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Review

Post-harvest losses in maize store-time and marketing model perspectives in Sub-Saharan Africa

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Post–harvest losses of maize are almost half of the produced grains in Sub–Saharan Africa. Efforts to reverse this trend are recommended. Thus, there is a prerequisite to create a post–harvest loss resilient strategy to guide small scale maize growing farmers in Africa. In this review, critical elements underlying post–harvest losses in Africa such as infestation by insect–pests, microbes, rodents, poor transportation infrastructure, poor storage facilities, injudicious store–time and unjustified marketing models have been discussed. Furthermore, we have proposed options for mitigating the post–harvest damage by highlighting possible pathways for farmers' friendly resilient strategies and areas needing research to eventually minimize post–harvest losses of maize in Sub Saharan Africa

Key words: Storage techniques, marketing prices, trade ban, spatial market, food security.

INTRODUCTION

Maize ranks next to wheat and rice in cereal production worldwide (Suleiman and Rosentrater, 2015), therefore becomes important crop in terms of food security. It contributes to per capita energy consumption and incomes especially in the developing countries (Muir et al., 2010), considering it as a cash crop as well as food crop. Recently, world maize production is about 10.14 billion MT (Suleiman and Rosentrater, 2015). The United States of America is the chief producer of maize, with over 30%; China, 21%; Brazil, 7.9% and Africa contributing about 7% of overall world production of grain maize. Two–thirds of all maize produced in Africa is from Eastern and Southern Africa (Verheye, 2010; Ranum et al., 2014). In Sub–Saharan Africa (SSA), about 1.2 billion people depend highly on maize as major cereal crop and staple food, thus occupies about one third of total land cultivated (Blackie, 1990). This justifies the importance of crop and farmers' commitment toward its production as well. Maize accounts for over 30% of the small–holder farmer earnings which adds–up to 60% of dietetic supplement in which protein accounts for 50% (Suleiman and Rosentrater, 2015; Amani, 2004). However, despite

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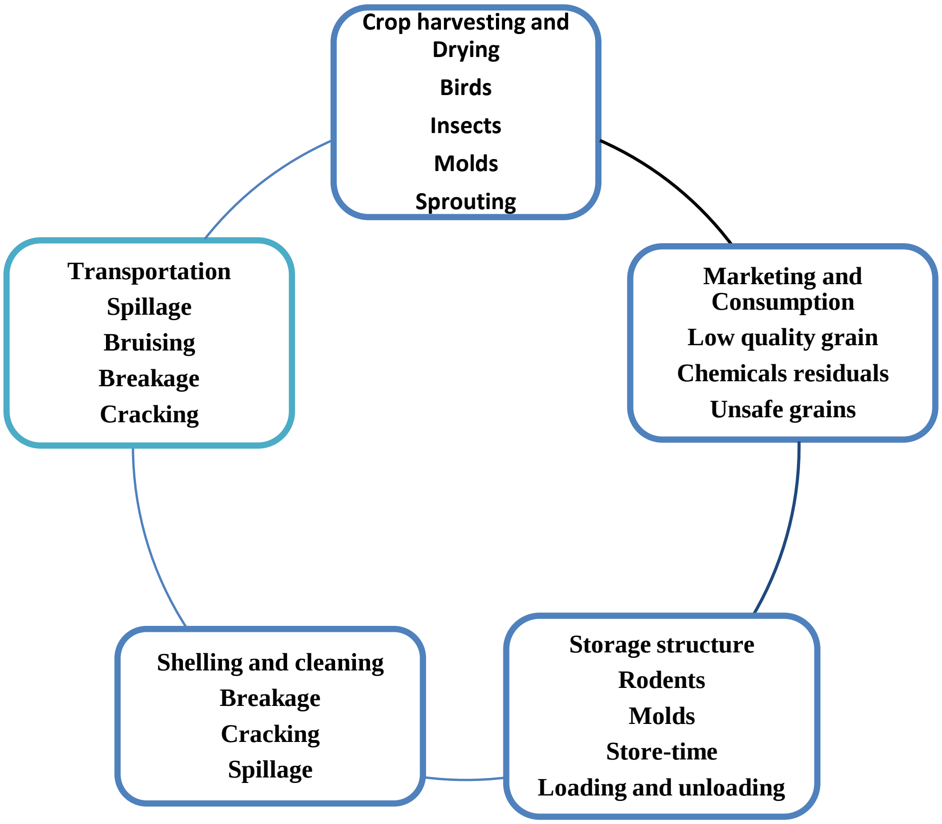

Figure 1. Post–harvest pipeline and pertaining to grain losses factors - a theoretical framework.

this contribution, there is significant post–harvest loss ranging from 12-46% of the harvested maize all along its production chain, that is harvesting (4-8%), transportation (2-4%), drying (1-2%), threshing and winnowing (1-3%), storage (2-25%) and marketing (2-4%) (Matthews, 2006; Hodges and Bernard, 2014). Inefficiencies along any of the production chain will result in maize post-harvest loss whereby among other aspects storage loss has a role. Such post–harvest losses call for urgent actions including designing post–harvest resilient strategies to be used by maize growers in Sub Saharan Africa. In this review, we provide comprehensive information on aspects underwriting grain losses and propose a farmers' friendly resilient strategy for minimizing post–harvest loss of maize grains in the Sub Saharan Africa.

