) per arable land – excludes several equipment such as fertilizer/lime/manure applicators, rippers, rotavators, inter-row cultivators, harvesters, self-propelled transporter, combine harvesters, threshers, shellers, milking machines and thus is inadequate and misleading. The availability of tractors may not imply that they are in a good working condition. In Nigeria for example, previous studies have linked low production efficiency to uses of old tractors which constant break down during operation (Olaoye & Rotimi, 2010).

The number of tractors as well as other indices such as farm power availability and ratio of mechanical power to total farm power are biased towards land preparation and crop production ignoring other significant parts of the value chain like processing and transport. Indeed, processing as well as logistics and transport may include more sophisticated mechanized operations than land preparation.

Gauging mechanization using the intensity of farm power maybe inadequate because it omits time dynamics (Sundaram et al., 2012). Furthermore, in most developing countries, tractors are used for both agricultural and non-agriculture activities, thus, quantification the actual farm power use of tractors based on machine power relative to total farm power, would be inaccurate. Thus it would be more relevant to identify and the actual utilization of any equipment for different operations along the value chain. Similarly, identifying the levels or patterns of mechanization based on machine energy relative total energy (human, animal, and machinery) should also be enumerated at different levels of the value chain in order to capture the actual energy expended (Singh., 2006; Abbas et al. 2017).

This study proposes to measure patterns of agricultural mechanization based on average annual machinery growth. Growth in the agricultural machinery as an indicator of patterns of agricultural machinery would be more desirable because it does not only consider the stock of available machine capital but also the additionally acquired machinery over time. It is also critical to consider entire value chain and different sectors (crop and livestock). Emerging technologies as well as domestically manufactured machinery should also be accounted for in measuring the levels and patterns of agricultural mechanization.

4 Measuring Agricultural Mechanization Patterns in Africa

4.1 *Definition and Measurement of Mechanization*

The variables used in this study are presented in Table 1. They are defined and measured as follows:

Farm machinery: Refers to the value of total stock of farm machinery in "40-CV tractor equivalents" (CV=metric horsepower). This is the achieved by aggregating the number of 2-wheel tractors, 4-wheel tractors, and combine-harvesters using data from FAO except 2-wheel tractors, which were compiled from national sources[1]. For weights, the following assumptions suffice: 2 wheel tractors average 12 CV, 4-wheel tractors 40 CV, and combine-harvesters 20 CV. Data sources: FAO except 2-wheel tractors, which were compiled from national sources (recorded in USDA, Economic Research Service). The first two columns of Table 1 present the average annual growth in machine across all countries in Africa. Figure 1 depicts the annual machinery growth.

