preventive methods such as grain cleaning, drying, cooling, and pest-proof storage structures. Now we have fewer and fewer pest control options. But can we offer sufficient data to convince farmers?

What happened to the United Nations (UN) Millennium Development Goal to cut down hunger by 50%? How can stored-product protection research be helpful to reach this goal? And is there sufficient research done?

The European Union (EU) did not make stored-product protection a topic in its calls for Horizon 2020 even though early on a number of colleagues wrote to their respective national contact points. So far, just mycotoxin-research is funded, but that insects locally increase moisture and thus facilitate mycotoxin formation is not taken into consideration. Who decides research funding policy, and who has sufficient oversight? Is there a way to make research funding a more flexible tool?

At least within Germany, there were national funds available for research projects within the last six years. But international cooperation mainly depended on personal scholarships by sources such as DAAD or Humboldt Foundation.

What needs to change?

As stored-product protection researchers, we are usually analyzing a specific problem and searching for specific improvements or solutions. But if I would lift my head to look at the greater picture, I would like to utter the following wishes:

1. EU: Please make stored-product protection research part of the funding for FP9!

2. EU and member states: Please provide funding and facilitate research cooperation between European and non-European stored-product protection scientists (travel grants, smaller and larger projects), while keeping administrative hurdles at a minimum.

3. FAO and UN World Food Programme (WFP): Please help initiating and coordinating stored-product protection research according to your needs, in organizing exchange of ideas and concepts. Participate more regularly in scientific conferences.

4. UN: Please develop an improved method on how to reach consensus and a clearer perspective on how to tackle pressing challenges (e.g., overpopulation, malnutrition and starvation, scarcity of fresh water, pollution).

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Counting losses to cut losses: quantifying legume postharvest losses to help achieve food and nutrition security

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Abstract

Projections suggest that by 2050 global food production will need to have increased by 70% to meet food demands associated with the world's population growth. Such forecasts, alongside growing awareness of the socio-ecological costs of food loss, and political ramifications of food crises have seen postharvest loss (PHL) reduction reappearing as a development priority. Particularly so in sub-Saharan Africa, a region deemed highly vulnerable to the impacts of climate change, where 307 million people are already affected by severe food insecurity, and the population is projected to double by 2050. Targets for reduced PHL are emphasised in the African Union's Malabo Declaration and Sustainable Development Goal 12.3. However, crop postharvest systems are complex and losses occur in various ways at different activity stages and due to a host of diverse reasons. To better target and prioritise loss reduction investments and policies we need to understand how much food is being lost postharvest, where, and why. The African Postharvest Losses Information Systems (APHLIS), brought a rigorous knowledge management approach to cereal PHLs. We are now expanding this to include key legume and other crops and estimates of the nutritional and financial values of these losses. The scientific literature was screened to build profiles of the PHLs occurring along the value chains, and combined with contextual information, to provide science-based estimates of PHLs where direct measurements are not available. We discuss these legume PHL profiles and the related opportunities and knowledge gaps.

Keywords: Legume crops, postharvest losses, PHL metrics, loss estimates, African Postharvest Loss Information System (APHLIS)

1. Introduction

With the world's population expected to reach 9.8 billion people by 2050, two-thirds of whom will be living in cities (UNDESA, 2017), projections suggest food production will need to have increased by 60% if the growing and changing food demands are to be met (Alexandratos and Bruinsma, 2012). Such forecasts, alongside a developing awareness of the socio-ecological costs of food production, food loss, and political ramifications of food crises have seen postharvest loss (PHL) reduction reappearing as a development priority (World Bank et al., 2011; Gustavsson et al., 2011; Foresight Review, 2011; FAO, 2013; Hodges & Stathers, 2013; Affognon et al., 2015; Mvumi and Stathers, 2014; Sheahan and Barrett, 2017). This is particularly so in sub-Saharan Africa (SSA), a region deemed highly vulnerable to the impacts of climate change (Niang et al., 2014), where the population is projected to double by 2050 (UNDESA, 2017), and where 307 million people already suffer from severe food insecurity (FAO et al., 2017). Sustainable food security will not be achieved through focusing on reducing postharvest losses alone. Increased food production must be achieved with less impact on the environment, alongside actions to modify resource intensive consumption patterns and population growth, improve governance systems, and reduce food loss and waste (Godfray and Garnett, 2014).