REVIEW METHODS

Information presented in this paper has been collected with the aid of Mendeley and Google scholar databanks guided with some key words like "Post-harvest loss, "food security", "marketing model", "marketing chain", "storage structure", "maize production" and "improved storage structures". Throughout the development of this review paper, post-harvest loss, store-time and marketing model were used interchangeably for a clear information searching. Studies obtained focus on the contributions of biotic and abiotic factors in maize post-harvest loss, operating maize marketing models, assessment of maize value chain, maize production trends and maize price trends, efficiencies in maize storage structures.

MAIZE POST–HARVEST PIPELINE IN RELATION TO GRAIN LOSS

Maize post–harvest handling arises shortly next to reaping from field drying and harvesting, transportation, shelling and winnowing, storage, marketing and finally consumption. Inefficiency in any of the after–harvest channel can result in grain loss as presented in the theoretical framework (Figure 1).

CAUSES OF MAIZE POSTHARVEST LOSSES IN SSA

The term 'post–harvest loss' (PHL) refers to assessable numerical qualitative and economics of grain loss across the post–harvest pipeline due to rodents, insects, mites, and fungi (Aulakh nd Regmi, 2013; Tafera, 2012). All the causative agents should be weighted equally in order to minimize losses. Matthews (2006) asserts that these losses may happen when the grain is dispersed or leaked, or in the processes of bio deterioration where grain becomes rotten following mold attack or, is physically consumed by pests like insects, rats or birds. It involves both biotic and abiotic factors which contribute highly to physical value deteriorations of maize grain resulting in poor marketing. Furthermore, Wagacha and Muthomi (2008) add that, loss of grain quality may also encompass decline in dietary value and mold growth leading to toxins, e.g. aflatoxins in high moisture content incidence. Considering these, farmers need to be well equipped with improved drying facilities instead of relying on sun drying during pre and post-harvest to attain safe storage grain moisture level which discourages fungus growth and minimizes aflatoxin. Most of grain damage losses are the combination of various externally functions of antagonistic factors. Post–harvest losses in Africa are often projected to fall within a range of 62% along its value chain, that is, handling and storage, 37%; processing, 7%; distribution and marketing, 13%; consumption, 5% (Lipinski et al*.,* 2013); thus, much efforts should be geared on improving road infrastructure to enhance marketing and distributions, and provide farmers with proper packaging facilities to minimize losses. Storage facilities need to be given much attention for contributes to high post-harvest loss; stabilizes food demand and supply based on storage-time. As a matter of fact, post–harvest loss decline will definitely result in increasing food availability without calling for excess factors of production, hence, competence in use of resources in SSA and Africa at large (Hodges et al*,* 2011). This achievement cannot be made without a proper and an improved grain (maize) store–time strategy together with its marketing models. Hence, the storage–time and marketing model needs to be given enough consideration as a way forward toward supporting the use of tool to safeguard diet security in the region.

Losses due to poor harvesting techniques

Under normal circumstances most grains have a single harvesting season except in bimodal rainfall areas, to name some examples; Togo, Benin, Nigeria, Ivory Coast and Ghana. Basically, maize get matures physiologically 7–8 weeks following blossoming, with moisture ranging from 30–40% and maximum dry weight. This makes grains subject to beetle irritation (Kaaya et al., 2005). This is an issue based on the fact that, storage is the major activity following harvesting for most SSA farmers; at the same time, farmers do not know how to use proper techniques for lowering maize grain moisture before storage, cannot access the recommended moisture meters and thus rely on the indigenous techniques such as bare hand, kennels biting and salt tests. Based on the fact asserted by Hodges et al*.* (2011) that, wet condition during harvesting periods reduces the value of kernels before storage, fosters early insect pest and microbial infestation signifying huge maize grain loss. Thus, farmers should plan in advance so as to accommodate harvesting exercise well and timely to minimize loss as reported by Boxall (1986) that, if harvesting delays, the matured grain will severely be affected by insects, attacked by fungi, bacteria and vertebrate pest and become more exposed to store insect pest outbreak; this increases the chances of being contaminated by *Aspergillus*–produced aflatoxin in maize sinking grain quality (Kaaya et al*.*, 2005). Following Kaaya et al. (2005)'s line of thinking , aflatoxin levels may be raised from 4–fold to 7–fold within 3 and 4 weeks of harvesting overdue respectively, leading to maize qualitative losses.

In SSA, the degree of losses in traditional methods of grain drying and harvesting varies from country to country as it has been observed in Swaziland and Zimbabwe with losses of about 16.3 and 5.8–9.5% respectively (Tefera et al*.,* 2011). To cut down these losses; grains ought to be harvested timely with favorable harvesting condition. Nevertheless, the exercise must begin when farmer is confident of maximizing earnings; seeing maize price yield potentiality, span of harvesting period, dominant reaping weather conditions, and other related costs that is equipment, labor, and energy. Farmers should be well informed of the maize maturity cycle instead of depending on the physiological maturity, and agronomic aspects. It is highly acclaimed that; farmers should reap maize at most 3 weeks following full maturity. Actually, it would have been better to integrate traditional and improved harvesting techniques such as combined harvesters to minimize yield mortalities and rescue human health as far as aflatoxin is concerned.

