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Socio-economic determinants of agricultural mechanisation in Africa: A research note based on cassava cultivation mechanisation

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ABSTRACT

While global agricultural mechanisation is on the increase, societal resistance has left its adoption stagnant in developing countries. Optimizing the successful adoption of mechanized processes in these countries involves amongst other things, identification of salient problems and adequate planning to prevent them. This note highlights some possible causes of perceived societal resistance to mechanized farming in light of the limited progress in the mechanisation of one of Africa's leading crops, cassava (*Manihot esculenta* Crantz). Potential approaches to improving the development and adoption of mechanisation for this crop and region as well as the research gaps preventing adoption success forms the discussions in this note.

1. Introduction

While it might seem exciting and gratifying to introduce new, ground-breaking agricultural technologies into developing societies in order to improve the quality of life and enhance food security, it may be erroneous to assume that the introduction of such technologies will not meet with some level of resistance by certain sectors of the society. The introduction of any technology can have either positive or negative effects on a society, depending on the rate at which it is introduced and adopted by the society and the expected skill level of the new technologies' target users. The adoption of agricultural technology by a farming population would normally depend to a large extent on the society's socio-cultural and economic ideologies as well as the application of these technologies to local production systems (IFAD-FAO, 2005). Few sub-Saharan countries have high agricultural mechanisation adoption rates, largely because of the abysmal failure of prior efforts to ensure the continued adoption of new farming technologies by the farming population once initial government support came to an end (Mrema et al., 2008; Pingali, 2007) and also due to societal resistance especially to biotechnological related innovations; all despite documented gains (Pinstrup-Andersen et al., 1999; Owombo et al., 2012; Parente and Prescott, 1994).

In Africa, agriculture (primarily subsistence) has been by far the single most important economic activity; employing about two-thirds of the workforce in sub-Saharan Africa. By this means, it contributes an average of 30 to 60% of the region's gross domestic product (GDP) and constituting about 30% of the value of exports (SRID, 2011). However, with a prediction of as much as 98% contribution to the increase of the world's population by 2020 coming from Africa, most of the developing countries of Africa will become increasingly urbanized and face food security challenges. The successful implantation of mechanisation, therefore, has an impending positive implication for food availability and job creation on a global perspective. Using cassava as model crop, we highlight some of the possible causes of agricultural mechanisation stagnation in the African region.

1.1. Cassava cultivation and mechanisation

Cassava (*Manihot esculenta* Crantz) is grown all over the world and in Africa is the most produced ahead of sugar cane and maize (Fig. 1a,b) (FAOSTAT, 2016). Common amongst the lowland tropics, sub-humid tropics of West and Central Africa, it is a primary source of calorie for about two-fifths of Africans (Oni and Oyelade, 2014). Its cultivation produced the largest number of calories per hectare of any crop; it grows on poor soils, and it has a high resistance to drought, pests, and diseases (Nweke et al., 2002). With these characteristics, its cultivation steadily expanded in almost all of the last two decades particularly in western and central Africa; displacing yam (*Dioscorea* sp. L.) cultivation in many areas and improving its significance as more than just a famine reserve. Over 90% of cassava production takes place on small farms and accounts for about 26% of cash income from all food crops (IFAD-FAO, 2005).

