Food security challenges in Sub-Saharan Africa: The potential contribution of postharvest skills, science and technology in closing the gap

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Abstract

More than half of global population growth between 2013 and 2050 is expected to occur in Africa and is projected to more than double from 1.1 billion to 2.4 billion people by 2050. Estimates suggest that globally, sustainable food production will need to increase by 70%. It is essential that postharvest loss (PHL) reduction occurs alongside this increase in sustainable food production and access to meet the enormous food demand. The paper examines the grain PHL levels in Sub-Saharan Africa (SSA) and their implications. The PHL reduction strategies, their merits and limitations are analysed in terms of appropriateness to smallholder farmers, who form the majority of the farming community in Africa. The paper further identifies emerging postharvest research and development issues and the implications at various levels. The need to consolidate the understanding, approaches and metrics of PHL is highlighted. This will enable losses to be measured more quickly, objectively and comparably across commodities and geographical locations in Africa and beyond, and to assist in decision-making and measuring the impact of different initiatives. That PHL reduction is now an aspiration of many high-level development plans across SSA is a significant step forward. However, the challenge still remains of converting this attention into meaningful practical actions and increased knowledge and skills at the scale required to enhance food security across the region.

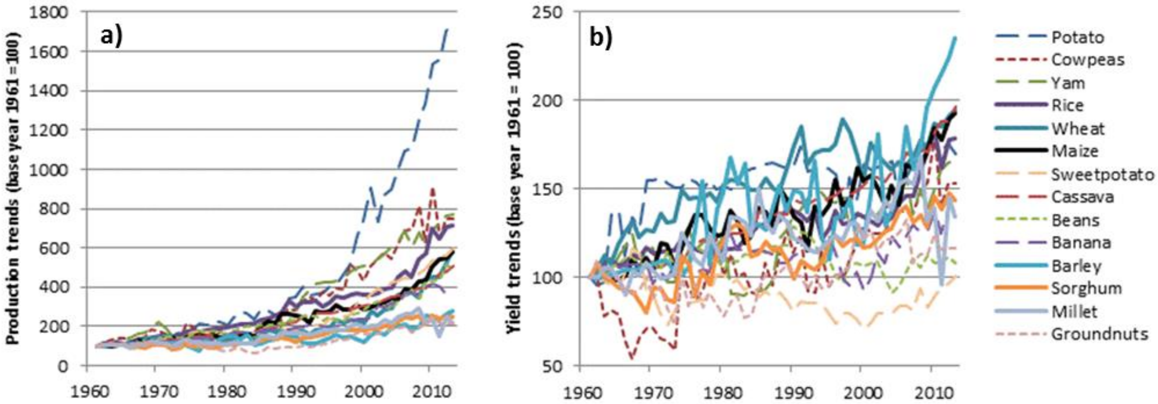
Keywords: food production, PHL reduction, PHL metrics, smallholder farmers, postharvest interventions

1. Introduction

Sub-Saharan Africa's (SSAs) population has been increasing rapidly, and projections suggest it will more than double between 2015 and 2050, growing from 949 million to 2.074 billion people (UNDESA, 2014). In 2050, 50 % of these 2 billion people will be urban-based, and the median age will be 23.6 years. Domestic food production and/or imports will have to increase to meet the growing food demand driven by both the population increase and consumption changes associated with projected greater per capita income. Estimates suggest that globally, sustainable food production will need to increase by at least 70% by 2050 (FAO, 2006; Bruinsma, 2009; Davies et al., 2009; Tilman et al., 2011).

However, although sufficient food is currently produced to feed the world's population, 870 million people remain hungry, and while the prevalence is decreasing, 23.8% of SSA's population is still undernourished (FAO et al., 2012; 2014). Food security encompasses not just the availability of sufficient food, but also the ability of all people to have stable access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996).

Trends for the main staple food crops in SSA show that since 1961, crop production has increased substantially for many of these crops (Fig. 1a), due to them being grown over larger areas of the land, as well as increasing yields (Fig. 1b) (FAOSTAT, 2014). Whether these trends continue is dependent on many interacting physical, social, economic, ecological and technological factors. The environmental impacts involved in meeting such escalating crop demand depend on the trajectories chosen, and will differ by location (Tilman et al., 2011).