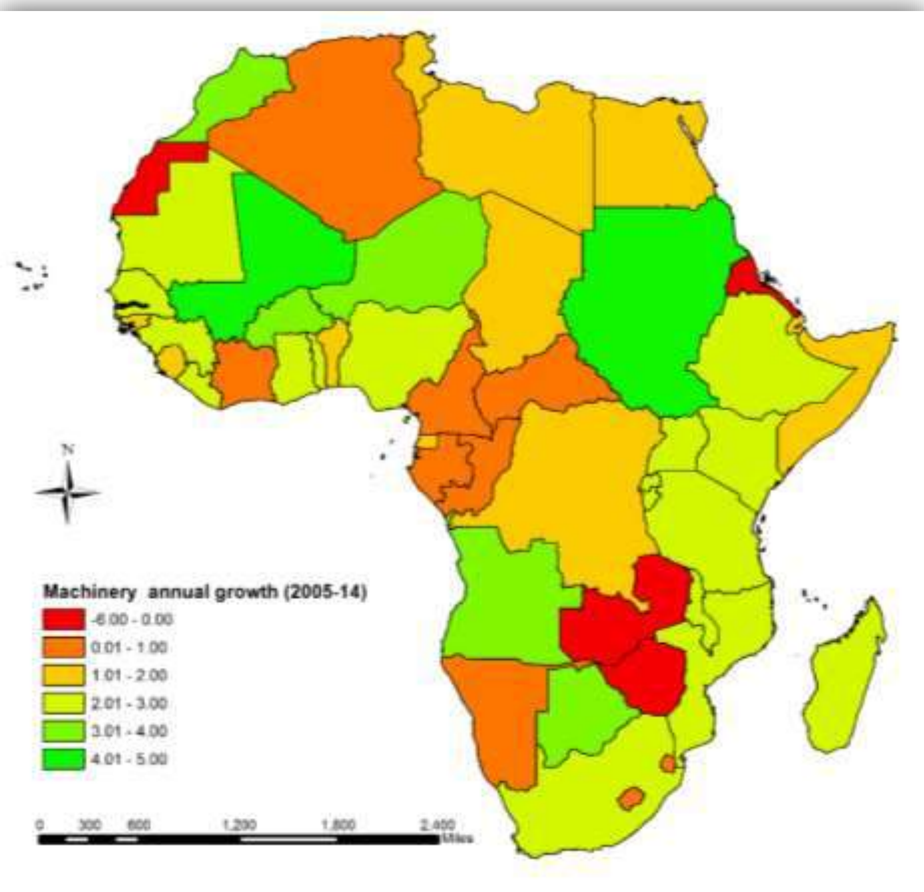

Figure 1: Average annual machinery growth rate in Africa
Source: Authors' compilation.

[1] The stock of assets acquired from past periods are corrected for depreciation to attain the net capital stock. These assets are valued at their market prices which are lower than their "as new" prices by the amount of accumulated consumption of fixed capital.

Table 1: Data on Machinery and agricultural growth rate in Africa (for the period 2005-2014)

Machinery: avg. number of agricultural machinery units		**Machinery: avg. annual growth rate (in %)**		**Agric. output growth rate (in %)**	
Country	**last 10 years (2005-14)**	**Country**	**last 10 years (2005-14)**	**Country**	**last 10 years (2005-14)**
Algeria	**108999.4**	Sudan, former	**4.70**	Zambia	**8.54**
Egypt	**108544.7**	Mali	**4.65**	Angola	**7.36**
South Africa	**79996.4**	Morocco	**3.67**	Sierra Leone	**7.15**
Morocco	**53931.2**	Niger	**3.47**	Algeria	**6.67**
Libya	**44247.9**	Angola	**3.31**	Tanzania	**6.62**
Tunisia	**42925.2**	Burkina Faso	**3.28**	Malawi	**6.17**
Tanzania	**25974.6**	Zambia	**3.12**	Rwanda	**5.55**
Nigeria	**25478.5**	Botswana	**3.02**	Benin	**5.28**
Sudan, former	**25079.9**	Gambia	**2.92**	Ethiopia	**5.23**
Zimbabwe	**24993.1**	Tanzania	**2.88**	Cameroon	**5.12**
Kenya	**14973.7**	Burundi	**2.82**	Ghana	**4.80**
Angola	**12867.0**	Togo	**2.77**	Chad	**4.80**
Côte d'Ivoire	**8951.9**	Ethiopia	**2.75**	Mali	**4.66**
Zambia	**7152.4**	South Africa	**2.73**	Mozambique	**4.19**
Mozambique	**6645.5**	Rwanda	**2.73**	Togo	**4.18**
Guinea	**6481.0**	Senegal	**2.71**	Morocco	**3.96**
Uganda	**5580.1**	Malawi	**2.69**	Botswana	**3.92**
Ethiopia	**4317.4**	Sao Tome	2.60	Niger	**3.89**
Botswana	3362.9	Madagascar	2.56	Guinea-Bissau	3.80
Namibia	3152.3	Uganda	2.54	Guinea	3.30
DRC	2714.8	Guinea	2.50	Congo	3.22
Burkina Faso	2527.6	Comoros	2.42	Burkina Faso	2.96
Ghana	2266.7	Mauritania	2.41	Côte d'Ivoire	2.71
Lesotho	2016.1	Ghana	2.36	Senegal	2.66
Mali	1662.8	Liberia	2.30	Mauritania	2.59
Malawi	1655.9	Mozambique	2.13	South Africa	2.49
Swaziland	1557.3	Kenya	2.05	Djibouti	2.40
Gabon	1464.0	Nigeria	2.04	Gabon	2.32
Somalia	1435.6	Egypt	1.98	Kenya	2.25
Senegal	1315.8	Guinea-Bissau	1.88	CAR	2.18
Madagascar	865.2	Chad	1.82	Sudan, former	2.14
Congo	787.3	Djibouti	1.81	Madagascar	1.97