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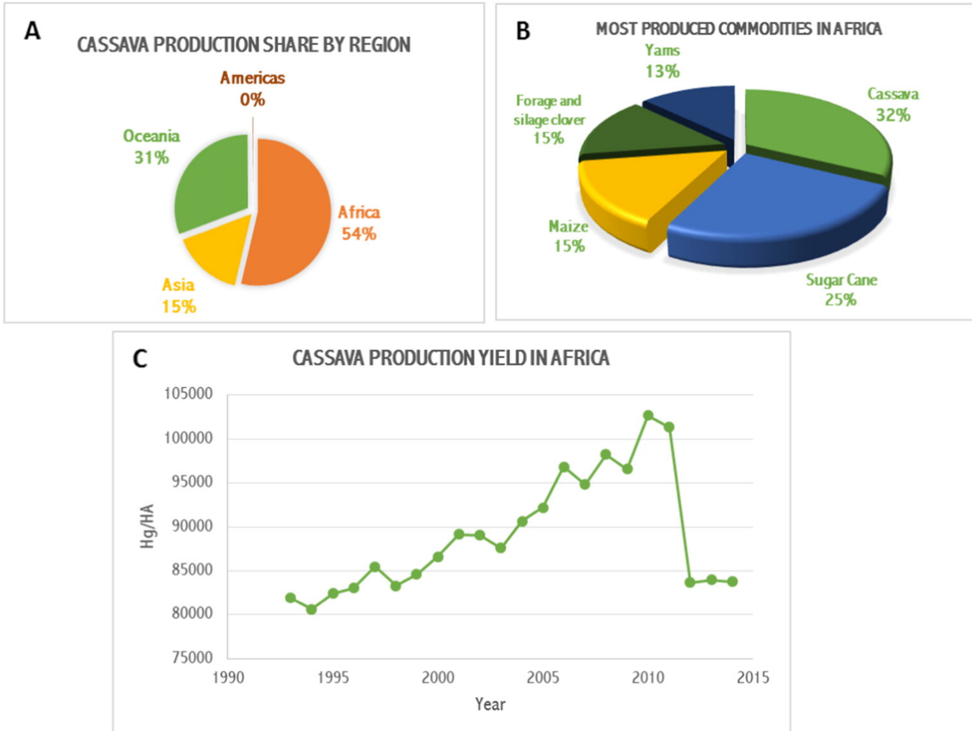

Fig. 1. Cassava production statistics.
(Source: FAOStat 2016 Database)

It is all thus logical that the mechanisation of cassava cultivation is explored and driven to technological levels that can sustain growth and cater to the growing African population. Experience and data have shown though that the mechanisation of cassava cultivation processes is relatively difficult in execution and adoption (ref), solutions for the automation of the cassava cultivation process existed and are being developed further every year. Land preparation systems, irrigation systems, transportation systems as well as pest and diseases management are readily available and are adaptable for cassava cultivation. Also, specialized machinery such as the stem planting machines, cassava root collector, cassava harvester (Lungkapin et al., 2007) are being developed to improve the mechanisation process.

Unfortunately, the progress made technologically often does not translate into actual field realisations, and it is very convenient to point outrightly (erroneously) at the expensiveness of these technologies as the culprit for this negative correlation. However, in most cases, tied to the economic limitation is the social aspect as it concerns the users of these technologies. In Africa, heavily influenced by tradition, religion and education, the lack of proper considerations for these social factors in the introduction of technology into cassava farming and by extension other agricultural practices, has led to an almost non-existent adoption level. While these factors are not entirely unique to Africa, their effects are seemingly stronger in the continent when compared to other less developed regions of the world. For example, fertilizer use is far less in Sub-Saharan Africa than it is in other less developed regions. In 2007, average use was just 13 kg/ha compared with 208 kg in Asia and Latin America (WorldBank, 2007). Irrigation accounts for only 5% of the cultivated area, compared to more than 38% recorded in other countries in Asia and Latin America. Tractors per 1000 ha are a paltry 28 as against 241 in other parts of the world (FAO and UNIDO, 2008).

These constraints are however not the same across Africa, even though some general common problem areas exist. Most efforts by the government to encourage agricultural mechanisation in Africa have been in the area of tractors utilisation, and they are not meeting expectations (Ashburner and Kienzle, 2009; FAO, 2013). Today, the rate of use of agricultural machinery is still below that which is considered necessary to meet the rising demand for food (Mrema, 2011). For instance, the use of manual (hand) power dominates in central Africa while draught animals dominate in western and eastern Africa. On average hand power still dominate in the continent (Clarke, 2008). Combined, hand and animal power contribute close to 90% of the agricultural work efforts in four (central, western, eastern and southern) out of the five regions of the continent (Clarke, 2008; FAO and UNIDO, 2008).

