



Research article

The cost of postharvest losses in Ethiopia: economic and food security implications



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ABSTRACT

This research was designed to estimate the food security and economic burdens of postharvest losses of important food and cash crops produced in Ethiopia. Data of food production, food values and consumption patterns as well as the number of severely and moderately food insecure persons were obtained from FAOSTAT database for Ethiopia. The food security implications of the postharvest losses in the country showed that a volume of crops that could feed over 23 million citizens could be saved with proper postharvest management. The economic meaning of the losses of major food and cash crops was 1.2 billion US dollars per annum, which literally is 10% of the average annual national budget of the country for the years 2018–2022. If the losses could be managed to be lower by 50%, it could have meaningfully contributed to the food and nutrition security as well as the GDP of the country. The approach used in the current analysis could be either adopted to generate clear data for awareness creation community education or it could be developed into a more robust model to estimate annual losses or food security and economic gain potentials.

1. Introduction

Postharvest losses of food and cash crops are matters of great concern in the tropics, particularly in the sub-Saharan region. However, there have been limited actions taken to reduce the postharvest losses in the region, or not much information on the extent and impacts of postharvest losses (PHL) are well documented [1]. Reducing food losses could be a major contribution to satisfying higher global food demand and to improving food security and resource use efficiency in developing countries [2, 3, 4].

The rate of postharvest losses of different categories of foods is different depending on the nature of the foods, climatic conditions and postharvest management practices. Unprocessed foods can broadly be classified into two categories: perishables and durables. Foods with higher moisture and readily hydrolyzable nutrients (such as fats) are more likely to undergo postharvest losses that are manifested in the forms of weight losses, quality loss, value loss or multiple of these [5]. Those rapidly changing types of foods are categorized as perishables and are given special considerations in postharvest management [6]. Perishable foods include fruits, vegetables, roots, dairy products and meat, poultry, fish and other seafoods [7, 8]. Dry grains such as cereals and pulses are slow in their natural metabolic and biochemical changes (unless attacked by pests) and are termed as durables [9].

The proportions of postharvest losses of both perishables and durables are reported to be very high in the developing world, particularly in the sub-Saharan African region. Ethiopia is one of the developing countries in the region with the second-largest population in Africa, being affected by high postharvest losses of foods due to poor handling and market infrastructure at all stages along the value chain for almost all food crops [10], with missing or limited number of roads to farm gates, cold chain and proper packaging facilities. The factors associated with high levels of PHL of perishable crops were socio-demographic characters of the farming community, and the handling practices of the products [11], where income, education level and gender of the farming community, as well as limited private investment in the sector, are contributing factors. Crop-specific PHL data are also reported recently for the major horticultural crops in different pockets of production in Ethiopia [12, 13]. The PHL of the durable crops is high although, it sounds comparatively lower than those for perishables (Table 1). More quality losses due to aflatoxin contaminations are common in Ethiopia for grains, oilseeds and spices [14, 15]. The agricultural practices in Ethiopia are characterized by fragmented landholdings that are not suitable for mechanization with the quality of products being inconsistent. The inconsistency in raw food products makes them unfit for processing into commercial products with predictable quality characteristics. The extent of postharvest losses is too high and the experience of postharvest value

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Table 1. Major crops production, their market values and estimated postharvest loss.

Crops	Total Production tonnes (2009–2019)	8 yrs Average Price (USD/tonne)	Total Average Crop Values (USD)	PHL Percentages	References
Barley	21756828	323	7019187849	23%	Hengsdijk & Boer (2017) [2]
Dry Beans	6972425	468	3265326076	21%	FAO (2017) [21]
Dry Peas	3630513	527	1913861233	21%	FAO (2017) [21]
Maize	85418423	202	17234021024	15%	FAO (2017) [21]
Wheat	44424225	355	15776375024	14%	FAO (2017) [21]
Potatoes	8853026	160	1416307099	25%	Tadesse, Bakala, & Mariam (2018) [22]
Sorghum	47631641	278	13224448807	27%	FAO (2017) [21]
Sesame	2813782	969	2726470345	17%	Desale, Jema, & Bosena (2019) [23]

PHL = postharvest loss; USD = United States' Dollar [currency]; FAO = Food and Agricultural Organization of the United Nations.

addition to crops is non-existent, where parts of the crops such as pulses and oilseeds are exported raw, fetching very low return to the farmers [16]. The volume of some of the major food and cash crops produced in Ethiopia are documented in literature as one of the highest, but there is still less attention given to the challenge. The objective of this study was to analyze the impact of postharvest losses of major food security and cash crops in terms of dollar value and food security potentials.