Machinery: avg. number of agricultural machinery units		Machinery: avg. annual growth rate (in %)		Agric. output growth rate (in %)	
Country	**last 10 years (2005-14)**	**Country**	**last 10 years (2005-14)**	**Country**	**last 10 years (2005-14)**
Cameroon	525.2	DRC	1.71	Burundi	1.80
Mauritania	445.1	Tunisia	1.70	Somalia	1.77
Liberia	371.6	Libya	1.67	Swaziland	1.73
Mauritius	295.8	Eq. Guinea	1.67	Egypt	1.64
Niger	251.0	Somalia	1.65	Libya	1.60
Chad	208.7	Benin	1.45	Eq. Guinea	1.60
Burundi	208.6	Sierra Leone	1.21	DRC	1.40
Benin	206.4	Zimbabwe	1.07	Sao Tome	1.31
Eq. Guinea	190.0	Congo	0.98	Nigeria	1.15
Sao Tome	141.2	Cameroon	0.88	Tunisia	1.13
Togo	139.3	CAR	0.72	Lesotho	0.92
Sierra Leone	113.4	Algeria	0.67	Seychelles	0.85
Rwanda	65.1	Swaziland	0.41	Liberia	0.78
Gambia	63.0	Namibia	0.34	Zimbabwe	0.68
Cape Verde	52.1	Côte d'Ivoire	0.27	Comoros	0.53
CAR	49.4	Lesotho	0.21	Gambia	0.36
Seychelles	42.6	Gabon	0.14	Mauritius	-0.17
Guinea-Bissau	21.0	Seychelles	-0.48	Cape Verde	-1.03
Djibouti	6.4	Cape Verde	-1.37	Uganda	-1.12
Comoros	5.8	Mauritius	-3.18	Namibia	-1.53

Source: Author’s compilation based on data from several sources[2]

Note: The average number of agricultural machinery units is expressed in “40-CV (horse-power) tractor-equivalents”.

[2] Data sources: World Bank, FAO, USDA Economic Research Service, national statistical offices

Over the ten year period eight countries (Sudan, Mali, Morocco, Niger, Angola, Burkina Faso, Zambia and Botswana) recorded growth in agricultural machinery of at least three percent. Others including the Gambia, Tanzania, Burundi, Togo, Ethiopia, South Africa, Rwanda, Senegal, and Malawi also reported a growth rates of between 2.69 percent and three percent. Together, these countries form the top (highest) tercile. However, a few countries (Seychelles, Cape Verde, and Mauritius) reported a negative growth rate over the same period (Table 1, Figure 1).

Agricultural output: FAO gross agricultural output is the sum of the value of production of 189 crop and livestock commodities, valued at constant, global-average prices from 2004-2006 and measuring in international 2005 $. This output measure is equivalent to a Paasche Quantity Index where annual quantities vary and end-period prices are fixed. Sources FAO. The last columns of Table 1 presents the average annual in agricultural output growth over 2005-2014 period. These are also depicted in Figure 2. Over the ten year period ten countries (Zambia, Angola, Sierra Leone, Algeria, Tanzania, Malawi, Rwanda, Benin, Ethiopia, and Cameroon) recorded growth in agricultural output of at least five percent. However, four countries (Mauritius, Cape Verde, Uganda, and Namibia) reported a negative growth rate over the same period (Table 1, Figure 2).