Losses due to drying methods and operations (field and on–farm)

Most farmers in Africa, equally minor and major scale, highly depend almost absolutely on natural drying of crops that is combination of sunshine and movement of atmospheric air through the product as their regular drying techniques. At most 12% grain moisture content considered as a safe level is attributed to unfavorable environment for insects to feed and reproduce themselves (Harris and Lindblad, 1977). Regardless of these, there remains a big challenge among SSA farmers due to lack of enough capital to purchase the recommended oven and drying equipment. It has been reported by Basavaraja et al*.* (2007) in India–Karnataka that, losses due to drying operation in grains were assessed to be 0.80 kg/0.1 ton in rice and 0.66 kg/0.1 ton in wheat in the course of farmers customary drying procedures. Considering the biology of maize as grain compared to wheat, higher estimates of PHL may be realized in maize. Proper timing of all necessary activities involved in the production cycle is crucial to overcome the losses. This can only be done under close supervision and accessible extension services as part of farmers' decision supporting tools.

Usually, greatest damage occurs during re–wetting, specifically, if grains of different wetness ranks are mixed together in the same dryer simultaneously, and when rain or dew re–wets grain in a yard (Harris and Lindblad, 1977). Farmers should have enough dryers to avoid this mixture; with greater precautions on climatic dynamics during maize grains drying. Dehydrating the grain to optimum humidity and proper pest management strategies would minimize loss. However, it cannot stand alone as a medication counter to entirely PHL because birds, rodents, and insects may spell a completely dried prior to harvest and on store (Hodges and Bernard, 2014). This suggests that, proper minimization of PHL is a function of good pre and post– harvest practices. Therefore, farmers are advised to understand this synergetic relationship to get minimize PHL to the maximum for food and trade.

Loses due to storage structures

Maize storage plays a role food supply series besides post–harvest pipeline; it plays a great role in food security stability as far as seasonality is concerned. In most cases, soon after harvest; grains are subjected to storage for either short or long period as food reserves and/ or seeds. Surprisingly, maximum losses amounting to approximately 40% to total loss may happen during this operation (Aulakh and Regmi, 2013; Majumder et al., 2016); poor storage facilities used by farmers is the main cause. A study conducted by Tefera and Abass, (2012) and Costa (2014) reported that, farmers are using traditional storage structures such as granary/ polypropylene bags which are exceedingly prone to pest invasion, leading to PHL of about 48–59% in maize grains after being exposed to storage for 90 days. Regarding this trend, the efforts devoted by farmers will end up in feeding insects instead of the intended community. Regardless of the accessibility to improved storage facilities, farmers should be well informed of the safe grain moisture level before exposing grain to storage to balance the interface of moisture and temperature as key to sustain grain quality and best price as well. Thus, it is highly recommended harvested crops to be dried to safer moisture levels of 10–13% for cereals and 7–8% for oil seeds almost immediately after harvesting (Waliyar et al., 2015). Despite the fact that, molds can grow over an extensive array of temperatures, growth rate is lower with lower temperature and less water availability. Proctor (1994) asserts that grain maize might be kept for a year at a moisture level of 15% and a temperature of 15 °C without any fungal development; nevertheless, the similar maize exposed to 30°C as storage temperature may result in significantly destruction initiated by fungi just three months later. Hence, farmers' understanding of the biophysical component of the maize storage ecosystem is key to minimizing PHL and they should bear in mind that grains need to be dried separately from the farm with little interface with the ground to reduce fungal contamination during storage. The physical, inorganic and organic characteristics of grain in ecofriendly settings during growth, harvesting methods and handling practices prior to storage influence storability (Zhang, et al; 1992). Farmers should put ample work on grain sorting to minimize threat debris, broken seeds, chaff and dust to improve aeration in store.

Loses due to attack by fungi pathogens

Attack by fungi in the field

As the name suggests, field fungi are principally responsible for grains contaminations in the field mostly before or after ripeness earlier to harvest. To list some, are *Alternaria*, *Cladosporium*, *Fusarium*, *Helminthosporium*, and *Pullularia*. Their favorable growing conditions are relative high humidity (>90%) and moisture content of 24–25% wet–weight or about 30–33% dry–weight in the starchy cereal (Koehler, 1938); therefore they hardly arise in the low moistness and low oxygen environments post-ensiling. Settlement of field fungi can be observed in already damaged kernels which serve as reservoir for the coming season; the same case might happen on the soil as well. Soon after harvest maize grain or seed become inactive due to drying; at this stage grain moisture content and grain temperature become the main dictators for fungal further development. In most cases, field fungi as primary invaders are not likely to continue their development in, or to reinvade grains once they have been dried and then remoistened, or formerly subjugated by other fungi. Furthermore, poor storage technique attracts further fungi development, for example, unshelled maize stored on the cob in cribs and exposed to wet might be invaded by fungi with high moisture requirements, comprising typical field fungi referring to "advanced–decay fungi" (Christensen, 1957). It is worth noting that, fumonisins can be produced during post-harvest when storage conditions are inadequate. SSA farmers should be well informed of the combination of pre-harvest cultural practices such as, seed selection, crop rotation, land cleaning and preparations management, insect and pest management practices and all other necessary Integrated Pest Management practices to minimize PHL resulting from field fungi. Soon after harvest grains need to be stored with a safe moisture contents below those required by the field fungi to discourage further growth. Hence, proper storage equipment with a justifiable store–time should be readily available to SSA farmers to cut down losses.