2. Materials and methods

2.1. Data sources

The production data for top food and cash crops in Ethiopia were obtained from the FAOSTAT [17]. Ten consecutive years (2009–2019) of crop production were used for data analyses. Data from FASTAT has limitations in accuracy, particularly from developing countries as they are rough estimations based on national reports by governments. Data used in this research were obtained only from the same sources and were used as such just to show estimated economic and food security pressures that could be relieved if the PHL is better controlled for the major crops. In this sense, the accuracy of the data is outweighed by the important information generated for awareness creation for policy-level interventions and further modeling research for better handling of the PHL issues in developing countries.

Postharvest loss data were obtained from literature and FAO estimation reports for the different crops (cereals: barley, maize, wheat, sorghum; pulses: dry beans and peas; tubers: potato, and oilseeds: sesame) were included in the research based on the availability of production, dollar value and consumption per capita data in the FAOSTAT database (Table 1). The dollar values of the crops for the selected production years have also been obtained from FAOSTAT [18]. The trends of population growth in Ethiopia were also obtained from World Bank Country Information for Ethiopia for the specified years considered in this analysis [19]. The food security indicators of the Ethiopian population - the number of severely as well as severely and moderately food insecure persons (million) were also obtained from FAOSTAT data-base [20].

2.2. Estimated volume of postharvest losses

The estimated postharvest loss of each crop was computed as the percentage of the total crop produced each year. The total volume of lost crops was then estimated by taking the summation of losses over the 10 years (equation 1).

$$\sum_{y=1}^{10} (X_i) \quad \text{Eq. (1)}$$

where X_i = total production of each crop.

2.3. Dollar values of postharvest losses in Ethiopia

The dollar value of each crop and the total postharvest loss of the 10 years was computed by multiplying the total loss of each crop by its market values of every year as shown in Eq. (2) below. The monetary value of the postharvest loss during the last decade was used to discuss the equivalence of development expenditures in the country during the same period.

$$\sum_{y=1}^{10} (X_i \times P_j) \quad \text{Eq. (2)}$$

where X_i = total production of each crop; P_j = percentage of postharvest loss for each crop.

The production and postharvest loss volume estimates were presented as a graph and discussed in terms of food security potentials of the losses if part of it could be saved. The monetary value equivalences of the PHL of the selected crops for the specified period were discussed in terms of community development investments and national gross domestic products (GDP).

2.4. Per capita consumption of cereals and pulses in Ethiopia

The per capita food consumption of Ethiopians (cereals, pulses and roots) were obtained from the FAOSTAT food balance database as an average of three consecutive years (2011–2013) [24]. The three years average per capita consumption data (kg/person/year) was about 150, 18 and 75 for cereals, pulses and starchy roots, respectively. The sum of the cereals and pulses (168 kg/person/year) was used to estimate the minimum number of people (millions) who could be fed to avoid severe and moderate food insecurity levels (Figure 1 [A]) if at most 50% of the PHL could be saved. Eq. (3) was used to make a rough estimation of the number of potential food secured persons if just 50% of the PHL could be managed:

$$PFS \text{ (million persons)} = \frac{\text{total PHL} \times 0.5 \text{ (tonnes)} \times 1000}{PCGC \text{ (kg/person/year)}} \quad \text{Eq. (3)}$$

where: PFS stands for potential food security; PHL is postharvest losses; 0.5 represents 50% reduction in PHL; 1000 is a conversion factor from tonnes to kilograms and PCGC stands for per capita grains consumption (168 kg/person/year).

