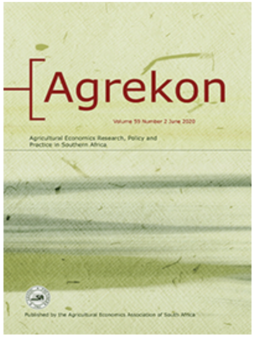


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# Postharvest losses at the farm level and its economy-wide costs: the case of the maize sector in Mozambique

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**ABSTRACT**

With increasing population and demand for food, reducing food loss and waste is one of the greatest challenges worldwide. Current estimates point to over 1 billion tons of food lost and wasted worldwide, though nearly 10 percent of the global population is suffering from undernourishment and food insecurity. In Mozambique, about one-quarter of the population suffers from undernourishment and food insecurity. Estimates from FAO point to postharvest losses of maize in Mozambique at about 3.69 to 7.92 percent; this is less than one-fifth of the on-farm losses reported by other authors. In this study, an Equilibrium Displacement model is used to assess the economy-wide impact of postharvest losses of maize at the farm level. The impact of a 3 percent postharvest loss is tested. Results suggest that even this very conservative percentage of postharvest losses has a direct annual net cost of around $USD 28 million for both farmers and consumers domestically. This is equivalent to over 1 percent of the national budget. It is also higher than the average cost of food aid programs received over the last three years. Therefore, reducing postharvest losses of maize along with other interventions is crucial to achieve sustainable development and economic growth.

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**JEL CLASSIFICATION**
Q11; Q13; Q18

## 1. Introduction

With a total population of about 29 million people (INE 2017), agriculture is a dominant activity in Mozambique. Data from the Ministry of Work, Employment and Social Safety (MITESS 2016) suggest that the majority of Mozambicans (around 78%) rely on agriculture as their main economic activity. Likewise, this sector makes a major contribution to the country's economy, contributing about one-quarter of Mozambique's total Gross Domestic Product (GDP) (World Bank 2018a).

Despite its large contribution to GDP, agriculture still remains poorly developed in the country. Nearly 4.2 million out of the 4.3 million farmers are still operating at a small-scale level, with farmers cultivating on average less than 1.5 hectares each (Magaua 2012; MASA 2015). In addition, their production system is mostly based on rain-fed conditions with farmers still relying on traditional agricultural techniques with limited use and access to improved agricultural inputs (seeds, fertilisers, pesticides) and machinery (Magaua 2012; MASA 2015; World Bank 2012). For instance, data reported by MASA (2015) shows that between 2012 and 2014 less than 6% of all small and medium-scale holdings have used fertilisers and pesticides, and only 2.9%[1] have used improved (certified) seeds. These data mirror the profile of the small-scale farmers, who are mostly subsistence-oriented.

Overall, nearly 95% of the total agricultural output in the country is produced by small-scale farmers (MASA 2011). For the majority of these farmers, maize is the most important crop produced.

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It is estimated that about 80% of the small-scale farmers cultivate maize, and maize production accounts for around 80% of the total cereals production in the country (Magaua 2012; MASA 2011, 2015; World Bank 2012). However, the country is not self-sufficient in maize (nor in many other agricultural commodities), which results in Mozambique being a net food importer. Data from the United States Department of Agriculture (USDA 2018) and the United Nations trade database (UN COMTRADE 2018) show that maize imports account on average (2008–2017) for over 7% of Mozambique's total consumption of this cereal, valued at more than USD 27 million per year.

Within the Southern Africa region, Mozambique's production level of maize is amongst the lowest. Over the last 10 years (2008–2017) domestic production was on average around 1.7 million tons/year and yield about 1.0 ton/ha (USDA 2018). This is very low compared to the productivity levels of neighbouring countries such as South Africa, Malawi and Zambia. Data from the Regional Network of Agricultural Policy Research Institutes (ReNAPRI 2015) as well as USDA (2018) show that in the last few years maize productivity in South Africa has been around 4 tons/ha, whilst in Malawi and Zambia it has been at least twice the productivity in Mozambique.