Already effects of lapses in the failure of mechanisation adoption can be seen in a reduction of Africa's leading crop (cassava) production by as much as 18% between 2011 & 2014 (Fig. 1C). It is, therefore, paramount that more researchers begin to develop applicable models and also create information on the critical socio-economic determinants to cassava mechanisation adoption that will help technologists and government policy makers solve this nagging problem that can lead to greater fallouts in the future. The information obtained from this will, in general, assist in the improvement, development and introduction to and adoption of mechanisation in this continent.

2. Critical factors affecting mechanisation adoption in Africa

The need to have food security is critical and the inability of countries in Africa to mechanize agriculture has remained a daunting task that has frustrated efforts at improving crop yields and by extension, prosperity. There are factors that have always undermined the efforts in this direction and these factors are critical because they form the nexus and basis for the inability of African countries to adopt mechanization. Therefore, these factors affect every facet of the aspirations of African developmental efforts. They relate directly to the traditionalistic outlook of the continent including the religious and communal values that may likely inhibit infusion of change and prosperity. Although the process of change may be inherently painful, acceptance of change can be particularly difficult especially as they depend on the internal dynamics of social and cultural structures of a society. In other words, new technology does not change society on their own, it is the response to technology that stimulates change. In most cases, in Africa, innovations are quickly recognised but are however not put to use for a very long time. In this section, we discuss some of these factors.

2.1. Social structure

"Diffusion is a very social process that involves interpersonal communication relationships" (Rogers, 2003). Since diffusion of innovations takes place in the social system, it is influenced by the social structure (including norms, shared social experience, and perceptions) of the social system (Sahin, 2006). According to Rogers, the nature of the social system affects individuals' innovativeness, which is the primary criterion for categorizing adopters.

The acceptability of innovation by a society is arguably primarily determined by the perceived or actual net impact of the trade-off between the negative effects and functionality of such an innovation. The economic and social structure of the society, rather than any benefits or enhanced functionality arising from new technologies, play a greater role in the way the society accepts innovation (Arends-Kuenning and Makundi, 2000). Target users of new agricultural technology (i.e. farmers) in Africa and for example cassava farmers, are more likely to accept a new technology which they believe poses the least threat to their existing social structure. The implication of this is that the social, political and economic structures prevalent in the user society of a new innovation should be considered at the conceptualisation stage in order to enhance a smooth introduction and acceptance.

For major crops like cassava, family and communal production makes up majority of the entire production at any given time and these forms, found in Africa, are consistent with its economic production system (over 90% cassava production occurs in small farms). However, restrictions exist in these communal settings. For example, in some rural West Africa communities, a social structure may exist in the caste or in family units form (Tamari, 1991) depicted by Fig. 2. These structures provide stable and long-lasting domestic units able to work as a single cooperative group, to defend itself against others, and to care for all of its members throughout their lifetimes thus emphasizing the significance of the society's hierarchy. In addition, arable land is allocated through a complex system of communal tenure and ownership, rather than through individually acquired title. As technology provides economic mobility for involved individual (Galor and Tsiddon, 1997), adoption of some form of new technology tends to stretch this social structure towards rupture. As a result, the society actively resists infusion and continued use of such innovation and over time, the gains and sustained presence of the technological advancements reduces and collapses.

Another factor within this social context and structure in African economies that potentially influenced the acceptability of mechanisation is that the private sector, rather than public institutions or not-for-profit organizations, have spearheaded the development and commercialisation of these innovations. In Africa, targeted users of these new technologies are skeptical about using technology that are developed by a company (usually foreign) whose underlying interest is in profit-making. This is demonstrated, for instance, by the fact that African cassava farmers hardly ever purchase inputs that are foreign to the area of production (IFAD-FAO, 2005) especially when compared to government provided inputs which are typically subsidized and cheaper thus encouraging participation (Delmon, 2009). Above and beyond the risks of corruption and abandonment due to government change, such governmental participation helps in the overall process from possible stakeholder engagement to affordability and enhanced trust.