3. Results and discussions

3.1. Highlights of postharvest losses in Ethiopia

The total production volume of cereal food crops in Ethiopia between 2009 and 2019, was 21,756,828 tonnes for barley; 85,418,423 tonnes for maize, 44,424,225 tonnes for wheat and 47,631,641 tonnes for sorghum (Table 1), making up a total major cereals production of 199,231,117

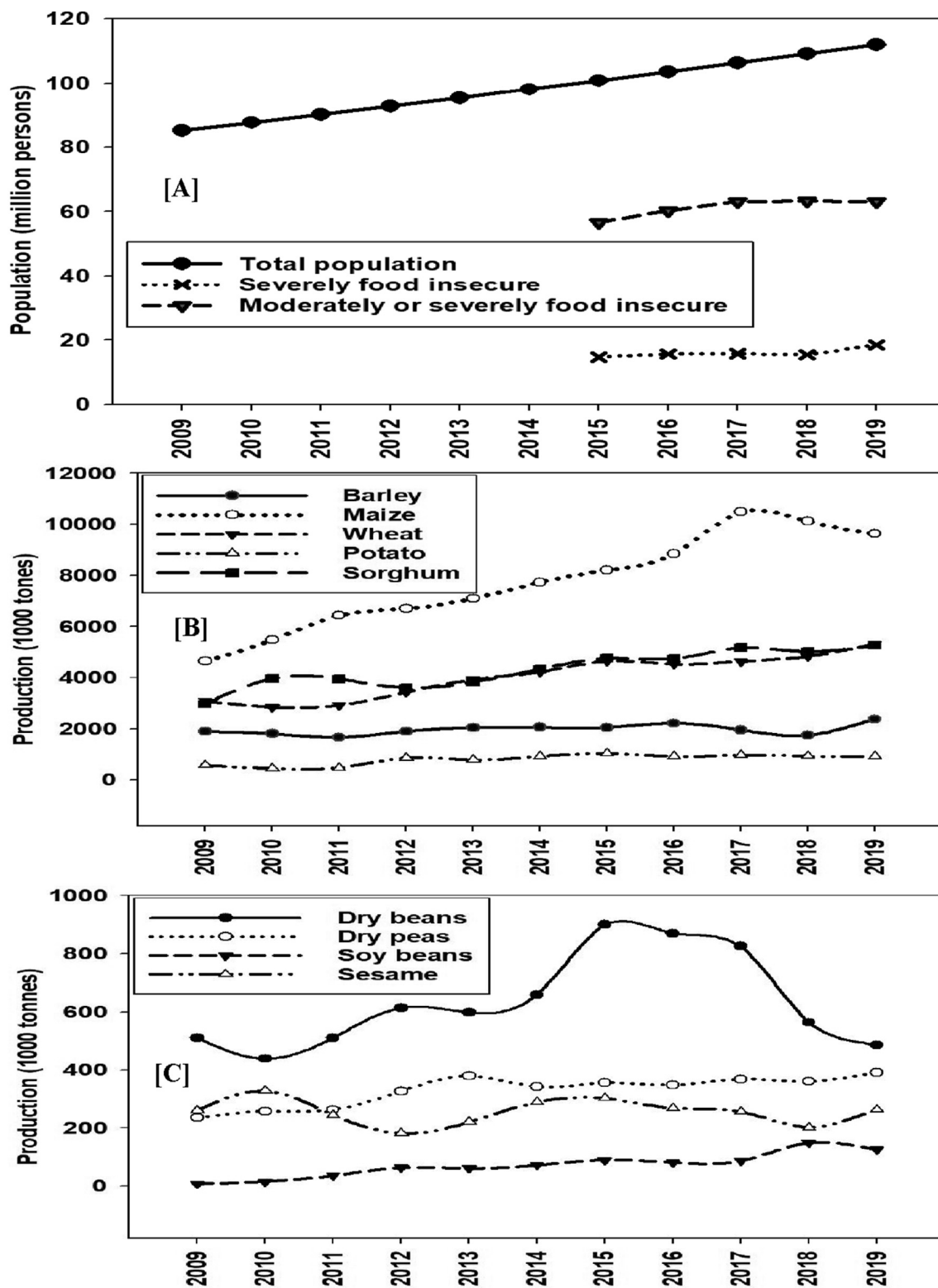


Figure 1. Trends of population growth [A] and production of selected crops [B & C] in Ethiopia over the last 10 years (2009–2019).

tonnes over the 10 years [17]. Out of the reported estimate production, postharvest losses (PHL) of 23% for barley [2], 15% for maize [21], 14% for wheat [21] and 27% for sorghum [21], were reported. The PHL volumes (tonnes) were 5,004,070 for barley, 12,812,764 for maize, 6,219,392 for wheat and 12,860,543 for sorghum; totaling to 36,896,769 tonnes of cereal grains over the 10 years.