Apart from the traditional production technologies in place, several other factors add to the country's poor overall agricultural performance. Firstly, poor marketing infrastructure limits farmers from trading their produce through formal channels (World Bank 2012). Accordingly, MASA (2011) notes that less than 10% of farmers usually trade their maize. Although the country has to rely on imports to satisfy the local demand, evidence from the field suggests that informal exports of maize from Mozambique (mainly from the North and Centre regions) to neighbouring countries (Malawi, mainly) have been considerable (ReNAPRI 2015; FAO 2014).

Secondly, climate conditions have been impacting negatively on Mozambique's agricultural production. Within the Southern Africa region, the country is considered historically as the one most affected by natural hazards and, worldwide, it is ranked fifth for its vulnerability to climate changes according to the vulnerability index as referred to by the (former) Ministry for Coordination of Environmental Affairs (MICOA 2005, 2013). Frequent major weather events such as cyclones, droughts and floods have been impacting negatively on farmers' outcomes, including maize yields. For instance, over the 45 years to 2005, the country was affected by at least 53 major natural hazards (MICOA 2005).

Finally, poor postharvest management practices lead to reduced availability of maize in the country. Over the 14 years up to 2013, estimates from FAO (2018a) point to postharvest losses (PHL) on maize in Mozambique ranging from 3.69–7.92% of the total production. However, evidence from other authors suggest that maize losses are much higher at the farm level – reaching more than 5 times the estimates from FAO – as a result of poor on-farm grain drying processes and farmers' poor storage facilities (Cugala et al. 2012; Hugo 2008). Past Government interventions to reverse the losses of maize include programmes aimed to improve farmers' storage capabilities through the promotion of improved silos to farmers and training of local artisans to make metal silos (Coulter and Schneider 2004). Nonetheless, such actions failed to address sustainability, mainly due "*to lack of long-term commitment, consistent monitoring and follow-up, and coherent approach to sharing of knowledge and experiences*" (Cugala et al. 2012, 23).

The issue of food wastage, however, is of global concern. The most recent estimates point to over 820 million people (nearly 10% of the population) suffering from undernourishment and food insecurity worldwide (FAO et al. 2018). In Sub-Saharan Africa this is relatively worse, where between 2015 and 2017 the population suffering from undernourishment and severe food insecurity increased from over 25% to nearly 34% (FAO et al. 2018; WFP 2015). Mozambique is no exception, with about one-quarter of the population suffering from this issue (GoM 2015; World Bank 2018b). Nevertheless, limited attention has been given by the Government to address food waste in general and PHL in particular. The literature on the economic impact of food loss and waste is also scarce in the country.

This study aims to assess the economy-wide impact of maize losses at the farm level in Mozambique. The main contribution of this study is the increased awareness of the economic implications of food losses for the major stakeholders in the maize value chain in Mozambique.

## 2. Drivers of food loss at the farm level in Mozambique

Global concerns with food loss and waste are long standing (Parfitt, Barthel, and Macnaughton 2010). However, after many years the definition of food loss and waste is not yet universal. In this study the term food loss is used in accordance to the FAO[2] definition.

Overall, several driving factors of food loss and waste can be identified. From the nature of the product (e.g., perishability), technologies in use, to organisational and political inefficiencies along the supply chain as well as social factors including consumers' expectations and individuals' behaviour (Canali et al. 2014). Other factors may include demography related drivers (such as population density, elderly dependency and immigration ratios and gender dominance), dietary transitions (mainly for higher income consumers), increased food price and inflation, as well as quality competition from international trade (Cerciello, Agovino, and Garofalo 2018; Parfitt, Barthel, and Macnaughton 2010; Segré et al. 2014).

In the case of the maize sector in Mozambique, food loss at the farm level seems to be driven mainly by technology and supply chain inefficiencies. Usually, at the postharvest stage, maize farmers store "*their produce on the floor, or in traditional storage basket, open granaries, calabashes, earthen pots, normal woven bags, or in traditionally raised cylindrical or conical granaries*" (Cugala et al. 2012, 8, 9), which enhances the odds of pest and disease occurrence. In addition, marketing barriers such as excessive transportation costs that limit trade between the surplus (North and Centre) and deficit (South) regions are also important to explain food loss. As some studies suggest, due to inefficiencies (infrequent and poor quality of services), transporting a container from the North to the South of Mozambique is over two times more expensive than the transportation costs of the same container from Guangzhou (China) or Dubai (United Arab Emirates) (Coughlin 2006). As a strategy to minimise food loss, farmers usually sell their produce immediately after harvest, at the risk of facing hunger in periods of food scarcity (Cugala et al. 2012).