Postharvest losses are not just a loss of valuable food, but also of all the resources invested in producing the food. As climate change impacts, population growth, environmental awareness, and competition for water for agriculture increase, so does the pressure to reduce losses. This recent recognition of the importance of and socio-ecological benefits of postharvest loss (PHL) reduction has led to significant investments in improved postharvest management, particularly storage technologies, by governments and donors across SSA. Major targets for reducing PHL have been set. African Union member states in the June 2014 Malabo Declaration for Africa Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods agreed to reduce current levels of PHL by 50% by the year 2025 (African Union, 2014). In 2015, all member states of the United Nations adopted a set of Sustainable Development Goals (SDGs). SDG 12 aims to ensure sustainable consumption and production patterns, and includes target 12.3 of 'by 2030, halving per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses' (UN General Assembly, 2015).

Crop postharvest systems cover a range of different activity stages and are typically spread spatially and temporally across different locations and actors, and are thus both complex and dynamic. They include the harvesting, transport from field, drying, threshing/shelling, cleaning and sorting, storage, packaging, further transport, marketing, processing, and consumption of the crop. Losses can occur in a multitude of ways at each activity stage and due to a host of diverse reasons (e.g., grain left in field at harvest, spilt during transport, or consumed by pests during storage, etc.). To decide how to reduce PHLs, and which investments and policies to implement, it is important to understand not just how much food is being lost postharvest, but at which activity stages these PHLs are occurring, how, and why.

The 2008 food crisis acted as the trigger for development agencies involved in improving food security across SSA to realise they needed a more detailed and accurate understanding of the level of postharvest loss of staple food crops occurring (World Bank et al., 2011; Hodges & Stathers, 2013). This led to the European Commission funding the development of an online African Postharvest Losses Information System (APHLIS) www.aphlis.net, which was launched in 2009, bringing a rigorous knowledge management approach to cereal PHL estimates (Rembold et al., 2011).

To create APHLIS, the scientific literature on cereal PHLs in SSA was screened and weight loss data extracted to build PHL profiles for nine key cereal crops. Seasonal data were then supplied by a network of experts for each province of 37 SSA countries on: the quantity of each of the cereal crops produced, whether rain had occurred at harvest, whether the devastating maize storage insect pest the larger grain borer (LGB), *Prostephanus truncatus* had been present, % of the crop marketed versus stored on-farm, typical storage durations, farm-scale proportions, and climate types. An algorithm was then used to adjust the PHL profile according to the seasonal factors supplied for each location to produce a contextualised science-based estimate of PHL occurring at each PH activity stage for each of the focal crops. This system provided an overview of PHLs by crop across countries and years. The PHL estimate was then presented as % weight loss and quantity of crop lost. The data were used by development agencies for refining their food security assessments. As such, APHLIS provides governments and international organisations and bodies with science-based estimates of cereal PHLs by crop, postharvest activity stage, province, and year, filling a valuable information gap for the majority of locations where direct measurements of PHLs have never been made. As transparency regarding how the loss estimates had been calculated was viewed as important, the APHLIS system enables the data and original studies behind the calculation of each PHL estimate and a rating of the reliability of each loss figure in a profile to be identified, and updated or improved where necessary (Hodges et al., 2014).