Looking at the major pulses (dried beans and peas), a total (tonnes) of 6,972,425 dried beans and 3,630,513 dried peas were produced for the 10 years covered in this investigation [17]. The total rate of postharvest loss for the two pulse grains was 21% [21], which were estimated to be 1,464,209 and 762,408 tonnes for dried beans and peas respectively, giving 2,226,617 tonnes of PHL for major pulses. Irish potato is the major



Figure 2. The whole vicious circle of fragmented production from plots of smallholder farmers with inconsistent quality; not fit for processing; high PHL, food insecurity and economic burdens in Ethiopia.

tuber crop staple produced in Ethiopian farming systems that plays a great role in the achievement of food security programs due to its plasticity to environmental conditions and yielding capacity [25, 26]. The total production for the periods considered in this research was 8,853,026 tonnes out of which 24.89% (2,203,518 tonnes) were lost after harvest as reported by Tadesse, Bakala, & Mariam (2018) [22].

Sesame is among the most valuable cash crops for Ethiopian smallholder farmers' economy and livelihood [27]. Sesame was included in this investigation as it is one of the major high-value crops compared to many other food grains (Table 1). The total production of sesame over the 10 years selected for this research was 2,813,782 tonnes as estimated by [17]. The PHL level for sesame is about 17% as reported by Desale, Jema, & Bosena (2019) [23], which results in a total volume loss of 478,343 tonnes of this highly valuable crop.

The trends of production of the different categories of foods are presented in Figure 1. The increase in the production of cereals (Figure 1 [B]), as well as that of pulses and sesame (Figure 1 [C]), was not keeping pace with the national population growth (Figure 1 [A]), which keeps widening the national food security gap regardless of efforts being made. Of course, feeding humanity into the future is expected to remain one of the global grand challenges [28]. High postharvest loss percentages presented in this analysis (Table 1 and Figure 2), add to the food security challenges, and the detailed food security implications of PLH in Ethiopia is discussed in the next section (3.2.). One of the contributing factors to the high magnitudes of PHL in the tropics is a lack awareness and policy focuses by governments and scientists [29, 30].

3.2. Postharvest losses and food security

It is obvious that the extent of PHL in Ethiopia is high that greatly impacts the food security of a significant proportion of the population. Considering only the staple crops (cereals and pulses), a great deal of food security potential and opportunities are missed due to the high rates of PHL in the country. Eq. (3) was used to estimate the number of people who could be fed if only 50% of the PHL of grains could have been saved. Taking the total volume of PHL in grains (cereals and pulses), which was

39,123,386 tonnes or 39,123,385,440 kg of grains, which is about 3,912,338,544 kg every year between 2009 and 2019.

A five years (2015–2019) average number of severely and moderately food insecure persons in Ethiopia (Figure 1 [A]) is estimated to be 61 million [20]. It is recalled that the Ethiopian per capita consumption of grains is 168 kg/person/year (section 2.4 [24]). By dividing the total estimated average annual PHL of grains over the ten years by the per capital grains consumption (eq. 3), we obtain the potential food security impact of the losses after harvest, which is feeding 23,458,502 persons every year between the specified study period. This means that Ethiopia could reduce the number of severely and moderately food insecure persons from 61.36 to 37,901,498 persons, which is a 38.23% improvement in food security. To be very practical, 100% PHL management may not be realistic and if only 50% of the PHL in grains in Ethiopia could be saved, 11,729,251 persons could be fed up to the national grain per capita consumption, which is almost 20% improvement in national food security. Taking the experiences of other countries, it is estimated that grain postharvest losses could be reduced to 2% (98% saving [31]), which could greatly contribute to national, regional and global food security.