Maize farmers (and traders) from the North and Centre of Mozambique usually engage in informal trade across the border regions. Between 2005 and 2015[3], for instance, the Famine Early Warning System Network (FEWSNET 2018) reported informal exports ranging from 19,000–78,000 tons from the surplus regions to countries in the neighbourhood, mainly to Malawi (more than 90%). Conversely, the South – often a deficit region due to unfavourable conditions for agricultural production – relies on maize imports mostly from South Africa. Average (2008–2017) imports account for over 7% of the total domestic demand for maize, valued at more than USD 27 million per year (UN COMTRADE 2018; USDA 2018).

The differences in the maize value chains between the two regions are represented in Figure 1. Whilst the maize milling industry in the South is strongly reliant on maize imports, in the Central and Northern regions most of the maize processed by the industry is supplied locally. Overall, compared to the South, farmers from these regions also benefit the most from seed and other agricultural aid programmes by the Government and donors. Figure 1 is drawn based on a review of relevant literature, with some emphasis given to the Mozambique's Commodity Exchange ("*Bolsa de Mercadorias de Moçambique*", BMM) as an emerging governmental institution playing the role as an assembler. This institution (created in late 2012) provides storage and quality assurance services for its customers, ensuring at the same time an important linkage between sellers (farmers and private assemblers) and buyers (BMM 2016). However, the effectiveness of BMM is not yet perceived, as very few farmers actually rely on the services provided.

## 3. Methods

To assess the economy-wide impact of food loss in the maize sector at the farm level in Mozambique, an equilibrium displacement model (EDM) is used. This EDM assumes a multiple horizontal market scenario as described later.