Dataset source: FAOSTAT, 2014 – SSA countries excluding South Africa

Figure 1 Production and yield trends for key food crops across Sub-Saharan Africa between 1961 and 2013.

Achieving further production increases is unlikely to be any easier than in the past, as land and water resources are now more stressed (Godfray et al., 2010). Alongside population growth other drivers of change affecting the SSA region include: climate change, urbanisation, economic growth, soil degradation, fluctuating commodity prices, changing policies, market demands, input subsidy programmes, communication technologies, disease, and conflict. Climate change projections suggest mean annual temperatures will rise faster over Africa than globally, possibly exceeding a 3°C rise by 2100 (Niang et al., 2014). Rainfall projections are less certain. Estimates of yield losses for SSA vary, but are around -22% for maize and -8% for cassava by 2046-2065 (Schlenker & Lobell, 2010).

The focus has been on the impacts of climatic changes on crop production, ignoring how they will also affect what happens after harvest, during drying, transportation, processing, pest and disease management, storage, trading, and utilisation; all of which are relevant to food security as discussed by Stathers et al. (2013).

In the face of increasing food demands, more variable and risky crop production, and degraded ecosystems it is crucial that we safeguard our increasingly valuable food, and the resources (land, nutrients, water, inputs and labour) used to produce it. Postharvest skills, science and technology have an important role to play in improving food security by closing the growing gap between the projected additional food requirements and the available and accessible food stocks, as well as maintaining their nutritional and economic value. Postharvest loss (PHL) reduction will help build resilience against climate-related shocks and lessen the need for biodiversity threatening agricultural extensification (Stathers et al., 2013; FAO, 2013). It is estimated that SSA loses 13.5% of its cereal grains postharvest, this amounts to an annual loss of US$4 billion, or the annual caloric requirement of at least 48 million people (World Bank et al., 2011). As the struggle to obtain sufficient food grows, so too does our responsibility to reduce the losses of this food. SSA is likely to employ a combination of strategies to meet the food demands of its rapidly growing population. These will include increased domestic food production through intensification of existing farming systems and by bringing more land into agricultural use, increased food imports and food aid, changing consumption patterns, and a reduction in the amount of food lost after harvest.

2. Postharvest losses (PHLs)

Postharvest agricultural systems are diverse due to the range of: crops involved, successive operations in the postharvest system, and causes of losses; all of which interact with physical, technical, economic, environmental, institutional, political, ecological, and socio-cultural conditions; and affect the agents of deterioration and consequently losses. These factors vary with resource availability, timing and intentions, which influence the decision-making at each stage (Stathers et al., 2013). As a result, an enormous variety of approaches and forms of postharvest loss analysis are found in the literature depending on the authors' aims.

Postharvest food loss (PHL) is defined as food lost along the supply chain from harvest until consumption (or other end uses) (Hodges et al., 2011; Aulakh et al., 2013). Postharvest loss may be described quantitatively or qualitatively. Quantitative food loss implies a reduction in the available quantity as a result of: infestation by pests at harvest or storage; physical loss during handling; or reduction in quantity because of changes in temperature, moisture content, or chemical composition. Qualitative food loss results in changes which lower its economic or nutrient value. This can occur due to: spoilage by pests or diseases; physical or chemical changes due to a lack of climate-controlled storage and handling facilities; food contaminated with non-food material; or adverse taste, texture, or other changes due to improper processing. PHL can also include loss of: agricultural inputs, seed or grain viability and brewing ability, opportunity cost and goodwill. Most postharvest loss assessments or estimations have focused on the quantitative loss.

Reliable PHL measurements based on comprehensive studies at farm level are scanty. To-date we still rely on PHL data collected between 1975 and 1985 (Table 1). More robust and "live" loss assessment systems are required to cater for diverse crops, stages of the value chain, socio-economic circumstances and to represent different agro-ecological zones. Most of the reported losses relate to on-farm storage, insects and maize yet SSA is dependent on many other staples. There is an increasing realisation among postharvest scientists that postharvest losses due to storage insect attack are not as high as the widely used figures of up to 40-50% in maize. There is a general consensus that in the absence of the larger grain borer (LGB), *Prostephanus truncatus*, a devastating insect pest; and when using local varieties (which tend to be less susceptible), storage weight losses would be typically 5% or less annually, but can double when LGB damage occurs; combined with use of hybrid varieties (which tend to be more susceptible) (Boxall, 2002). Data on grain weight losses during storage need to better take farmers' withdrawals for consumption, sale, and other uses into account. Farmers often avoid total physical loss by reusing the affected produce in different ways and/or price discounting (Affognon et al., 2015).