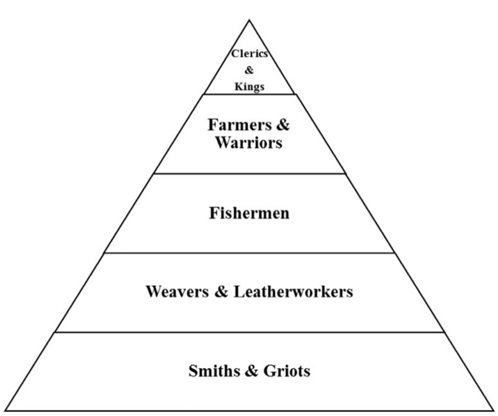

Fig. 2. A typical communal caste system in West Africa (adapted from Tamari, 1991).

2.2. Culture & religion

Studies have shown that the way technology impacts a society is determined by the gender, religion, and economic position of the people. Most developing nations, particularly in Africa, are highly religious, and this seems to be concomitant with comparatively low innovation adoption rate. In fact, a global index report of religiosity and atheism (Gilani et al., 2012; WIN-Gallup International, 2012), suggests that at least 30% of the countries with over 70% great importance attached to religion are from Africa as shown in Fig. 3.

The Pew survey of April, 2010 suggests that, on a continent-wide basis, sub-Saharan Africa emerges the most religious place on earth as religion is very important in the lives of more than three-quarters of the population. According to the report, religiosity in the continent, ranged from 69% in Botswana to 98% in Senegal. In these countries, belief is supreme and the use of certain kind of innovation in agriculture such as altering a plant's genome, is considered to seemingly arrogate to men the ability to "play God". This particularly applies to cassava farming and may hold far reaching implications for the material prosperity of farmers. This trend is unsurprisingly noticeable when the GDP per capita of countries were compared with their religiosity. As shown in Fig. 4, most of the countries occupying the most religious but poorer sections are African countries.

In adopting agricultural technology, therefore, policy makers must take cognizant of the religious nature of the society involved. A typical scenario can be seen when tissue culture and genetic engineering are examined. In contrast with genetic engineering, tissue culture techniques do not change the DNA within plant cells. Therefore, tissue culture might be more suitable for developing countries because tissue culture is not only relatively low cost, has high spill-over potential, does not incite concerns about bio-safety, biodiversity, or food safety (Byerlee and Gregory, 1999), it does not change the natural genetic profile of the crop.

2.3. Unemployment concerns

Extolled as a very dependable crop, offering society vast employment opportunities in its cultivation and processing, cassava contributes significantly to employment creation and income generation in Africa. In Africa, the total amount of labour allocated to the cultivation and processing of cassava is highest under recurrent cultivation and remains statistically unchanged whether produced under shifting or continuous cultivation systems (IFAD-FAO, 2005). Presently only three operations in cassava production are usually mechanized: land clearing, seedbed preparation and field-to-home transportation although human operations are required in several other aspects (Fig. 5).

Therefore, a full-scale introduction of technology into cassava agriculture, for example, which does not consider the positive and negative after-effects which such technology might bring may further compound what is already a hopeless situation of unemployment in a continent where the vast majority of the populace survive on subsistence farming.

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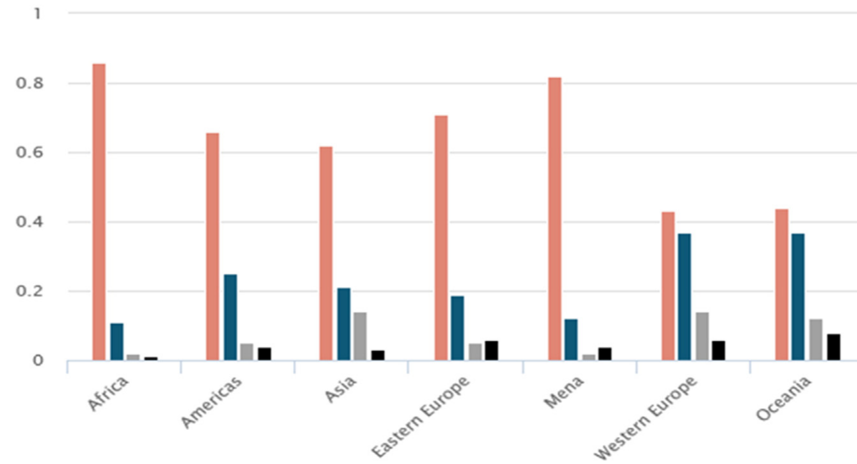

Fig. 3. Religion by continent (WIN-Gallup International, 2012).