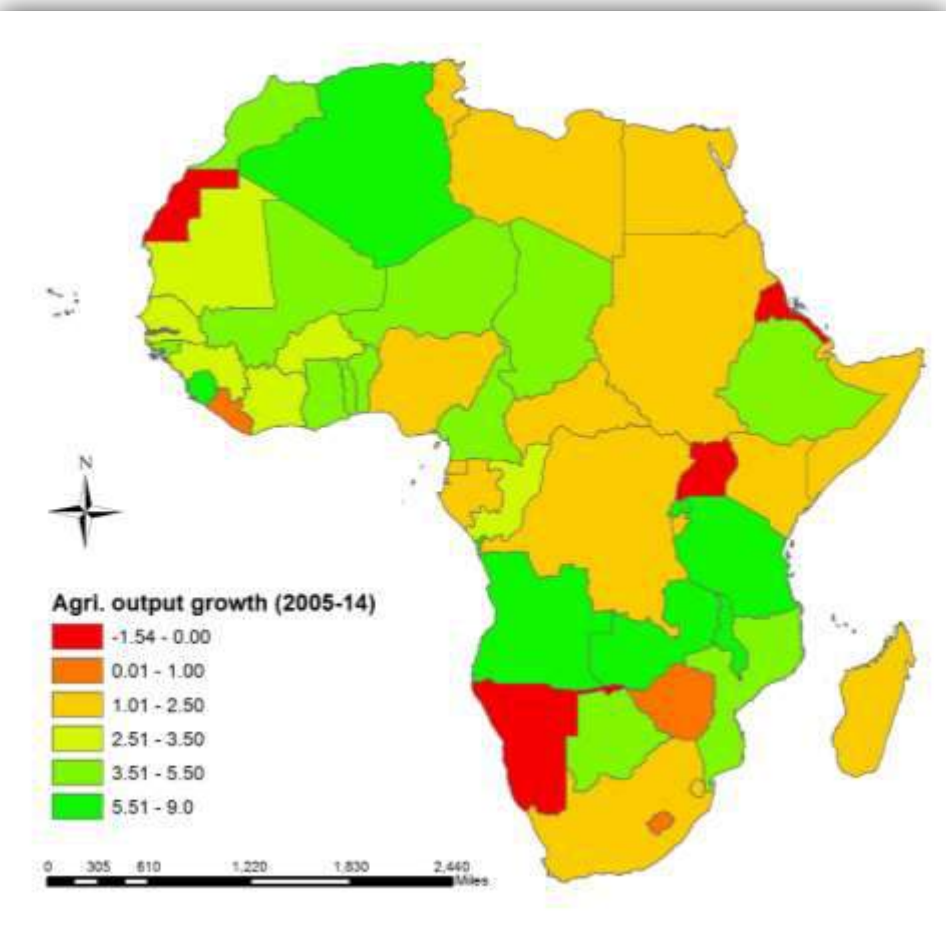

Figure 2: Average agricultural output growth rate in Africa
Source: Authors' compilation

4.2 Patterns of Agricultural Mechanization: a Clustering Approach

Several countries across Africa have made remarkable progress in improving the level of agricultural mechanization in the last 2-3 decades. Based on data availability. To identify the patterns of agricultural mechanization (in past 10 years) we rely on the average annual machinery growth rate and agricultural output growth rate to measure country efforts in mechanization their likely impact in the food value chains. We develop a 2x2 table, which presents levels of mechanization verses levels of agricultural growth resulting in four clusters as shown in Table 2 and depicted in Figure 3.