The African Postharvest Loss System (APHLIS) estimates the 5-year (2007-2012) average grain weight losses throughout the maize, rice, sorghum and millets postharvest systems as 18.0%, 13.9%, 12.4% and 9.6% respectively (www.aphlis.net). APHLIS supports a network of local experts across SSA, a loss calculator and a free access database of key information

(Hodges *et al.*, 2010). The loss calculator works out loss figures derived from the best literature available and by local experts. With APHLIS, PHLs are estimated by crop, country, province and year taking into account scale of farming, climate type, number of harvests, proportion marketed, proportion stored, proportion consumed, occurrence of LGB, occurrence of wet conditions at harvest (Hodges et al., 2010). A comparative analysis of the APHLIS model versus standard conventional weight loss assessment methods (Boxall, 2002) is given in Table 2.

Table 1 Examples of comprehensive studies to measure storage losses at farm level (Tyler & Boxall, 1984).

Country	Crop	Storage period (months)	Cause of loss	Estimated % weight loss (SD)
Zambia	maize	7	insects	1.7 to 5.6
Kenya	maize	up to 9	insects, rodents	3.5±0.25
Malawi	maize	up to 9	insects	3.2±3.34
	maize	up to 9	insects	1.8±3.5
	sorghum	up to 9	insects	1.7±0.5
Tanzania	maize	3-6.5	Insects	8.7*
Swaziland	maize	unspecified	insects	3.66
			moulds	0.53
			rodents	0.16

*High loss figure is associated with the occurrence of the Larger Grain Borer.

Table 2 Comparative analysis of the PHL assessment using the African Postharvest Loss Information System (APHLIS) versus the standard conventional methods.

APHLIS Estimates	Standard Conventional Weight Loss Methods
• PHLs are based on the best data available, not necessarily very accurate e.g. survey data • Can be upgraded annually if more up-to-date data are availed • Factors in spatial and temporal details of data collection/sources to generate PHL visual maps • Some countries do not have reliable and consistent data collection systems eg due to political/economic instability • National data collection requires resources eg human, financial, infrastructure, transport, communication technology • Need capacity development for the people involved in the APHLIS network • Requires buy-in of policy-makers • Is online and freely accessible to anyone which is not the case for a lot of conventional weight loss assessment studies	• Cumbersome and massive and therefore prone to errors especially if dealing with large numbers of samples • Requires skilled personnel and appropriate laboratory equipment – Grain samples have to be carefully taken and transported to laboratory for analysis. • National scale measurements often result in sample pile-up – Compromises the accuracy and quality of the data • One can rarely do a weight loss assessment at the scale required to get an overview of losses across a country or region by crop, over time • Need good sampling techniques to represent different scenarios and generate national PHL statistics – Currently biased towards quantitative assessment – In some countries still required to contribute towards better APHLIS estimates

More recently PHL magnitudes reported in various documents from Benin, Ghana, Kenya, Malawi, Mozambique, Tanzania were analysed regardless of value chain level involved (Affognon et al., 2015). In the absence of any PHL reduction measures, grain storage weight losses were on average 4-6 times greater than when intervention measures were taken (Table 3). Much higher losses were experienced with some root and tuber crops, probably as their higher moisture content makes them more perishable.

Table 3 Postharvest weight losses in stored grains and other staple foods summarised from meta-analysis of literature from six countries in Africa.