Since the introduction of mechanisation into agriculture drastically reduces the total man-hours required to achieve a specific task, a typical effect of technological improvements in agriculture is a temporary increase in the number of unemployed individuals in the society. A practical example of such technological induced employment shedding was particularly noticeable when mechanisations were first introduced in the South African region (Dunne and Edwards, 2006). While it appears logical to assume that such an increase in unemployment would be restricted to the sector directly affected by the innovation, the overall impact on unemployment in the country could be large, since the adoption of technology has been known to reduce labour requirements by up to 84%, particularly for certain types of skilled workers. As can be seen from the information provided in Table 1 (Tshiunza, 1996), cassava cultivation can require as much as 222 person days/ha, therefore an introduction of mechanisations that will lead to a displacement of these workforce/labour requirements will perhaps be met with immense (subtle and not direct) social resistance. This issue can be avoided only if the government is responsive enough to provide proactive programs to stimulate the economy, including initiatives such as skill acquisition programs which genuinely target those to be affected and affected by structural unemployment.

2.4. Gender factors

It is common in some African regions to find that agriculture is deemed the exclusive purview of women in the society in modern

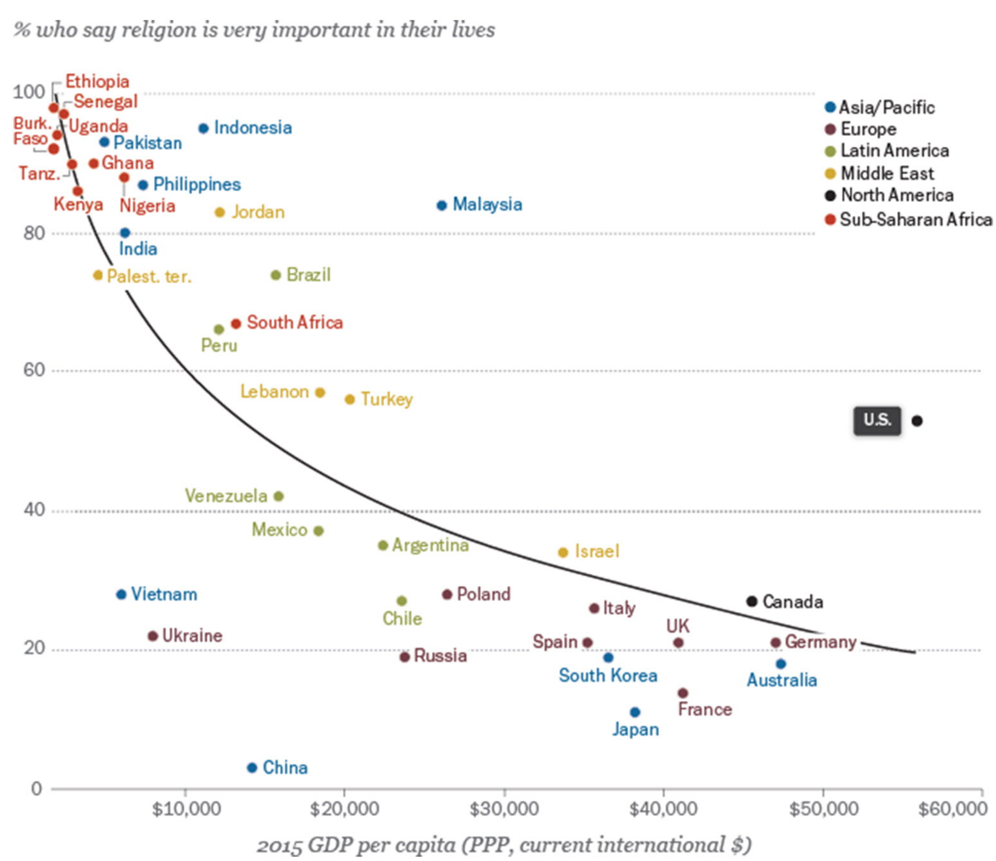

Fig. 4. Religion and economic prosperity (Centre, 2015).