The procedure was completed in two stages. In stage 1, the countries showing scores for the average annual machinery growth rate above the higher tercile which is 2.6 percent were grouped within the *Higher Mechanization* clusters, while the countries ranking below this cut-off were grouped within the *Lower Mechanization* clusters. In the second stage countries that reported an average rate of agricultural output growth above the higher tercile which is 3.9 percent were categorized under high agricultural growth, while countries below that rate were categorized under lower agricultural growth. This resulted in four clusters as follows (Table 2):

a. **Cluster 1:** high mechanization and high agricultural growth rates cluster – eleven countries; Angola, Botswana, Ethiopia, Malawi, Mali, Morocco, Niger, Rwanda, Tanzania, Togo, and Zambia.

b. **Cluster 2:** high mechanization and low agricultural growth rates cluster – six countries; Burkina Faso, Burundi, Gambia, Senegal, South Africa, former Sudan

c. **Cluster 3:** low mechanization and high agricultural growth rates cluster – seven countries; Algeria, Benin, Cameroon, Chad, Ghana, Mozambique, Sierra Leone

d. **Cluster 4:** low mechanization and low agricultural growth rates cluster – twenty eight countries; Cape Verde, CAR, Comoros, Congo, Côte d'Ivoire, Djibouti, DRC, Egypt, Eq. Guinea, Gabon, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya,, Madagascar, Mauritania, Mauritius, Namibia, Nigeria, Sao Tome, Seychelles, Somalia, Swaziland, Tunisia, Uganda Zimbabwe

Table 2: average annual machinery growth vs average annual agricultural output growth

	High agric. Growth	Low agric. growth
High mechanization growth	Angola, Botswana, Ethiopia, Malawi, Mali, Morocco, Niger, Rwanda, Tanzania, Togo, Zambia	Burkina Faso, Burundi, Gambia, Senegal, South Africa, Former Sudan
Low mechanization growth	Algeria, Benin, Cameroon, Chad, Ghana, Mozambique, Sierra Leone	Cape Verde, CAR, Comoros, Congo, Côte d'Ivoire, Djibouti, DRC, Egypt, Eq. Guinea, Gabon, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Mauritania, Mauritius, Namibia, Nigeria, Sao Tome, Seychelles, Somalia, Swaziland, Tunisia, Uganda, Zimbabwe

Source: Authors' compilation.