	Minimum Postharvest Loss[a]		Maximum Postharvest Loss[b]	
Crop	No. of documents	Mean (SD)	No. of documents	Mean (SD)
Maize[c]	63	5.6 (5.4)	66	25.5 (15.3)
Cowpea[c]	8	4.3 (6.9)	9	23.5 (220)
Cassava[c]	7	28.0 (24.3)	9	42.3(27.6)
Yam[c]	8	18.8 (11.4)	7	41.6 (10.3)
Beans[c]	2	2.1 (3.0)	2	14.0 (1.0)
Sweetpotato[d]	12	7.4 (3.5)	6	43.6 (27.4)
Rice[c]	3	5.4 (5.3)	4	25.6 (27.4)
Banana[d]	1	-	1	35.7 (-)
Groundnuts[d]	1	3.1 (-)	1	10.1 (-)
Irish Potato[d]	3	7.0 (2.8)	3	21.6 (7.5)

a= Losses incurred when various types of interventions were applied; b= Losses incurred when no intervention were applied; c=weight loss; d = Quantities sorted and discarded because of deterioration. Adapted from Affognon et al., 2015.

3. PHL reduction interventions and limitations

PHL reduction technologies have been developed but many are not being fully utilised for various reasons (Table 4). Technology uptake and adoption is influenced by efficacy, culture, socio-economics, cost, awareness-raising, political stability, and the way the technology is introduced. Many PHL technology projects do not sufficiently involve key stakeholders, often resulting in lack of technical back-stopping, or acceptance by the target group, or other services such as informed marketing.

Research and development partners still face a number of challenges including: lack of properly designed loss assessment studies for various crops along the whole system and using credible and comparable methodologies to support estimates; inadequate involvement of private sector in PHL reduction activities; lack of national policy support (.national budgetary support); heavy bias by policy-makers towards the crop production phase; insufficient emphasis given to food safety issues in postharvest management e.g. improper application of pesticides and aflatoxins; effectiveness of the “Training of Trainers” approach in cascading postharvest (PH) knowledge and skills is not certain as . follow-ups for quality control monitoring and lesson learning are often missing; challenges of taking pilots to scale; many funders do not support up-scaling projects; accessible and appropriate training materials for different circumstances, commodities, and levels. Good quality manuals have been developed but are they sufficiently available and easily adapted to the contexts of different countries?

Table 4 An overview of limitations of PHL reduction technologies across Sub-Saharan Africa.

PHL Reduction Technology	Limitations
Synthetic pesticides	Effective and convenient, but concerns with environmental, human health and resistance challenges. In some countries pesticide access, cost and adulteration are hampering the use of this technology
Diatomaceous earths	Extremely effective and acceptable to farmers, but private sector investment required for wider scale availability
Breeding for resistance to pest attack	Good progress but farmer access to the varieties still limited. Bird attack (small grains) and storage insect pest attack (maize and small grains) still discouraging farmers from growing some otherwise improved and/or high-yielding varieties
Botanicals	A lot of research and development done but very limited products on the market. Key areas requiring strengthening include cultivation, propagation and sustainable harvesting plus private sector engagement. Most of the work has been laboratory-based
Hermetic storage systems	Huge potential especially in bag form; more evidence needed that they work in LGB- and rodent-infested areas; Metal silos effective but affordability is anissue; Challenges in facilitating trained local artisans to take over manufacture and supply; Workmanship to ensure silos are airtight coupled with farmer maintenance of hermetic conditions needs further strengthening; Airtight "cocoons" have potential for commercial or local entrepreneurs provided the zipping mechanism is well-managed and multiple "re-use" still needs to be verified.
Improved granaries	Huge potential but affordability issues. Indoor polypropylene bag storage is increasing in eastern and southern Africa and replacing the solid-walled granaries. This is mainly for security, flexibility and marketing reasons. The bags are affordable and easy to manage
Grain banks and warehouse receipt systems	Have potential to reduce PHLs, increase food security and increase income generation but require functional institutional arrangements, strong management, and external injection of resources to kick-off the process; market linkages and group dynamics are key drivers.
Mechanised peelers, chippers/graters and dryers (for root and tuber crops); threshers/ shellers, dehullers (grain)	Reduce processing time, labour, and food losses with significant impact on women; May work best under group arrangements.
PH management training of farmers and service providers (skills/knowledge)	Essential to optimise use of, adaptation of, and scaling out of PHL technologies. However, very limited funding for PH training/capacity building exists compared to the support for tangible technologies.

4. Amplifying the PHL Reduction momentum

There are a wide range of stakeholders involved in PH service provision, and together with the farming households they form the postharvest innovation system (Fig. 2).