A sizeable body of literature exists that discusses and debates postharvest cereal loss assessment methods. Much of the work has focused on different methods for measuring weight losses occurring during cereal storage, which is viewed as a critical loss stage with crop storage in SSA typically occurring at farm-level and often for periods of up to 10 months. However, a focus on just the physical weight loss occurring at different PH stages underestimates the overall value and multi-dimensional nature of PHL, as the quality as well as the quantity of the crop can diminish postharvest. Qualitative losses include: the reduced financial value of damaged, contaminated, or aged produce; nutritional loss which may not always be directly proportional to the weight loss, as rodents and some insect species selectively feed on specific parts of the grains, such as the germ and thus may particularly remove fats or vitamins; reduced seed viability; commercial losses if control treatments have to be purchased, or legal costs are faced; and reputational losses (Boxall, 2001). Including qualitative as well as quantitative losses in PHL calculations would result in substantially higher figures and give a more accurate representation of their socio-economic impact. However, qualitative losses are more complex to measure and the perceived importance of loss in quality may be dependent on the: surrounding food availability situation, location, expectations and standards, intended use of the product (i.e., whether consumed as a whole grain, dehulled or milled product, or marketed), how easy they are to observe, knowledge about what caused them, etc. (Compton et al., 1998; Hoffman et al., 2013; Jones et al., 2014; Kadjo et al., 2016), and limited work has focused on them. They can also be complex to express, as many are not typically considered in monetary terms, i.e., well-being, farmer's time, wasted natural resource inputs, etc. As APHLIS further develops, elements of quality loss are being incorporated to help provide a more complete understanding of PHLs.

The original APHLIS focused on cereal grains. Whilst cereal grains are the main food staple crops in many areas of SSA, root and tuber and legume crops are also crucial staple foods; legumes are a major source of dietary protein in diets of the poor in SSA. In recognition of this, APHLIS is now expanding to include key legumes and other important staple food crops such as cassava. In the current paper, we present the legume PHL data and the process of developing legume PHL profiles and the related opportunities and knowledge gaps.

2. Materials and Methods

To create the PHL profile in APHLIS for each focal crop, the scientific published and 'grey' literature was screened, and reliable high quality data of the PHLs occurring in a specific context extracted and entered into a database along with details of where, when, at which PH stage, and how the loss figure was determined. This followed the method developed by Hodges et al. (2014), and ensures the PHL estimates are based on the best data available. Where limited SSA PHL data exists, the search was widened to include other countries with similar legume production and PH systems and climate types.

This complex multi-stage process involved a thorough search of the literature, followed by screening of the titles and abstracts of each potential PHL study identified during the search to determine whether quantitative data on PHLs was reported. The full versions of studies considered likely to contain quantitative PHL data were accessed and read. The loss assessment and sampling methodology, type of study, and presentation and interpretation of the results were critically examined to determine how reliable the measurements or estimates were likely to be, to determine whether the data should be included, and, if so, the quality rating of the study's data (high, medium, low, exclude). This screening process was based on that used by Hodges et al. (2014), and was similar to that followed by Affognon et al. (2015). If quantitative PHL figures had been collected during the study, they were extracted and entered into the appropriate crop group database (i.e., cereals, legumes, root, tuber, and banana).

For each PHL figure used, the accompanying data on the context in which that PHL occurred was recorded. This included the:

- crop type;
- PH activity stage that the loss figure occurred in (i.e., harvesting, field drying, stripping, transport to home, further drying, threshing, storage, transport to market, market);
- method used to obtain the loss figure (i.e., measured vs guestimate, and details of the loss assessment method, sampling technique, and accuracy of interpretation of results);
- type of study (i.e., field survey, field trial, or on-station trial);
- geographical location where the data were from;
- Koppen climate zone where the data were from;
- farm type and technology used (i.e., smallholder or larger-scale farmers and whether they were using an improved postharvest management method applicable to that PH stage);
- relevant details about the method and study (i.e., if storage stage, what storage container, treatment, duration, and sampling process that the loss was associated with);
- decision to include or exclude the study, and, if included, the quality rating of the study's data score (i.e., high, medium, or low)

Due to their importance as protein sources in the food systems of many African countries, the focal legume crops included are cowpeas (*Vigna unguiculata*), groundnuts (*Arachis hypogaea*), common beans (*Phaseolus vulgaris*), bambara nut (*Vigna subterranea*), pigeon pea (*Cajanus cajan*), and soy bean (*Glycine max*).