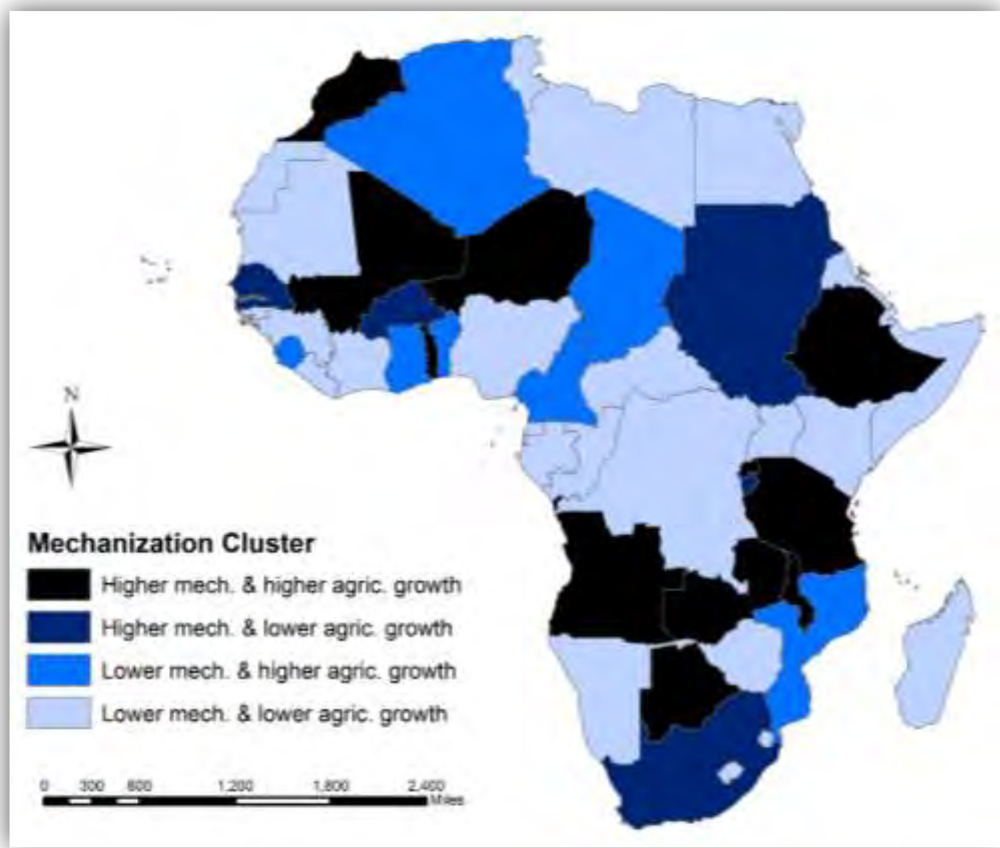

Figure 3: Clusters: Machinery growth rate vs agri. output growth rate in Africa
Source: Authors' compilation

5 Conclusions

This study provides an assessment of the patterns and dynamics of mechanization in agricultural value chains in Africa over a recent 10 year period (2005-2014).

The clustering facilitates comparisons of agricultural mechanization growth across countries. It does not only look at field level mechanization but includes mechanization along the value chain.

Findings highlight great diversity across Africa, which indicates scope for cross-country learning from experiences:

- Some countries have simultaneously experienced a higher growth rate in agricultural machinery and agricultural output, including; Angola, Botswana, Ethiopia, Malawi, Mali, Morocco, Niger, Rwanda, Tanzania, Togo, and Zambia.
- A large number of African countries combine a pattern of low growth in machinery with low agricultural output growth, including some large agricultural economies with potentials for growth, such as Côte d'Ivoire, DRC, Kenya, Madagascar, Nigeria, Tunisia, Uganda and Zimbabwe.
- It might be instructive for policy makers and planners from these countries, to gain insights from African those countries that managed to achieve higher agricultural growth, be it in combination with high machinery growth (as the cases listed above), or even with lower growth in machinery, which include countries like Ghana, Benin, Cameroon, and Mozambique.

Obviously, mechanization investments depend on a host of factors: agricultural ecologies, (small) farm and production structures, comparative advantages and opportunity costs of labor, access to finance and the development of machinery markets and services, etc. It may be assumed that agricultural output growth pulls mechanization and mechanization drives agricultural output growth. We find a strong positive correlation of 0.52 between agricultural machinery growth and agricultural output growth (and vice versa). Given the two-way relationship, this is of course not depicting causality.

Accelerating investments in agricultural mechanization and related value chains requires fresh policy consideration:

- Analyses of the determinants of mechanization, costs and benefits, and the related institutions, including cooperative sharing, and commercial leasing arrangements, seem worthwhile in order to define most suitable use of machine capital accessible to small holders.
- Such analyses might best be done at country and local levels rather than in the context of the broad identification of patterns and dynamics that were the aim of this review paper.
- Policy, however, also needs a country level strategic perspective, especially regarding machinery imports and services contracts, and for the build-up of African agricultural machinery industries.

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7 Appendix: Other Relevant Data

Table 3 presents other important data such as agricultural tractors, agricultural machinery import, value added per worker in agriculture, capital stocks, and capital stocks to labor ratio. These are defined and measured as follows:

(i) **Agricultural tractors**[3]**:** Tractors per 100 sq. km of arable land)

(ii) **Agricultural machinery Import**[4]**:** Import value index (in constant 2000 US$)

(iii) **Net Capital Stock (NCS)**[5]**:** The stock of assets surviving from past periods, and corrected for depreciation is the net or wealth capital stock. NCS is valued as if the capital good (used or new) were acquired on the date to which a balance sheet relates, that is, assets are valued at their market prices. These are lower than their "as new" prices by the amount of accumulated consumption of fixed capital. These market values are estimated by deducting accumulated consumption of fixed capital from the gross capital stock. The net capital stock is thus the value at a point in time of assets at the prices for new assets of the same type less the cumulative value of consumption of fixed capital accrued up to that point.