It is important to consider that the analysis of the food security potential of the lost food crops in Ethiopia is less than the actual figures as fruits, vegetables and animal products are excluded due mainly to lack of reliable data on the production, consumption and market values of the left-out commodities for the selected study periods. This is to imply that the actually missed opportunity in terms of food security with respect to the lost crops, is higher than the estimations made in this report. This is also exacerbated by the even higher PHL rates of the fruits, vegetables and animal source foods due to their high perishability.

The major challenge in Ethiopia is the lack of value addition to the vast majority of agricultural commodities as a strategy of PHL reduction. This is attributed to the limited development of agro-food processing sectors in the country, which is also partly due to the inferior quality and inconsistent properties of the agricultural raw materials, which obviously presents a vicious circle of poor production and post value additions (Figure 2). However, the scenario could potentially change if the necessary attention is given and transformative policy level measures are taken.

3.3. Economic and development implications of postharvest losses

Postharvest losses of both food and cash crops present a significant economic burden on the population being affected [32]. The economic losses associated with the PHL of food and cash crops over the ten years selected for this investigation were estimated in terms of dollar losses based on the crop values obtained from FAOSTAT data from 2009 to 2019 [20]. For the 10 years considered in this analysis, the major crops in

terms of both volumes of production and losses (Figure 3 [A]) as well as postharvest value losses (Figure 3 [B & C]) are maize, wheat and sorghum for cereals and dry beans and sesame in terms of pulses and cash crops. Over the 10 years, Ethiopia lost a total of 11,882,458,171 USD, which translates to around 1.2 billion USD monetary loss per annum. The annual budget of three consecutive years (2018/19 through 2021/22) of the government of Ethiopia is 12, 14 and 13 billion USD (Reuters, 2021, 2019), which gives an average of 13 billion USD. The economic loss