Many of the legume PH studies focus on the storage stage, but had recorded data on the % of insect damaged grains as opposed to the % weight loss, likely as a time-saving measure. Where these studies were of 'high' or 'medium' quality rating, the percentage damaged grain data were converted to percentage weight loss using crop specific conversion formulae from published studies, e.g., for cowpeas ($y = -0.0025x^2 + 0.3551x - 3.31$, x = % damaged grain, y = % weight loss (Wright and Golob, 1999)). While the actual conversion rate between % damage and % weight loss is likely to be influenced by variety, storage insect pest species present, etc., it was judged to be beneficial to convert the % damaged grain data in order to increase and widen the geographical source of the number of PH loss figures being used to build the storage loss part of the PHL profile.

The dataset was then manipulated to provide an overview of what data of what quality exists for each legume crop, climate zone, and PH stage. Where major gaps in the available data exist, in terms of missing information on some of the postharvest stages for some legume crops, decisions are then made as to whether it is appropriate to use data from a similar legume crop for that stage or to include 'low' quality rated data as well as 'medium' and 'high', until higher quality studies for the PH stage of the specific crop are undertaken. This overview stage allows decisions to be made regarding which data will be used to create a profile of the PHLs occurring at each postharvest stage of the value chain for each crop. Details on key loss-causing factors at each stage are also collected and screened to determine what contextual data could be collected to indicate to what degree the main loss-causing factors occurred which will then be used in the algorithm to adjust the loss estimate for that particular context.

3. Results

3.1. Quantity, quality, focal PH activity stage and crop of legume PHL data

Although accessing and screening of the legume PHL literature is still ongoing, to date legume PHL figures from 63 studies have been identified, resulting in a dataset of 694 legume PHL figures.

Analysis of these figures reveals that 525 (76%) were categorised as of 'high' or 'medium' quality rating, and, of these, 75% were measured figures. When these 'high' and 'medium' quality legume PHL figures were grouped by PH activity stage, the majority were related to storage losses, with 57% giving data on losses during farm-level storage and a further 20% on losses during market storage stage (Table 1). Where storage data were provided as % damaged grains, it was converted to % weight loss; 58% of farm-level storage loss figures and 52% of market storage figures required conversion. Limited data on the losses occurring during the other PH stages exist, and data from cowpeas, groundnuts, and common beans dominate: 36, 28, and 19% of the legume PHL figures, respectively. Inclusion of lower quality data would increase the number of data points from the different PH activity stages but would reduce the reliability of the estimates produced using the profile.

Table 1 Number of legume postharvest loss figures obtained by crop and postharvest activity stage

Postharvest activity stages	Bambara	Common beans	Cowpea	Groundnuts	Pigeon pea	Soy bean	Total
Harvesting, field drying, pod stripping				24	2	4	30
Transport from field				6			6
Further drying				11	1	3	15
Threshing / shelling, winnowing			12	16	2	3	33
Storage on-farm	18	101	110	48	21	3	301
Packing, sorting, grading				8	1	1	10
Transport to market				13	1	1	15
Market	20		67	13	4	3	107
Processing				6	1	1	8
Total	38	101	189	145	33	19	525

3.2. Climatic and geographical nature of legume PHL data

The climate, in addition to the crop, activity timing, practices, and technologies, influences the level of PHL. When the 'high' and 'medium' quality PHL figures are viewed by the climate type of the location where they occurred (using the Koppen climate classification), 46% are from tropical savannah (Aw) climate zones, 21% from warm semi-arid areas (BSh), 11% from humid subtropical climates (Cfa), and 8% from tropical monsoon areas (Am). These four climate types cover the majority of the crop producing areas of SSA.