Loss due to storage fungi

The PHL of maize in humid nations is donated by biological and environmental factors, for this case, insect pest and molds are among the biotic factors (Muir et al., 2010) whereas abiotic aspects are moistness and hotness (Giorni et al., 2008). The interface between these elements determines the occurrence of mold/fungi community and their relative development during storage (Cairns–Fuller et al., 2005); hence, there should be a clear match between these interactions. The storage fungi comprise mainly, several species of *Aspergillus*, particularly those in the *Aspergillus glaucus* group (Warcup, 1951), such as *Aspergillus amstelodami*, *Aspergillus chevalieri*, *Aspergillus repens*, *Aspergillus restrictus*, and *Aspergillus ruber*, plus *Aspergillus caltdidus*, *Aspergillus ochraceus*, and *Aspergillus flavus*. Key varieties of PHL as a result of storage fungi are; decrease in germination percentage; grain quality deterioration, grain biochemical changes and toxins that constitute healthy risks for human being and animals. Furthermore, fungal contamination in maize as animal feed, diminishing its dietary value and tastiness, promotes allergenic possibilities resulting in animal health problems, reduction in production and fertility, increased chances to diseases which later on reflect on human health and their livelihood. A study conducted by Ariño et al*,* (2007) stipulated that, most important fungal genera is Fusarium with inclusion of many pathogenic species responsible for broad range of plant diseases, contrary to others which are highly mycotoxigenic. Storage fungi are a risk to human and animal wellbeing being a causative agent of carcinogenic toxins. Additionally, already invaded maize by storage fungi deteriorates much more rapidly after being stored under favorable environment meant for fungi breed contrary to the ones not invaded (Christensen and Kaufmann, 1969). Therefore, it is highly emphasized that growers should be well familiar and be expertise related to storage fungi to reduce PHL and raise their income level other than improving their livelihood.

Losses due to termites

In SSA, the fungi–growing termites such as *Microtermes* spp., *Macrotermes* spp. and *Odontotermes*spp (Macrotermitinae) are among the central constraints in maize (Sekamatte et al., 2003). The *Macrotermitinae* are fungus growers' termite, widely dispersed all over the world except at high altitude and in desert area (Singleton et al*;* 2003; Wood et al 1989). Termite damage to maize commences at seedling stage and increases at the arrival of senescence (Riekert and Berg, 2003). In most cases, termites feed on dead plants materials although some might feed on fresh plants materials leading to a serious PHL particularly in semi–arid climatic regions. Furthermore, termite attack is more severe in prior diseased crops similar to physiologically damage crops specifically in water stressed areas and in the lowland crops (Riekert and Berg, 2003). What is more, termite attack in maize is severe in the high humidity fields. In particular, crops are often damaged close to harvest than early in the season (Wood et al., 1989) For that reason, delay in harvest might bring loss through lodging especially in maize. In this regard, insecticides apart from persistent organochlorides that could be applied correctively at somewhat late plant growth stages, or preventative treatments will contribute towards cost–effective maize production particularly in areas susceptible to termites. Some of these insecticides may however be too expensive, especially in marginal crop production areas where termite infestations usually occur; in which case, its subsidization will beyond doubt accelerate its demand.