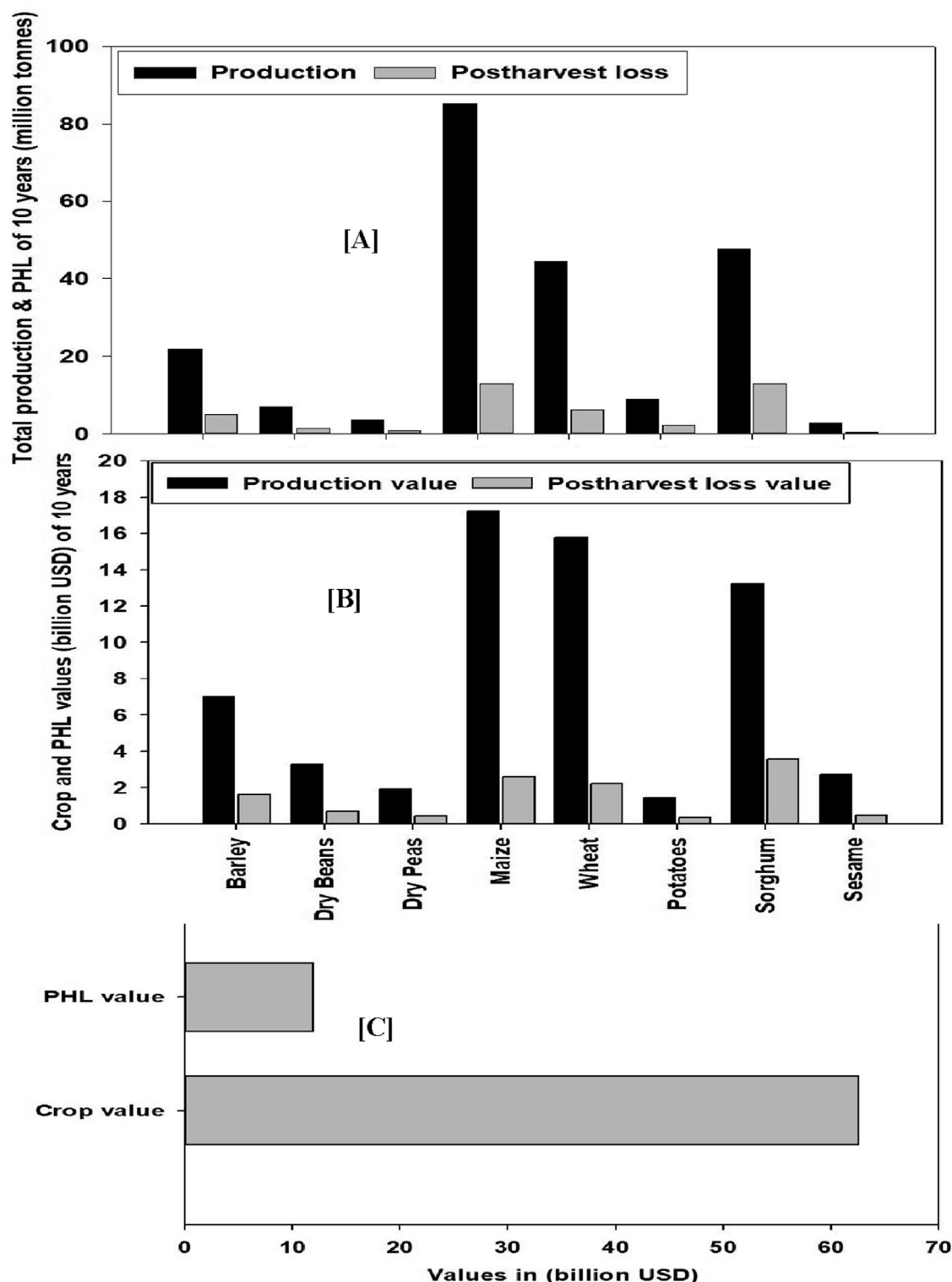


Figure 3. The cost of postharvest losses of major food and cash crops in Ethiopia in terms of volume [A] and value estimations [B & C].

experienced by Ethiopia between 2009 and 2019 (12 USD) was fairly comparable to the annual budget of the country in recent years. The 1.2 billion annual economic loss in Ethiopia, mainly attributed to the PHL of only selected major food and cash crops, is roughly 10% of the national annual budget, which is one of the highest in the tropics. Of course, saving 100% of PHL of all crops is unrealistic, specifically in the tropics and sub-Saharan Africa, but saving up to 50% of the losses can be achieved and could greatly contribute to the national economic progress.

It is worth noting that this estimation excluded major cash crops such as coffee and oilseeds, which are the backbone of the Ethiopian economy [35, 36]. The economic loss estimation of PHL in Ethiopia considered in this analysis did not include fresh horticultural produces (fresh flowers, chilled or dried vegetables) because of the lack of accurate data. This implies that the estimated burden of PHL in this article is the minimum and the actual challenge can be bigger. However, the information generated is insightful and should be used to aware the public, government offices and can be used to dictate policies and strategies for addressing the challenge better through policies that support private investments in postharvest management (PHM). Policies can support infrastructural developments that include cold chains, hermetic storage facilities, hygienic handling practices (proper packaging) in the form of tax waivers, and directing financial institutions to avail loan options for such investments.

The low attention given to the PHL issue of the country might be due to lacks of awareness and information generated by in-depth analysis of the challenge in terms of the economic and food security burdens it is posing on the national economy. The lack of awareness among producers, value chain actors and consumers on postharvest losses of durable crops (grains) was reported in the literature. The lack of awareness among the major players of the crop value chains was indicated in PHL assessments of rice in Ghana [37] and Sri Lanka [38] as well as PHL studies on maize in Kenya [39] and Tanzania [40]. The PHL of perishable horticultural crops are by far higher than those of durable grains and the associated nutritional and economic burdens are obviously higher and more impactful. But the awareness gaps are also reportedly high as reported in recent literature in different parts of the globe including Ethiopia [13, 41, 42, 43, 44]. It seems that it is about time to break the high and globally prevalent awareness gaps on the economic, food and nutrition security impacts of PHL. It is also apparent that governments particularly in the developing tropical and sub-tropical regions are capacitated with information and awareness as well as global cooperative research and development projects to help them able start a programmatic effort towards reducing PHL of crops with high economic and nutritional values. It is also important that the new global initiative, the United Nations Food Systems [45, 46], and programs to be developed and implemented in the future includes PHL in focus among other things that should be prioritized [47, 48].