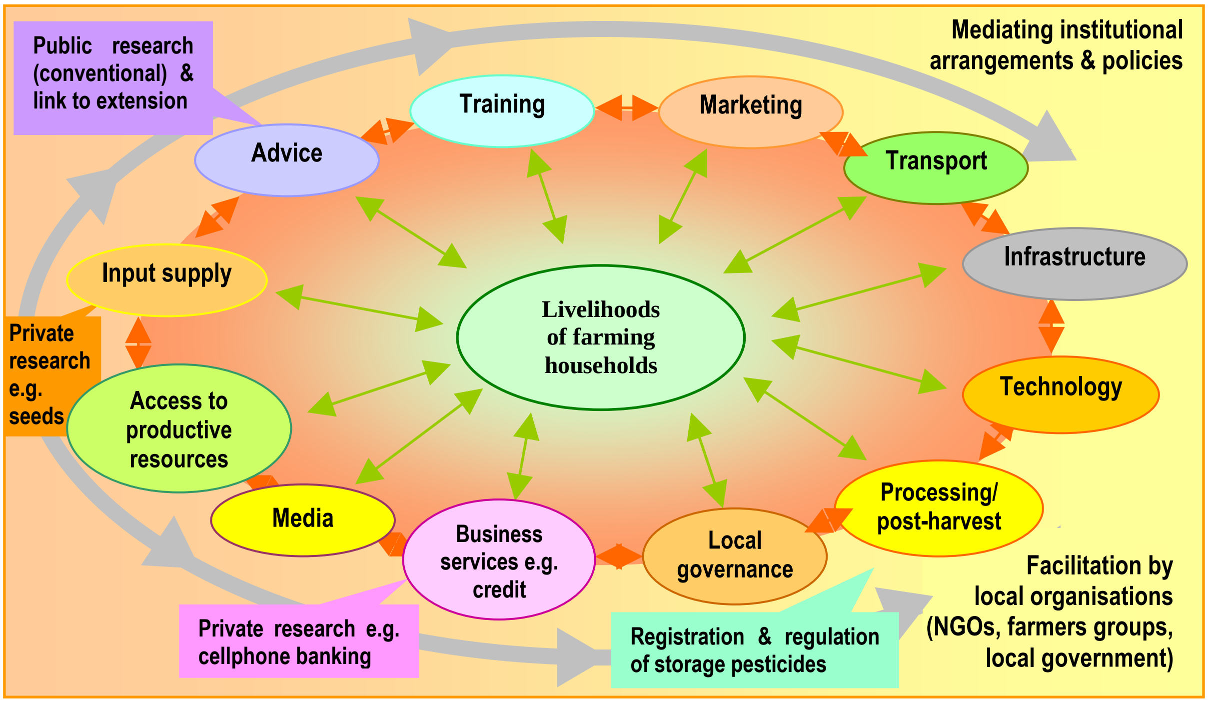


Figure 2 A postharvest agricultural innovation system from the farmers' perspective. Adapted from Goldman (2005) and Mvumi et al., (2008).

PH systems need to be viewed holistically and all the stages in the value chain considered. Postharvest systems are characterised by linkages between producers and consumers, and rural and urban areas, with markets, various technologies and organisations playing a major role in mediating these linkages (Stathers et al., 2013). The various players need to be involved to realise wide scale-uptake and sustainable use of PH technologies and loss reduction.

Interest in reducing postharvest losses of SSA food systems has oscillated during the past 50 years, with its prominence tending to surge following serious food price shocks (Fig. 3). When cereal prices worldwide rose in 1974, the response included investments in the Green Revolution technologies and a focus on postharvest loss assessment and reduction (Harris & Lindblad, 1978; FAO, 1996). The UN passed a resolution calling for a 50% reduction of postharvest losses by 1985 (UN, 1975). Many SSA countries established national food reserves. Several foreign aid programmes (e.g. FAO, UNDP, USA, Canada, UK, Germany, Denmark, Japan, Australia) supported food loss reduction programmes in SSA countries, and networks such as the Group for Assistance on Systems relating to Grain after Harvest (GASGA) which evolved into the Postharvest Forum (P*h*Action). However, most of these initiatives fizzled out in the 1990s, as agriculture for development support reduced and food prices reportedly fell (Wright & Bohenreith, 2009; Hodges & Stathers, 2013).