Losses due to common storage insect pests

In most developing countries, storage pests cause substantial economic losses (Boxall, 2002; World Bank, 2011)**.** Insects contribute highly to PHL through boring within the kernels and feeding on the surfaces, remove food and selectively consume nutritive components, encouraging higher moisture in the grain while promoting the development of microorganisms. These bring up essential insect pests for stored maize. Biophysical conditions of grain maize before and after harvesting in the cause of practices involved will have a final bearing on its susceptibility toward beetle pest occurrence during storage. The common grain insect pests are; the lesser grain borer (*Rhyzopertha dominica*), maize weevil (*Sitophilus zeamais*), and red flour beetle (*Tribolium castaneum*) (Dowell and Dowell, 2017). Additionally, *Sitophilus* (Curculionidae), *Tribolium* (Tenebrionidae), *Sitotroga cerealella* (Grain Moth), Grain Weevil *Sitophilus granarius* (L.) are prime storage pests in SSA (Dick, 1988; Holst et al., 2000). Above allof the earlier mentioned storage insect pests, in SSA, the chief grain storage beetle pest is the Larger Grain Borer (LGB) *Prostephanus truncatus* (Horn), (Bostrichidae), inborn in Mexico and Central America, which has been established in East and West Africa (Nyambo, 2008, Markha et al., 1994). This beetle is currently a more serious pest of stored maize and cassava in most parts of SSA than its innate Central America (Dick, 1988) with a significant contribution to PHL and food insecurity. Actually, in Ethiopia, one way to inhibit invasion of storage insect pest in maize is to combine with teff, which seals the inter–granular spaces precluding insect pest devastation (Haile, 2006). Definitely, the circumstance with maize is more diverse as it may or may not be infested by LGB. It has been documented that, storage pest contributes about 4-5% weight loss, where by LGB accounts for more than twice of the weight loss (Hodges, 1983; Dick K, 1988, Boxall, 2002) and a total loss for unchecked maize grain. Basically, primary basis of weight loss of P. truncates is the alteration of the maize grains into dust by mature digging. Cowley et al. (1980) detected that in a separate cluster sample whereby adults were retained on alleviated grains over 42 days; adults were the core grounds of the maize grain destruction until grains became flour to the extreme. Hodges (1986) asserts that, till a massive number of larvae have been proven; feeding activity seems to be of lesser meaning as source of loss. For this matter, *P. truncatus* may differ from other storage pest species, such as *zeamais,* whereby larval feeding is accountable for the common injury. Additionally, a study steered in Tanzania (Suleiman and Rosentrater, 2015) shows that; farmers storing cassava and maize in Tabora region experience a severe damage up to 30% of the stored grains and some experience extreme case, whereby, grains were fit for neither seed nor consumption; it was regarded as total loss just 90 to 180 days of storage. It was caused by unfamiliar beetle subsequently identified a *P. truncatus*.

Apart from grain loss, some grain–infesting insects harbor in their gut potentially harmful bacteria, such as pathogenic *Salmonella* (a common cause of food poisoning, found in feces), hemolytic *Streptococcus,* and *Escherichia coli* (also from feces), and they may well harbor also viruses capable of infecting man or his domestic animals (Christensen and Kaufmann, 1969). Most of literatures suggest that, shelling grain and storing in sacks (as well as addition of insecticide) are the standard recommendations to moderate injuries resulting from LGB attack. Perversely, agriculturalists in SSA are facing problems of accessing the recommended pesticides of the original quality at reasonable price, whereby some farmers have been experiencing grain loss regardless of insecticide applications; hence the problem remains unsolved. Additionally, farmers lack knowledge of the precise chemical, right timing, right dosage and right place/location in the application of insecticides. All these have led to non–judicious use of insecticide including threats to human and livestock health, impaired trade due to insecticide residues, water pollution and biodiversity loss. Therefore, designing an improved maize marketing model with justifiable store-time would be a solution to justify the storage cost and expected return to investment to speed up maize investments. A successful store-time model may serve as a decision supporting tool for scaling up widely to appropriate areas.

Losses due to rodents

Rodents might cause interminable destruction and waste to stored food attributable to their stools, urine, saliva and fur leading to quality deterioration, possible disease spread and boost grains' vulnerability to fungal and bacterial invasions throughout storage (Taylor et al., 2012). Mostly, outbreak of mice contributes highly to post–harvest loss very quickly correlating further with biotic factor. Rodents among other pests, establish one small, but major, portion in the massive of post-harvest loss riddle (Green, 1977); though some farmers pay little or no attentions in eradicating them, rather count them as part of their community. The extent of food losses due to rodent all over the world is least estimated to be 30% (Ennis et al*.,* 2016), which is contrary to SSA as documented by Food and Agriculture Organization of the United Nations (FAO) news release (March, 1967). Furthermore; Taylor et al*.* (2012) quantify the unit of storage maize kernels destruction brought by rodent to be up to 35% of the stored grains; almost similar conclusion drawn by FAO (2009) that, in SSA rodent destructions significantly contributes to around 1.3 million tons of food loss annually. Awareness creations on the magnitude of rodent destructions should be made to farmers so that they can no longer take them as a normal thing but fight against them. Taylor et al*.* (2012) testify of a severe destruction of grains caused by rodent donates to food famine in rural societies of Tanzania along with their monetary losses. As asserted by Singleton et al. (2003) that, this sum of missing maize kernel as a result of rodent destructions would be sufficient to feed 7 million folks for a year at a rate of 0.5 kg/day/person with a projected value of 141.7 million USD that is 11.1 US$ for every 100 kg. It is worth enough to invest wasted amount of money on other income generating activities to boost up rural communities livelihood rather than feeding rodents. Necessary effort needs to be put in investigating the costs benefits ratio of the improved grain storage structure versus other rodent management practices together with the final grain quality; this can stop the damages caused by rodents to secure people's health status and economic losses as well as maize agribusiness.