This approach of monetizing the extents of PHL in crops of high economic and food security values is the first of its kind with the potential to be adopted to other countries and even regions as deemed necessary. Data on crop production, dollar values of the major crops, and consumption patterns, for which data are available in the global repositories such as FAOSTAT or national data sources and indicators of the World Bank Groups can be used to get estimated data for analysis. The economic implications of postharvest losses are reported for certain grain crops [32] and fruits and vegetables [49] in India, although not as comprehensive and multidimensional as the present study. This approach has also the potential to be developed into simple predictive models and indices for future estimations and routine reporting.

3.4. Efforts by Ethiopian government in PHL reduction

The Ethiopian government recognized the burden of PHL to be about 1.16 billion USD in the form of grains import since 2010 [50], an initiative that was recently adopted in the East African region [51] and at

the African Union level [50]. Ethiopia worked on designing strategies to address PHL in the different categories of crops and a PHL reduction policy strategy was devised for durable crops (cereals, pulses and oilseeds) since 2018 [52]. It is expected that strategic approaches would follow soon for the perishable crops (fruits, vegetables and animal source foods). In implementing the policies and strategies, the government of Ethiopia has organized an agency called Industrial Parks Development Agency (IPDA) that follows up and supports agro-processing and value addition investments. The government constructed infrastructures in multiple agricultural regions (Bure in Amahara; Bulbula, Robe and Jimma in Oromia; Hawassa and Yirgalem in Sidama) [53]. The government of Ethiopia is working to reduce the PHL of food crops, but the pace and levels of commitment don't seem to be enough for the severity and urgency of the matter.

3.5. Ways forward

Reduction of food losses along the supply chain is among the targets set in the global development goals (SGD 12.3), which is particularly important in the sub-Saharan Africa Region [54, 55]. Ethiopia and other sub-Saharan African Nations should recognize that the post-harvest losses of crops are an important challenge that deserves due attention. The Ethiopian government should formulate policies that support PHM infrastructures by waiving taxes for input imports and also strengthening clustered farming approaches for small holdings of lands to enable agricultural mechanizations. Policy directions on raising public awareness on the impacts of PHL on the national economy and food security dimensions should be spearheaded by the government of Ethiopia, with pooled efforts of local and international partners running development projects. National infrastructural development policies focusing on connecting farms to markets road constructions should be devised, rather than the traditional towns to city and city to city tying.

Other tropical countries may need to devise a programmatic approach towards making significant efforts to make progress in reducing post-harvest losses coupled with efforts of ensuring food security and sustainable economic development. Ethiopia is also challenged by the large proportion of youth unemployment [56], in addition to high rates of PHL and food insecurity. However, a comprehensive multilevel solution may be thought of to create small-scale enterprises focusing on postharvest value addition of food and other agricultural productions as employment opportunities for the youth. Integrated policy efforts with reduction of PHL can solve multiple problems with expected synergistic effects on the national economy and household food security. Similar mechanisms could be devised in many other countries, which in total sum contributes to the availability of more foods at the global level. More innovative ways could be designed to meet national growth plans and sustainable development goals at the global level.

4. Take-home messages and recommendations

The 10 years analysis revealed that PHL is among factors contributing to food insecurity and economic loss in Ethiopia, resulting in losses of foods that could feed over 23 million citizens per annum. In other words, the extent of PHL in Ethiopia can be expressed as economic losses amounting to 10% of the country's annual budget, which could have greatly contributed to the GDP every year. It is implied from the analysis given in this article that Ethiopia and other nations in the tropics redirect their policies towards sustainable infrastructure development that helps in maintaining the qualities of fresh agricultural products with added values for better economic and food security outcomes. Policies that support investments in cold chain and hermetic packaging and storage are of paramount importance. The PHL estimation reported here is the minimum losses as the highly perishable horticultural crops (fruits, vegetables, herbs) and animal-based foods (meat, fish, poultry and dairy

products) have been excluded due to lack of reliable data for analysis, implying that the real loss can be way bigger.

Declarations

Author contribution statement

Tadesse Fikre Teferre: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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