Capital Stocks to labor ratio: Is computed as a ratio between Net Agriculture Capital Stocks to agricultural labor force.

(iv) **Agriculture value added per worker**[6]**:** (in constant 2010 US$). The remarkable increase in the value added by agriculture (i.e., the net output of the sector after adding up all outputs and subtracting intermediate inputs), particularly over the past decade (Table 3), has made investment in agricultural inputs such as fertilizers possible in countries such as South Africa, Mauritius, Nigeria, Tunisia, Egypt and Algeria. However, in contrast with other countries that experienced the Green Revolution (e.g., India), the farm power available per area of agricultural land is still very low over the past three decades.

[3] Data sources: FAO
[4] Data sources: FAO, World Bank
[5] FAO, World Bank
[6] Data sources: World Bank, FAO

Table 3: Other relevant data

Tractors/ 100 sq km		Machinery import value		Agric. capital stocks		Value added/ worker		Capital/Labor ratio	
Country	**Tractors/ 100 sq km**	**Country**	**Machinery import value**	**Country**	**Agric. capital stocks**	**Country**	**Value added/ worker**	**Country**	**Capital : labor ratio**
Egypt	356.04	Eq. Guinea	752.55	Nigeria	18708.37	South Africa	7145.98	Libya	11.92
Botswana	138.95	Congo, Rep.	708.21	Morocco	18463.13	Mauritius	7096.97	South Africa	11.73
Algeria	133.38	Ethiopia	648.14	Egypt	18034.21	Nigeria	6354.91	Mauritius	10.91
Tunisia	130.87	Chad	622.40	South Africa	16654.73	Tunisia	4293.52	Tunisia	10.12
Swaziland	83.70	Rwanda	601.35	Cote d'Ivoire	10211.56	Egypt	4278.94	Swaziland	6.95
Djibouti	67.69	DRC	579.84	Ghana	8523.56	Algeria	4243.57	Gabon	5.67
South Africa	49.07	Sierra Leone	577.23	Tunisia	6310.89	Cabo Verde	3872.38	Namibia	4.52
Cote d'Ivoire	32.08	Zambia	569.90	Ethiopia	5982.64	Morocco	3627.01	Angola	4.16
Kenya	24.87	Angola	496.38	Libya	5182.20	Namibia	3618.23	Morocco	3.46
Tanzania	23.03	Tanzania	449.56	Uganda	4299.14	Swaziland	3421.01	Egypt	1.75
Cape Verde	11.27	Sudan	429.11	Kenya	4028.60	Gabon	3265.55	Cabo Verde	1.61
Somalia	9.92	Niger	405.16	Tanzania	3966.58	Cote d'Ivoire	2450.35	Cote d'Ivoire	1.40
Sudan	9.68	Nigeria	404.43	Angola	3574.10	Sudan	2344.59	Algeria	1.20
Mauritania	9.37	Mozambique	402.46	Cameroon	3169.94	Chad	1840.52	Ghana	0.99
Nigeria	6.39	Comoros	402.27	Somalia	3042.48	Ghana	1458.92	Sao Tome	0.93
Ghana	4.65	Algeria	375.38	Algeria	2335.43	Equatorial Guinea	1134.67	Eq. Guinea	0.91
Mali	2.24	Mauritania	370.83	DRC	1954.71	Mali	1062.60	Mauritania	0.83
Madagascar	2.15	Burkina Faso	343.77	Mali	1686.87	Cameroon	1023.47	Nigeria	0.60
Senegal	2.09	Kenya	334.55	Namibia	1466.48	Benin	972.93	Botswana	0.44
Rwanda	0.54	Malawi	327.89	Zimbabwe	1419.97	Sierra Leone	944.61	Benin	0.40
Togo	0.47	Ghana	325.90	Zambia	1153.81	Togo	899.35	Mali	0.39
Mozambique		Sao Tome	323.10	Benin	1121.37	Congo, Rep.	892.09	Cameroon	0.36
Angola		Mali	319.94	Guinea	1061.33	Seychelles	882.12	Liberia	0.35
Benin		Cameroon	316.59	Burkina Faso	925.48	Botswana	869.61	Congo, Rep.	0.33
Comoros		Burundi	310.86	Chad	840.86	Guinea-Bissau	841.69	Lesotho	0.31
Gambia, The		Namibia	305.04	Niger	835.28	Kenya	760.14	Kenya	0.26
Burundi		Benin	302.68	Gabon	833.48	CAR	699.62	Guinea-Bissau	0.24
Namibia		Libya	297.40	Madagascar	822.66	Zambia	671.69	Uganda	0.23
South Sudan		Senegal	295.65	Rwanda	761.92	Liberia	659.49	Somalia	0.21
Congo, Rep.		Cote d'Ivoire	288.23	Swaziland	697.99	Sao Tome	653.17	Guinea	0.20
Burkina Faso		Egypt	286.63	Mozambique	636.52	Tanzania	529.07	Togo	0.20
Seychelles		South Africa	283.89	Mauritius	628.89	Uganda	488.49	Zambia	0.19