By 2003, African leaders' concern over low agricultural productivity led them to ratify the Comprehensive Africa Agriculture Development Program (CAADP), with the explicit goal of eliminating hunger and reducing poverty through investing in agriculture.

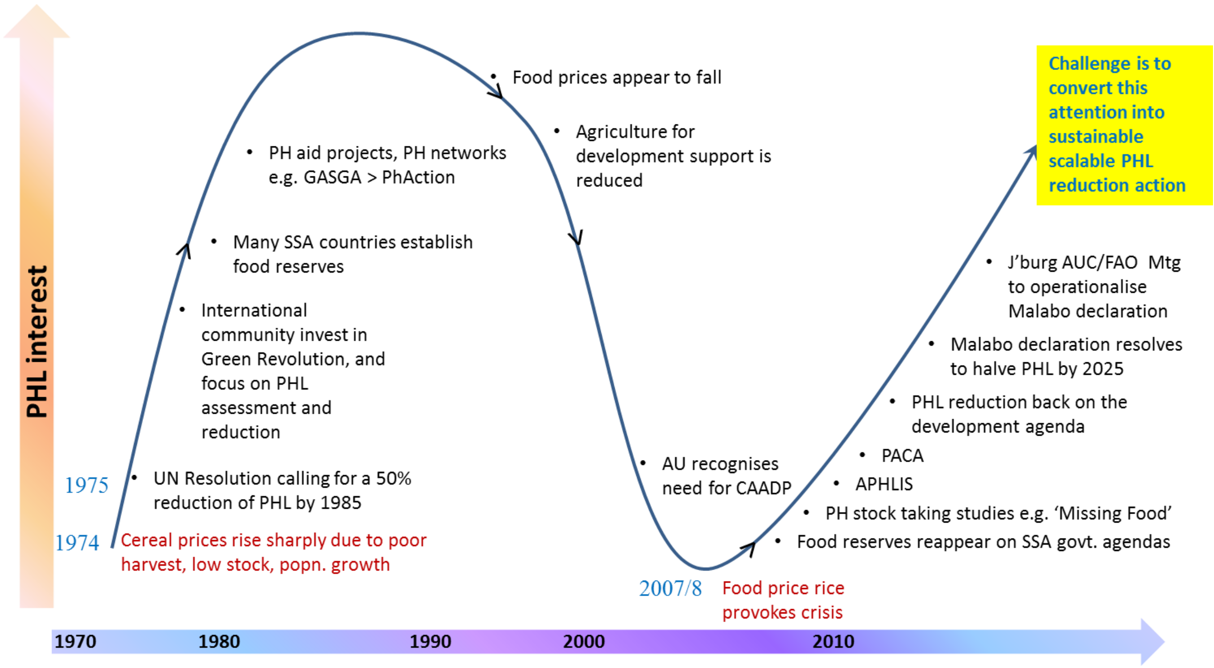


Figure 3 The pattern of interest in SSAs postharvest losses over the decades.

The 2007/08 food price rise provoked fears of a systemic change in the balance between food supply and demand (Koning & van Ittersum, 2009). The price spikes led to world food summits, riots and political unrest in a number of countries (including 14 African countries (Berazneva & Lee, 2013)), and acted as an indicator of potentially increasing threats to food supplies (particularly for the poor) from the interconnected challenges of climate change, natural resource degradation, continued rapid population increase and associated demands for food and feed (Dorward, 2011). While high food crop prices are beneficial for farmers, the high proportion of net buyers to net sellers in SSA means the overall impacts are negative. It is the poorest households in both rural and urban areas who spend the highest proportion of their budget on food (Compton et al., 2010; von Braun et al., 2008).

The latest crisis served to again remind the world of the vital importance of agriculture and PHL reduction. Food reserves to assist in cushioning against short-term shocks reappeared on the agendas of many African governments and their development partners, along with the old challenges of minimizing their operational costs and negative impact on the markets and farmers' production incentives. Studies such as 'Missing Food: the case of postharvest grain losses in SSA' (World Bank et al., 2011) were commissioned to take stock of: promising crop postharvest technologies, key actors, and the quantities of grain being lost. The debate concerning the magnitude of PHLs and the desire to measure and quantify losses in order to track progress in reducing them was re-awakened, leading to the development of APHLIS (Hodges et al., 2010). Two multi-stakeholder initiatives are developing and field-testing standardised measurement protocols for PHL. The FAO-led, Save Food - Global Initiative on Food Loss and Waste Reduction (FAO, 2014), and the World Resources Institute (WRI) coordinated Food Loss and Waste (FLW) Protocol Standard which aims to enable countries and organizations, to quantify in a credible, practical and consistent manner the extent of FLW and to identify where it occurs.