Geographically, the legume PHL data came from a number of countries across sub-Saharan Africa, with 56 % of the studies coming from West African countries, particularly Nigeria, Ghana, and Niger (Figure 1). Relevant data from India, Brazil, and Thailand have also been included.

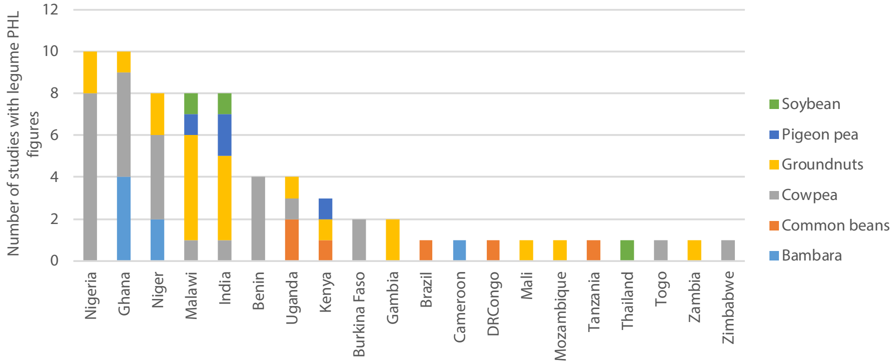

Figure 1 Number of studies with legume PHL figures by country

3.3. Age of legume PHL data

Analysis of the reporting year of the legume PHL data shows that 63% of the studies were published since 2000, reflecting the renewed interest in PHL reduction in SSA (Figure 2). Some high quality studies of legume PHL from before 1980 were also included.

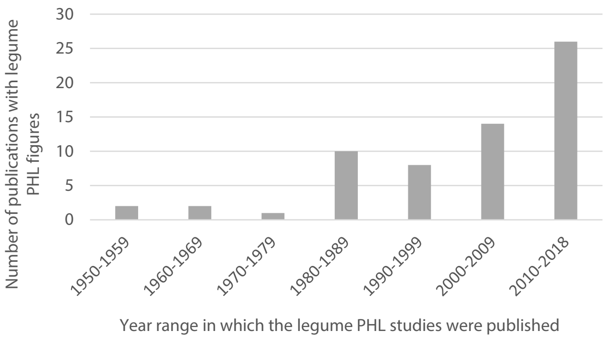

Figure 2 Age range of the legume PHL loss data

3.4. Storage losses from different treatments

The PHL data set includes 301 storage loss figures, and these are from a range of different storage treatments, with 36% from legumes stored untreated in sacks or outdoor granaries; 27% from legumes stored admixed with ash, sand, clay, botanicals, or above fire places; 17% from legumes stored in hermetic bags or other hermetic containers; and 3% from legumes stored admixed with synthetic pesticides (Figure 3). Where storage loss data were from surveys of a number of farmers who were using different treatments, including untreated, botanicals, and synthetic pesticides, it was recorded as ‘range of treatments’. Most (70%) of the storage loss data came from legumes stored using the more traditional practices, e.g., untreated shelled or in pods, or admixed with ash, sand, clay, botanicals, or kept above fire place. The majority of these storage loss data came from studies on cowpeas (39%), or common beans (36%). A preliminary comparison of the average loss levels occurring in the different treatments when loss figures were extrapolated to a standardised five month storage duration, revealed that the traditional practices resulted in average weight losses more than twice as high (>9% loss) as the improved treatments (<4% loss).