Tractors/ 100 sq km		Machinery import value		Agric. capital stocks		Value added/ worker		Capital/Labor ratio	
Country	**Tractors/ 100 sq km**	**Country**	**Machinery import value**	**Country**	**Agric. capital stocks**	**Country**	**Value added/ worker**	**Country**	**Capital : labor ratio**
Sierra Leone		Togo	283.03	Malawi	612.98	Zimbabwe	475.06	Zimbabwe	0.19
Sao Tome		Guinea-Bissau	277.96	Togo	598.04	Senegal	460.03	Gambia, The	0.18
Cameroon		Morocco	272.37	Comoros	571.99	Malawi	418.15	Djibouti	0.18
Niger		Cabo Verde	265.84	Mauritania	545.00	Burkina Faso	413.13	Sierra Leone	0.17
Congo, Dem. Rep.		Gabon	258.93	Senegal	520.35	Ethiopia	371.62	Senegal	0.17
Libya		Somalia	254.13	Sierra Leone	456.09	Rwanda	364.81	Ethiopia	0.15
Equatorial Guinea		Uganda	250.18	Burundi	435.40	Lesotho	355.81	Tanzania	0.15
Ethiopia		Djibouti	247.67	Liberia	377.55	Gambia, The	350.33	Chad	0.14
Malawi		Seychelles	244.10	Congo, Rep.	358.87	DRC	324.01	Niger	0.13
Morocco		Botswana	241.33	Guinea-Bissau	153.94	Madagascar	306.97	Rwanda	0.12
Zimbabwe		Guinea	229.26	Cabo Verde	149.83	Guinea	303.63	Burkina Faso	0.09
Uganda		Madagascar	219.75	Lesotho	145.15	Mozambique	287.84	Malawi	0.08
Mauritius		Lesotho	216.30	Botswana	140.26	Burundi	228.07	Eritrea	0.07
Zambia		Tunisia	213.95	Eritrea	133.78	Somalia		Burundi	0.07
Lesotho		CAR	212.24	Eq. Guinea	118.49	Angola		DRC	0.07
Eritrea		Mauritius	180.32	Seychelles	97.92	Mauritania		Madagascar	0.06
Gabon		Zimbabwe	165.16	CAR	59.90	Djibouti		Mozambique	0.06
Guinea		Swaziland	157.45	Gambia, The	56.26	Libya		CAR	
Chad		Gambia, The	156.21	Sao Tome	20.60	Comoros		Seychelles	
CAR		Eritrea	150.96	Djibouti	18.42	Eritrea		Sudan	
Liberia		Liberia	116.55	Sudan		Niger		Comoros	
Guinea-Bissau		South Sudan		South Sudan		South Sudan		South Sudan	

Source: Author's compilation based on data from several sources[7]

[7] Data sources: World Bank, FAO, USDA Economic Research Service, national statistical offices

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