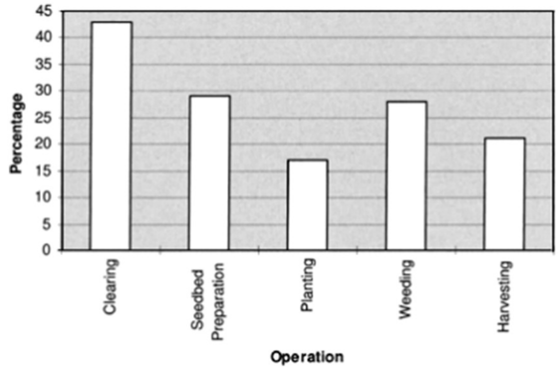

Fig. 5. Percentage of cassava cultivation operation creating employment (adapted from COSCA www.fao.org).

times. Traditionally, most women farm while most men hunt, fish and find alternative paid employment. For example, the labour-intensive aspects of cassava agriculture and processing, which the adoption of mechanisation would alleviate, are largely gender-specific and may help to achieve a more egalitarian distribution of income. While the sexes are equally represented in the trading of the crop, women and to some lesser extent children, are usually in charge of cassava processing (see Fig. 6). Moreover, a collaborative Study of Cassava in Africa (COSCA) data shows the volume of cassava sold by small-scale producers to be directly proportional to the total number of fields owned by women (Nweke, 1994).

Cassava processing (peeling, grating, boiling, fermenting, drying, frying and milling) is almost always performed by women (Romanoff and Lynam, 1992) and consequently has social and economic implications in the society. The introduction of mechanisation into cassava processing, without a strategy that helps improves women technical skill, may likely result in a number of women losing their jobs on account of lack of new or complementary technical competence, thereby further compounding the systemic gender inequality already existing in the labour force and altering the societal social structure. Indeed, more men would be involved in cassava production as they would most likely be those controlling and operating the machines as has been reported in many parts of Africa (IFAD-FAO, 2005). Therefore, policy-makers must take into consideration the gender inequality that may arise in the labour force when an agricultural production process is mechanized, so as to ensure that the continent achieves its millennium development goals of promoting gender equality and empowering women. An increased focus on gender issues would therefore accelerate the achievement of millennium development goals (Kabeer, 2003; Grown, 2005; Heyzer, 2005). Policy-makers must not only bridge gender technical background gap, they must ensure that women actually use new machines. Research (Wetzel, 1993) suggests that even people who have technical backgrounds may not use new technology if they do not have knowledge of how to use it correctly. It is thus not enough for women, or the society for that matter, to have technical background alone, it matters that they know how to use innovation (Spotts, 1999). Knowledge and actual use experience are essential variables in the innovation-decision process. Ironically, according to Sahin (2006), only men appear to possess this technical readiness.

Table 1
Labour (person days/ha) requirements for cassava production in some African producers. (Source: FAO.org/cassava)

Factors	Overall	Côte d'Ivoire	Ghana	Nigeria	Tanzania	Uganda	Zaire
Population density							
High	194^{a}	–	188^{a}	225^{a}	182^{a}	190^{a}	$190^{\mathbf{a}}$
Low	191^{a}	181^{a}	179^{a}	221^{a}	184^{a}	$183^{\mathbf{a}}$	$194^{\mathbf{a}}$
Cultivation system							
Continuous	184^{a}	170^{a}	$182^{\mathbf{a}}$	218^{a}	168″	$182^{\mathbf{a}}$	$180^{\mathbf{a}}$
Recurrent	222″	198″	217^{b}	255°	204″	214^{b}	$240^{\mathbf{b}}$
Shifting	$183^{\mathbf{a}}$	158^{a}	186^{a}	200^{c}	$166^{\mathbf{a}}$	172^{a}	$195^{\mathbf{c}}$
Field location							
Nearby	$197^{\mathbf{a}}$	$175^{\mathbf{a}}$	$190^{\mathbf{a}}$	227^{a}	$201^{\mathbf{a}}$	$201^{\mathbf{a}}$	212^{a}
Distant	$192^{\mathbf{a}}$	$168^{\mathbf{a}}$	182^{a}	211″	176^{a}	176″	$202^{\mathbf{a}}$
Average	195	150	189	222	183	188	202