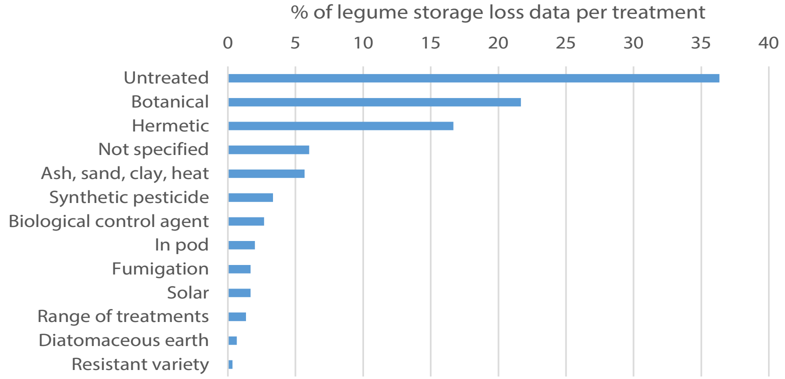

Figure 3 Overview of storage treatment methods from which the storage legume loss figures were obtained

While further calculations have been made using these data towards the calculation of PHL profiles for the different legume crops, it is premature to present this until further decisions are made by the legume technical expert panel regarding the sharing of data between crops and climate zones for cases where insufficient data exists on a particular crop at each PH stage in different climate zones.

During compilation of this legume PHL dataset, the loss causal factors have also been recorded, and these are being used to identify the seasonal or contextual factors that additional data is needed on to contextualise the losses to each location; these include: combining the PH activity timing with meteorological data (e.g., particularly for harvesting and drying), knowledge of the proportion of the focal population using different PH techniques, storage duration and number of harvests/ year, and the proportion of the crop marketed and the timing.

4. Discussion

The legume PHL scientific data are dominated by studies on cowpeas, groundnuts, and common beans, although other legume crops (e.g., pigeon pea) are widely grown and consumed in SSA. There is also more legume PHL data from West Africa than East, Southern, or Central Africa. Most research studies have focused on the storage losses which occur either on-farm or at the market place, and particularly those caused by insect pest damage. Very limited study has occurred of the losses which occur in legumes during harvesting, field drying, pod stripping, transport, further drying, threshing/ shelling, winnowing, sorting, or processing. A similar situation was observed with the cereal PHL data used to create APHLIS (Hodges et al., 2014), the durable crops included in the meta-analysis of PHL data from six SSA countries (Affognon et al., 2015), and a review of PHL in Organisation of Islamic Cooperation member states (Tomlins et al., 2016). However, whilst storage losses are clearly an important element of overall PHL and are the target of many PHL reduction investments, it is unlikely that a focus on reducing losses only during the storage stage will achieve the target of halving PHL by 2030. There is a need for losses at other PH activity stages to be reduced concurrently, and a more holistic and integrated view of pre- and postharvest crop systems.

To deepen understanding of legume PH systems and losses, studies of the non-storage stages are needed to provide greater insight into the proportional amounts being lost at each PH stage of the value chain and the reasons for these losses and opportunities for reducing them. This is important information to ensure available PHL reduction resources are being wisely targeted. Ideally, a PHL study should track the crop and its associated losses from field maturity stage onwards following it through the different activity stages which will typically occur at and between different locations and times after harvest, and as it changes hands between actors along the value chain. However, such studies are rare, as the logistics of doing such a study at any scale, unless based close to the farms, are complex and costly. Such data would produce a more comparative understanding of where, why, and at what scale losses occur postharvest, and help by removing problems of lack of consistency between measurement methods, aims, geographies, data reporting styles, etc., which are well-known challenges. Many studies use 'guestimates', whereby farmers or other stakeholders are asked to provide verbal estimates of what percentage of their crop they lose postharvest, with the better ones of these studies asking for PHL estimates at each of the different stages and triangulating the responses with rankings, etc. However, these are perceived estimations, and highly subjective, and should not be confused with measured loss assessment. They are of course comparatively cheap and easy to obtain, but their accuracy is not well-understood and will vary by study, and the data obtained with them demonstrably prone to errors. If we think carefully about a simpler question of what % of the food in our home we lost or wasted during the last year or last 5 years, without measuring it and without having kept records, how accurate an estimate would we make? The growing research focus on food waste in developed countries has found quantitative estimates made from memory regarding the weight of food purchased and discarded are very prone to error (see Jorissen et al., 2015; FLW Protocol, 2017 for discussion). For more rapidly quantifying storage losses *in situ*, several visual scales have over the years been developed for different crops (e.g., maize cobs – Compton et al., 1991; cassava – Compton et al, 1992; millet – Hodges, 2013) (Compton and Sherrington, 1999; Hodges, 2013; Hodges et al., 2014).