The green economy and climate-smart agriculture movements recognised the importance of reducing PHLs (FAO, 2010; UNEP, 2011; Foresight Review, 2011). Concerns about the public health and market development issues of mycotoxin contamination of grain led to the Partnership for Aflatoxin Control in Africa (PACA) in 2012. Other key postharvest aspects (e.g. storage, handling, transport, value chains, market access, training, dissemination of research) are being given increasing prominence by CAADP. The African Union's, Malabo Declaration in June 2014, resolved to halve the current levels of PHLs by 2025. Various philanthropic organisations and development partners have invested heavily during the past year in scoping and developing high impact PHL reduction strategies. The challenge is now to convert this attention into appropriate, sustainable large-scale loss reduction action.

Alongside international and regional initiatives, government policies also influence PHLs. However, postharvest systems are complex, with linkages between many players and factors. As with other analogous complex issues such as nutrition, climate change, water resource management, coordination between sectors is crucial. Multi-disciplinary, resourced 'units' to address PHLs, and systematic monitoring and measurement to enable meaningfully targeted and assessed policy interventions are required (Dahlberg, unpublished report).

Policy related aspects affecting crop postharvest systems include: appropriate varieties and crops; infrastructure; import tariffs; export bans; value addition; market opportunities and places; postharvest technologies; extension skills and resources; farmer capacity building; inclusion of postharvest topics in formal education systems at all levels; investments in postharvest agricultural research and development; effective monitoring and measurement systems; standard weights and measures; grading systems and practices; quality standards; packaging facilities; public private partnerships to support storage facilities and infrastructure; enabling environment for private sector investments; access to agricultural finance; input subsidies; tax on handling/ processing equipment; warehouse receipt and inventory credit systems; food safety standards and awareness; nutrition-sensitive agriculture; dietary diversity; nutrition education; rural energy; equipment maintenance; gender roles and dynamics; urban and rural food systems; food security strategies at national to household levels; pesticide regulations; cooperatives; natural resources; consumption patterns; and behavioural change communication. The complexity is challenging, if not overwhelming, and perhaps explains why policies and interventions all too often focus on just one of these areas in isolation, rather than on developing a wider understanding of the systems and the complex relationships between them.

5. Conclusion

Many crop postharvest management technologies have been developed but most tend to be project-based and mechanisms for bringing these technologies to scale are often missing. In addition, many projects do not factor in impact assessment after project termination to determine uptake and sustainability of the technologies. Some of the technologies are developed without participation of the end-users or in user's own circumstances, making long-term adoption of the technology unlikely as they are often inappropriate for addressing end-user's problems.

To respond to the June 2014, Malabo declaration for Africa's Accelerated Agricultural Growth and Transformation (3AGT), we, the PHL reduction community need to supply baseline data to measure the 50% reduction in PHL by 2025, which could be built on APHLIS. We also need to build a mechanism to strengthen stakeholder coordination along the PHL value chains, with emphasis on strengthening public-private sector and civil society partnerships. Stakeholder consensus on areas that guide policy regulation, harmonization and implementation related to PHL reduction need to be reached. We also need to identify and use ways to facilitate clear entry points for youth and women in PHL reduction to help ensure investments are effective and sustained.

PHL assessment studies have largely been quantitative yet consideration of qualitative loss could actually be greater; and include both nutritional loss and mycotoxin contamination with their serious human health implications. Financing and institutionalisation of postharvest management (PHM) implementation strategies are still negligible relative to crop production-related activities. PHL reduction successes need to be identified and scaling up and out strategies developed and supported. Private-Public Partnerships and value chain approaches are key to realising meaningful and sustainable PHM interventions. Coordination of PHM efforts for harmonisation and lobbying purposes is required. A combination of postharvest skills building amongst all key stakeholders, science and technology, and technology application and market-based approaches will enhance PHM and PHL reduction in SSA.

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