Losses during transportation (farm to households and households to market)

The general task of the supply chain is to exchange grain competently from the production area (farm) to the consumption area (market) at a rate and with favorite quality that meets the users' desires. In most least developing countries where majority of SSA belong, smallholder farmers are extremely affected by shipping costs due to undersized roads particularly rural feeder roads; this marks extraordinary shipping expenses (Isinika et al*.,* 2003). Therefore, the movement of grain from farm to home/store is regularly by head load or bicycle and in some places, by animal–drawn carts which are considered to be inefficient. As a matter of fact, during the process, leakage of bags or transport vehicles might occur resulting in grain loss along the way. Although such losses might sound very insignificant, interventions need to be in place to certify that losses during transportation from the production sites to the households and to the market places are minimized. Inefficiencies in transportation lead to unreasonable store-time and encourage farm get prices, hence lower down return to investment.

POSTHARVEST LOSSES VERSUS STORE–TIME AND PRICE

In SSA, normally farmers have a minimum of seven months maize store–time between two yield seasons. Alternatively, some farmers sell their crops just a little while after harvest amounting for 54 and 38% to cater for domestic and school fees consecutively, even though maize prices increased meaningfully in the period of 180 days of storage (Abass et al*.,* 2014). A different study conducted in Kenya links unpleasant selling price with poor storage facilities in the combination of improper storage store administration skills resulting in immediate sales after harvest (De Groote et al*.,* 2013). This makes maize to fetch low price with regards to law of demand and supply: if demand decreases and supply remains unchanged, then it leads to lower equilibrium price and lower quantity. Therefore, an immediate sale after harvest justifies low profit. Promising store–time marketing model would stand as a way forward to maximize profit gained by farmers.

Furthermore, another survey conducted in Uganda to determine effect of store–time on price for small–holder farmers reveals a significant correlation between store–time and gained profit. From the study, it has been observed that majority of maize harvested in December 2013 was sold directly to moderate post–harvest losses, whereby, maize in the initial weeks of January 2014 expected range of UGX 480 and UGX 520 per kg, whereas manipulating the better storing equipment for three months far ahead, April 2014, around UGX 760 and UGX 820 (Costa, 2014). Furthermore, an increment of 64% will be raised as additional earnings for a particular family. Hence, accessibility to proper storage facilities would improve farmers' waiting–time as means of solving maize price fluctuations and generating high profit.

In addition, as maize becomes scarce its price shoots up, as it has been validated by Chapoto and Jayne (2009) showing that; in Malawi real maize prices typically double in 24 weeks after harvesting season. Didier et al*.* (2013) conclude that, price variation drives the storage decision. From the study, 1% increase of the expected price variation increases the average quantity stored by 8.4 kg, with p-value less than 1%. Therefore, the household could increase profits by holding maize stocks until later in the marketing year because the market price would rise accordingly as maize becomes scarce. This validates long maize–store–time against immediate sales after harvest. Moreover, devaluation of maize grain quality in the cause of PHL leads to price discount as pointed out by Didier (2013) that is, 1% rise in kernel injury leads to down price for about 0.32%. Findings from this study are applicable to other SSA countries with similar pest damages and price trends as in Benin. These potential losses in value might bring a substantial difference in monetary expressions to a family's livelihood. Hence, it justifies the improvement of storage structures together with store–time so that crops may fetch better prices and generate more income. The present review suggests that, resilient postharvest strategies together with an improved storage methods need to be established and defended with a reasonable store-time to secure both income and nutrition security in the postharvest period. These would serve as farmers' decision supporting tools on input-output relationship before investment.

MAIZE VALUE CHAIN IN SSA

Research and development as a main actor along maize value chain transforms knowledge into tangible assets, that is, improved seed varieties, fertilizer, pesticides, storage techniques etc. Adaptation and adoption of various technologies/innovations by producers result in surplus yield which creates a need for storage facilities from both public and private investors so as to regulate maize prices. Furthermore, maize marketing is said to be accomplished if and only if the produces reach final users that is consumers, animals feed, breweries industries etc. There comes a need for grain traders undertaking either exportation or importation. Stakeholders along maize value chain interact freely. Basically, enormous share of maize produced in SSA is locally consumed; this gives domestic market high potentiality. Alternatively, maize is subjected to international trade fall under international market conditions- demand and supply which influences domestic prices. As part of price regulation, government imposes import tariffs to protect domestic producers from lowly priced maize imports. Taking maize as an industry, it thus becomes essential source of foreign exchange through exportation of maize and its products. This fact raises concerns about the improvement of marketing setup and agro–logistics on main maize producing regions within SSA (Figure 2).