Note: For each factor, means (in column) with the same letter (superscript) are statistically the same.

Some authors have argued that the introduction of modern agricultural technologies seems to replace female farming systems with male ones despite women active role. For instance, in Kenya, agricultural development planners have been reported to target men deliberately for agricultural training. They argue that men are the household heads and therefore the major decision makers for productive resources and also because tasks performed by men, such as land preparation, harvesting, and processing are the easiest to mechanize. More often than not, those female tasks which are often mechanized eventually become male tasks (Kramerae, 1988). These scholars observed that the introduction of modern technologies affects the existing labour divisions and often necessitates adjustments and reallocation of labour. They, therefore, appear to influence the traditional division of labour which as in most African societies goes along gender lines. It is an acknowledged fact that men and women do different things, have access to various resources and benefits, and play different roles in the production cycle.

By one estimate, women cultivate about half the volume of food produced in developing countries (FAO, 1985, as cited by Conway, 1997). Yet, past efforts (e.g., the Green Revolution) did not take into consideration the women who would be using the technologies to aid their processing. Agricultural programs were based primarily on a model where households were headed by men, and with women making little or no contribution to the way these programs would be implemented in their society (FAO, 1997). Aside from being unable to handle the machines, women typically had little access to land and credit, thereby restricting their ability to achieve some of the benefits generated by the Green Revolution and other agricultural programs brought into developing societies.

2.5. Perceived consequences

Getting a new idea adopted, even when is has obvious advantages to the society, is difficult, and ironically adoption cannot be simply decreed (Rogers, 2003). Potential adopting societies would normally weigh the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of the society. Perceptions of these characteristics predict the rate of adoption of innovations in the society.

The realization and acceptance that the agricultural mechanisation to be adopted in Africa has major impact on the environment is widespread (Karim et al., 2013). For example, the implementation of the Green Revolution, which offered insight into how locals perceive agricultural technology diffusion, has been criticized for its ecological consequences. The use of chemical fertilizers, pesticides, and irrigation that made the high-yielding varieties profitable during this period damaged the environment over time. Water aquifers throughout the world were drained at a faster rate than they were naturally replenished (Byerlee et al., 1998). Maximum yields of crops such as rice (*Oryza sativa* L.), wheat (*Triticum æstivum* L.), and corn (*Zea mays* L.) at CGIAR experiment stations also decreased over time because of soil damage. In addition, adverse health effects on humans were also noted due to heavy fertilizer use and subsequent nitrogen leaching into water systems. The use of pesticides resulted in pesticide-resistant pests and adverse health consequences to agricultural workers as can be seen in the increased consumption of insecticides in developing countries (Conway, 1997). All these consequences contribute to existing perceptions of agricultural technological in this region.

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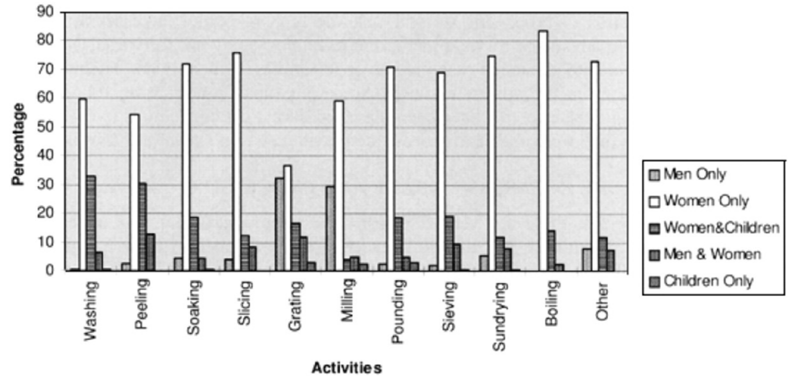

Fig. 6. Respondents' indication of different gender combination participation in alternative cassava processing activities (percent) (adapted from COSCA www.fao.org).