Combining qualitative with quantitative losses provides a more realistic idea of the level and value of PHLs. However, the rejection criteria for produce varies by location, wealth group (Kadjo et al., 2016) and season (depending on food availability and typical quality) (Compton et al., 1998; Jones et al., 2014). Not all quality attributes are visible (i.e., aflatoxins, pesticide residues), and some studies suggest unobservable maize quality attributes affect farmers' food purchasing decisions and explain the large premium farmers place on maize they have grown themselves relative to that available for purchase (Hoffman and Gatobu, 2014; Kadjo et al., 2016).

There is a frequent misunderstanding that the weight loss occurring during storage is the same as the % of damaged grains, but this is not the case. The physical weight loss of grain is a fraction of the % of grains damaged, typical ratios for % weight loss : % damaged grains are: maize grain 1:8; sorghum 1:4; and paddy rice 1:2 (Adams and Schulten, 1978; Harris and Lindblad, 1978). Therefore a storage weight loss of 12% can mean the damage to the grain is so severe that unless there is extremely limited food availability, the grain would neither be eaten nor could it be sold, thus resulting in a total PHL of all the grain not just a 12% weight loss. There needs to be improved communication and understanding of this important topic, which could be helped with visual imagery. Currently APHLIS presents % weight loss data, and combines this with crop production figures for the different provinces of the focal countries to calculate what amount of each crop that province or country is losing. Preliminary work has begun in the APHLIS+ project to calculate the nutritional loss occurring as a result of these PHLs, and the financial value. Presenting PHLs in terms of dollars lost, or annual requirement of nutrient X for Y million people lost, or the number of extra acres of land farmed or cleared and associated quantities of seed, fertiliser, and water lost is likely to help increase public engagement with and concern about PHLs. However, the difficulty and complexity of including the more qualitative dimensions of PHL should not be underestimated. Attempts to estimate the economic impact of mycotoxins in SSA, for example, were thwarted by the lack of good data (Wu et al., 2011).

Looking beyond the use of APHLIS to calculate science-based estimates of PHL occurring at the different PH stages, there is interest in developing APHLIS to enable it to capture a more nuanced understanding of PHL and how these are or could change over time. Such development could enable it to become a useful support tool for PH investment scenario planning or a PHL M&E tool, for governments or Malabo Declaration or SDG 12.3 Global Food Loss Index M&E frameworks. For example, the disaggregated storage loss data could be used to calculate changes in PHL as users adopt different improved crop storage practices. This could also be done for PHLs during non-storage stages if sufficient data were available. Governments wanting to better understand PH practices and technology use across their populations could ensure such questions were included in nationwide surveys such as the Living Standards Measurement Survey. However, it should also be noted that some 'improved' PH technologies or practices might be adopted to make a PH process less laborious or costly as opposed to reducing the quantity lost, and this may be of greater importance to the user.

Some improved pre or postharvest technologies or practices may actually increase PHLs, and these complex trade-offs need understanding; for example, some hybrid maize varieties had higher yields but were softer with poorer husk cover resulting in higher storage losses (Tyler, 1982, Boxall, 2001), mechanised harvesting and handling can result in higher levels of damaged grain which can render it more susceptible to attack by certain insect pests (Boxall, 2001), storage of milled rice is more susceptible to insect damage but takes up 25% less space than paddy (Boxall, 2001), double cropping may lead to increased annual production but may alter activity timings and disturb the traditional capability to conserve grain and lead to farmers putting wet season crop into store at higher moisture contents with markedly increased risks of spoilage (Wright, 1995; Boxall, 2001), and stricter food safety requirements and standards may result in increased removal of unsafe food from the food supply (Sheahan and Barrett, 2017). By contrast, a study in India reported rice showing signs of insect attack carried a price premium as it was taken as an indicator that the paddy was not freshly harvested and would taste better (Begum, 1991 cited by Wright, 1995). These examples highlight the importance of interaction and coordination between initiatives and a more holistic understanding of the whole interconnected agri-food system.