Maize marketing model in SSA

In SSA, maize prices are highly determined by market forces (demand and supply), yet maize shortages and maize price instability persist (Chapoto and Jayne, 2009). A lower maize price definitely affects all households that

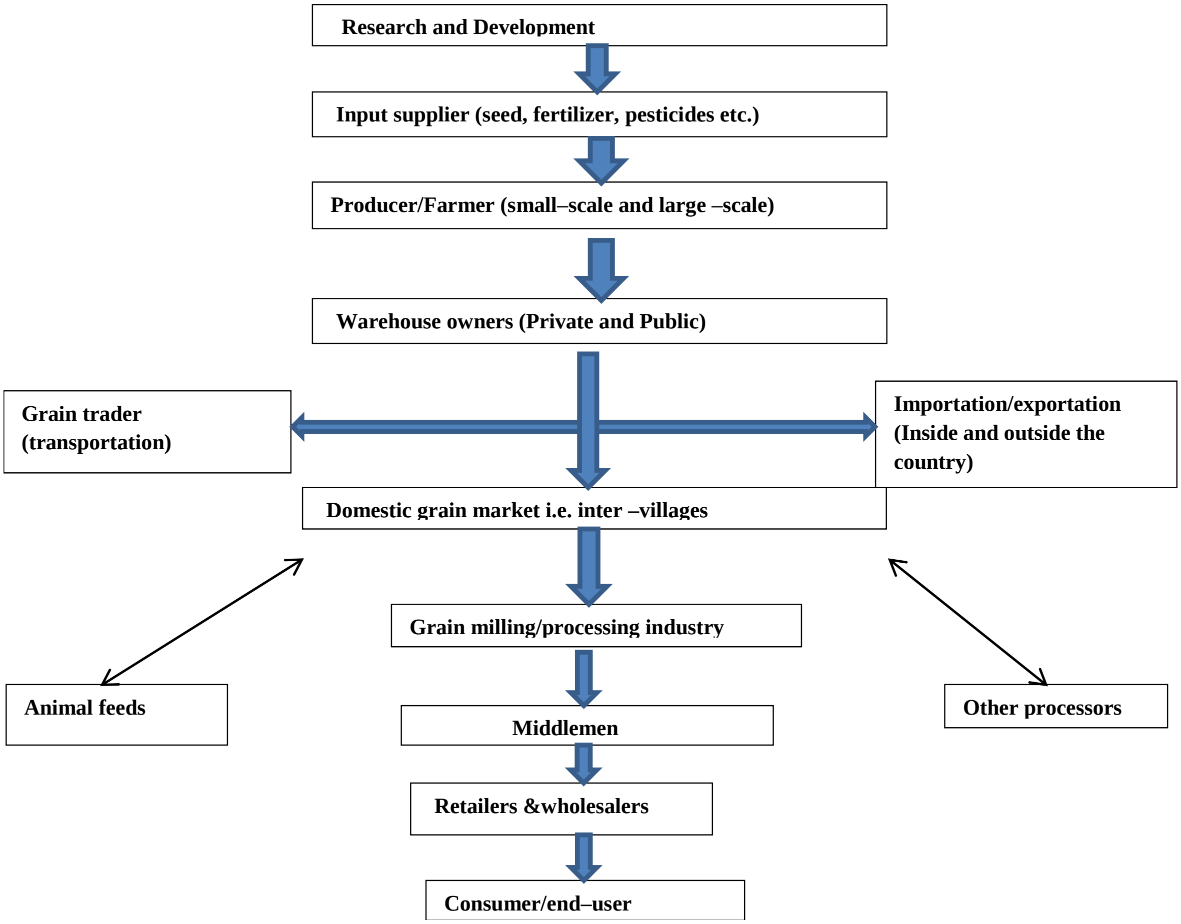

Figure 2. Illustrates the hypothetical maize value chain framework.

participate in maize markets both positively and negatively. In SSA maize profitability is regularly a gathering of carrying costs, capital rewards, and transactions costs. Maize three–dimensional market assimilation research in Malawi and Zambia (Goletti and Babu, 1994; Chirwa, 1999; Tostao et al, 2006; Abdulai, 2007; Myers, 2013; Burke, 2012; Mason et al, 2012; Ricker–gilbert et al., 2013) and for the wider region (Rashid, 2010; Mulenga and Campenhout, 2008) are mostly reliable in their findings that; maize markets are soundly well incorporated to the extent that they are suitable and their efficiency increases over time with decreasing marketing costs. This is to say; with the aid of a well–established marketing model the mentioned achievement would become more consistent in SSA resulting in commercial farming.

Taking Tanzania as an example of SSA countries, given its advantageous status in geographical location, that is, sharing border with Kenya taking advantage of weather variation impacts county trade off associates. Ahmed (2013) reports that maize trades would stand as foremost source of income. Following Kilima et al. (2008) line of thinking, trade is an essential element in moderating price volatility across regions, leading to much investment and future maize sub sectorial growth. Through efficient spatial arbitrage, the risk of crop failure in some regions is shared over a large market area, leading to price stability and shortage of food insecurity (Tostao et al.,, 2006). Hence, it becomes a good approach in economic wealth distributions and income inequality gap removal. Therefore, in modeling the effect of store–time on maize prices (specifically in *spatial–temporal* scenarios), that is, linkage between domestic prices (inter–village) and prices in regional markets (across region) should be accounted well to justify their linkage considering positive association among price and market participation. The implication is that, effectiveness of price incentive in maize marketing model is highly influenced by small–holder farmer's store–time and market spatial integration. Based on a research conducted in Malawi by Chirwa et al. (2010), sum of justifications pointed out increased maize prices in the face of growth production:

(i) Increased maize exports and purchases for the strategic grain reserve;

(ii) Rising real household income;
(iii) Increased storage losses according to long store-time

From a business perspective, concentration of very few sectors in the marketing channels will definitely rise therate and proportion of prices response (Miller and Hayenga, 2001), which results in long maize store–time with a significant contribution to PHL. Therefore, maize–store time and its marketing environment should be modeled to allow a reasonable store time for a profitable returns to maize investment. Furthermore, the export ban policy on raw maize for SSA should be discouraged regardless of its short term benefit that is domestic price regulation, until farmers will be full equipped with value addition skills both technically and financially, taking maize as a raw material for animal feed supplements industries, breweries, maize oil making industries, etc… Basically, export ban reduces farmers' revenue besides returns to investment, hence disincentive to maize marketing participation.