As it pertains to cassava cultivation, this perceived environmental effect might stem from problems regarding disposal of processing wastes which has been problematic for cassava producing nations. In some regions, rivers have been reportedly used as sinks for the disposal of cassava waste materials and effluents (Asoegwu and Asoegwu, 2007). Therefore, if cassava yield is to increase, the level of waste from its processing both in form of peels and stalks and acidic effluents is expected to increase. This will further increase the negative perception of mechanizing this process. However, in reality it is the general poor waste management practices of these agricultural producers that can make it difficult to control the impact of comparatively larger yield on the environment. Luckily, several opportunities for cassava wastes usage are emerging especially for energy generation and mechanisation of the process can for example increase bioethanol production potential and supplementary energy generation, all of which will negate perceived environmental damage (Adekunle et al., 2016).

In summary, traditional farmers in the developing world form their perceptions based on their previous experience in the decision-making process, and these opinions have served to reduce their adoption of mechanized farming. Consequently, only the use of technologies which have actual and perceived positive impacts economically and environmentally can be sustainable in the mechanisation efforts in Africa.

3. Conclusions

The rate of adoption of new mechanisation in processing or cultivation by the African population depends on a combination of factors. For the model crop adopted in this note, these factors will, for instance, include the circumstances surrounding production, the effect of the technology on gender equality in employment, the socio-cultural beliefs of the farming community, the economic realities of the society, sensitization and its applications to local production systems.

Since innovations with high public benefits are usually not economically profitable to the private sector - which is therefore less motivated to develop such technology - the public sector and not-for-profit organizations have important roles to play in ensuring that agricultural technologies are made available to the poor - who form the largest proportion of farmers - in developing countries. Governments will be expected to facilitate and support partnership initiatives between the public-sector and private-sector agencies and farmers. It must provide the enabling environment to attract private sector investments. Governments and not-for-profit organizations should play a key role in encouraging and funding the research needed to develop agricultural technologies needed by their specific society, in stimulating local content while enforcing widespread distribution of these technological innovations, thereby ensuring sustainable use of these technologies in the society. Governments must subsidise the cost of these technologies or establish rental services at the initial stage of distribution to make them accessible to the target users.

Education is key to technology adoption. Non-governmental organizations can help drive the necessary sensitisation process to help change traditional perceptions about the use of technology in agriculture that are potentially inhibitive of adoption behaviours. Farmer-to-farmer sensitisation can be supported by agencies working on development through farmers' associations and cooperatives.

Furthermore, access to these innovations should be made easy in order to bridge any unmet needs. This should be complemented by regular farm extension visits to target users of the new innovation to increase awareness, facilitate skill acquisition, assist in the proper understanding of technology and its relevance to farming, and work with farmers and researchers to develop indigenous solutions to problems. Government-run national agricultural extension systems (or programs) will be in a better position to serve the needs of the farmers especially if these extension systems are flexible.

Innovation could be initiated and produced locally since small-scale and artisan agro-industries that produce hand tools and processing machinery are important in the agricultural production system and usually provide a link to the industrial sector. This will help eliminate the suspicion that farmers are being used for testing new technology.

Acceptability of cassava mechanisation and other mechanisations in general in the African context with particular emphasis on the critical factors affecting cassava farming mechanisation has remained very scarce in literature, particularly in peer review journal even though this is a vital area of research that can help to improve food production and security in Africa. Although this note is an effort in this direction, beyond literature reviews and discussions, there is a need to sustain research in this area especially focusing on surveys using hard primary data since current available data in African agriculture and mechanization are mostly unreliable and outdated.

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