The rapid population growth and urbanisation occurring in SSA, the rise of the middle class (defined as those with purchasing power parity of 2 to 20 dollars a day (Ncube et al., 2011), and which is projected to reach 75% by 2040 (Tschirley et al., 2015)), and the growing consumption of food-away-from-home are also driving change in the agri-food systems. There are fears this will involve the consumption of more highly processed food, associated obesity, and unsustainable imports (USDA, 2013; Popkin, 2014), while hopes include demand for higher value and value-added agricultural products driving the creation of entrepreneurs and economic growth (Reardon et al., 2013; Badiane, 2014). Recent studies have found the share of dried legume and cereal grains in the diet reduces within the middle class, and the shares of fresh fruit, fresh fish, and eggs rise strongly, along with purchased maize meal replacing hand-pounded or custom-milled grain; and highly processed milk and vegetable oils and prepared food away from home rising sharply with income (Tschirley et al., 2015). This nutritional-transition will transform the agri-food system and very likely influence PHLs as diets diversify from staple roots, tubers, and grains to preferred cereals and increasing purchasing and consumption of more perishable dairy and meat products, vegetable oils, and fresh vegetables and fruits, which are known to have higher PHLs than cereal and pulses (Gustavsson et al., 2011). This will also come with environmental consequences, as many of these products are more land and water intensive to produce (Godfray and Garnett, 2014).

If PHLs are to be reduced by 50%, as per the Malabo and SDG 12.3 declarations, and make a serious and sustainable contribution to achieving food security in SSA, there is a need for: investment in deepening our understanding about and knowledge and awareness of the level, type, and reason for PHLs occurring along the value chain; institutionalised education of farmers and other stakeholders in postharvest management through practical hands-on learning opportunities (Hodges and Stathers, 2012) and ensuring postharvest management is woven into agricultural and agri-business curriculums; alongside supporting the promotion of appropriate and effective technologies and their distribution systems.

The APHLIS system has an important role to play in the postharvest system by providing science-based estimates of PHLs occurring at the different PH activity stages, for its focal crops by sub-national regions and years. These are useful to governments and development partners for informing investment decisions and tracking progress. Other crops can be incorporated into APHLIS if sufficient PHL figures exist in the scientific literature, and APHLIS could be expanded to cover other geographical regions, e.g., Asia or the Middle East. The APHLIS team are always looking for new, carefully measured PHL figures to incorporate into APHLIS to keep increasing its accuracy and relevancy; please contact us if you have or plan to gather such PHL figures from SSA for any of the cereal, legume, or root and tuber focal crops.

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Food fights for life: Food diplomacy for food security

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Abstract

Stored food production is critical to food security. Food security refers to the physical availability of, the economic and physical access to, and the ability to utilize food (FAO, 2008, available at; http://www.fao.org/docrep/013/al936e/al936e00.pdf). Stored food production is a vital link in that chain: enabling the protection of (surplus) harvest to be made available when needed. Indeed, the means of stored food production constitutes an incentive for (surplus) harvest itself. However, food, food security, and alongside both, food *diplomacy* are not only practical concerns and challenges but also political. Furthermore, the politics of food are intrinsically related to health security, water security, and climate security, issues with increasing effects across the globe if at different orders of magnitude. Food insecurity may be measured higher in arid regions without adequate water and harvests and storage, but it also exists in 'urban deserts' without affordable access to (fresh) produce. In this presentation, I outline a cartography to depict the interconnections between local and global food securities using the characterization of diplomacy *of* food and *for* food, and food science *for* diplomacy. The aim is to enhance exchange of ideas and experiences to benefit food security – and reduced waste – in both food secure and food insecure settings.