Post–harvest loss management strategies in Sub–Saharan Africa

There are several models which are mainly specific for individual countries in the SSA. For instance, in Ethiopia, farmers store their cereals using bags in house, heaped in house, metallic silo, elevated storage platform, unprotected pile and other traditional methods (Hengsdijk and de Boer, 2017). In the same country, a common maize–based postharvest model used involves storing maize together with teff followed by a single time application of pesticides, which minimize storage cost, based on the fact that, insecticide is been recommended to be applied after every three month of storage. Such strategies appear to protect 76% of the stored grains losing only 24% mainly due to chemical residue and discoloration (Hengsdijk and de Boer, 2017). In Rwanda, a three years (2010-2013) project named Post–harvest and Agribusiness Support Project (PASP) funded by USAID and IFAD, among other objective post–harvest management model was the focus; the developed strategy was provision of stable market soon after harvest through private sectors and national grain reserve; at the same time storage facilities were kept clean and in good conditions, thus resulting in postharvest loss dropout from 30 to 10%. The model of operation was rural cooperatives and the group members were the main project beneficiaries, whereby non–members can access the facilities with double price (IFAD, 2013). Regardless of some other project achievement, the strategy cannot be adopted as a successful one for it favors minority instead of national wise based on the fact that, post–harvest loss is a national issue rather than individual one.

In a research carried out in Tanzania by Daminger et al. (2016), it has been observed that the postharvest resilient strategy ought to be an effective utilization of Triple layer bags (PICS bags), considering its effectiveness in post–harvest loss reduction. Studies reported PICS bags efficiency reduces grains loss by over 90%. Contrarily, the strategy cannot be implemented built on the basis that, Tanzania farmers are more conscious of the present gain and loss rather than future one that is losing $10 today "aches" more than losing $10 some days later to the extent that, they are even willing to lose much in the future for the expense of present gains. This scenario has major implication on the proposed resilient strategy based on their prices, whereby one PICS bag costs five times the normal poly bag irrespective of its effectiveness in minimizing post–harvest loss (5000 Tsh vs. 1000 Tsh). Thus, growers might be willing to shift into PICS bag so they can earn more, but the return to investment stands as an obstacle, as investment will not pay off until the second or third year of investment. For this, the strategy cannot be taken as a resilient one.

Furthermore, studies directed on marketing model and store-time are highly important to maize production as an investment considering its potentiality as cash crop as well as food crop. Seeing climatic changes as big threat to SSA food security, it is necessary for continent policy makers and other stakeholder to invest on the cheap and friendly resilient strategies to minimize maize post-harvest loss with clear integration of marketing models and store-time. There should be regular interactions between Research and Development and farmers as main beneficiaries. In addition, most of the prior studies have been carried out on influences of other factors in post-harvest loss with no attention on economic factors especially marketing models and store-time which are crucial aspects in regulating maize grain supply.

CONCLUSION

In the developed world, post-harvest loss is highly concentrated in the latter stages of the production chain that is distribution and consumption, contrary to SSA whereby, most post-harvest losses happen during harvesting, post-harvest handling and on store. Advisably, stakeholders and investors along maize production pipeline should focus much on capacity building to small scale–farmers on proper post–harvest handling practices; subsidize the improved storage facilities such as metal silos, plastic silos, airtight bags and hermetic shells in order to improve farmers' accessibility. Normally, storage structures are purchased shortly before harvest time; in fact at this time farmers get small cash, while the marketing prices of PICS bags are high compared to traditional storage bags hence diminishing demand for PICS bag. The situation reverses farmers' income cycle, whereby during boom period farmers have no need of PICS bag regardless of their prices. To cut down this trend, PICS bag provision should be regarded among other agricultural inputs under input subsidy scheme to boost its accessibility with affordable prices. This will enable farmers to plan their purchase well in advance prior to harvest. There should be deliberate financial schemes as a source of fund for agro-dealers as key distributors for earlier mentioned post-harvest loss technologies to catalyze farmers' access to PHL strategies. Effort should be made to change farmers' mindset toward PICS bag initial investment cost in terms of not only its long life span (three years) but also efficient in post-harvest loss minimization in favor of the conversional bags considering purchasing cost, pesticide cost, complexity in application which needs to be accounted for among other costs. Utilizing these types of behavioral solutions may increase uptake of the PICS bag and other improved storage structures as solution toward post-harvest loss in store-time and marketing model perspectives.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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