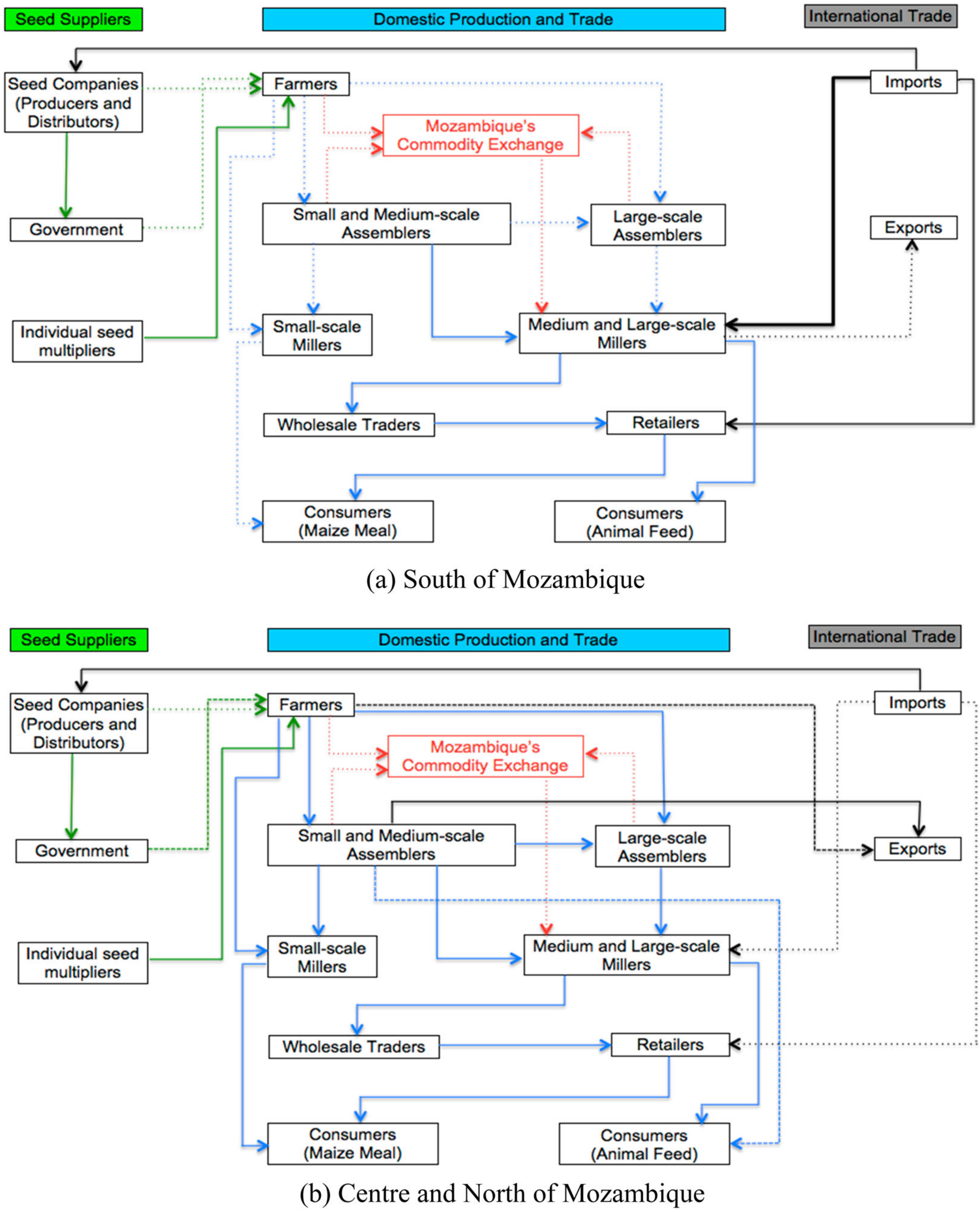



**Figure 1.** Maize value chain in the deficit (a) and surplus (b) regions of Mozambique.

EDMs and general equilibrium models are widely used in studies of this nature, to assess the economic impact of technology, policy or other changes in a particular country or region context. The major advantage of these models over the classic econometric approaches is their lesser demand for data (Alston, Norton, and Pardey 1995; Zhao et al. 2000). As Alston, Norton, and Pardey (1995) point out, the general equilibrium model and EDM have many aspects in common, and the major difference between them relies on the *mutatis mutandis* and *ceteris paribus* assumptions. Whilst at its extreme the general equilibrium model is defined to allow for the endogeneity of every variable to capture their spill-over effects to the wide economy, EDM is a simplification of it that limits the endogeneity assumption for a particular set of variables (generally price and quantity) in the specific market of interest (Alston, Norton, and Pardey 1995; Francois and Keith Hall 1998). However, as suggested by Alston, Norton, and Pardey (1995), *mutatis mutandis* is a very strong assumption so that even in the general equilibrium model few variables are often taken as exogenous.

Overall, the applied general equilibrium model (also called computable general equilibrium, CGE) is quite demanding in data and computation compared to EDM, mainly for the number of variables (and parameters) included for capturing the spill-over effects to the wide economy (Alston, Norton, and Pardey 1995; André, Alejandro Cardenete, and Romero 2010; Wing 2004). In contrast, EDM, which is based on the Marshallian demand and supply framework for a comparative statics approach, allows a more transparent and rapid analysis to assess the impact of changes in a single (or very limited number of) commodity market(s) (Alston, Norton, and Pardey 1995; Francois and Keith Hall 1998). There have been many applications of this model for the agricultural sector (Alston, Norton, and Pardey 1995; Pathiraja 2016; Zhao et al. 2000). Recently, Li et al. (2017) have used EDM for the Australian grain industry to assess the returns to investments in research and development. However, the current study is amongst only a few that relies on EDM to assess the economic impacts of food loss.

EDM is based on economic surplus measurement to assess the impact of changes to social welfare. Accuracy of results from this model is strongly and inversely related to the magnitude of the induced (supply or demand) shift tested. Usually, outcomes from EDM are valuable when "*measuring the displacement effects of small* [up to 10 percent] *finite changes in exogenous variables*" (Piggott 1992, 133).

In the case of the maize value chain in Mozambique, multiple markets need to be specified. Usually, the North and Centre, which display better agro-ecological conditions for agricultural production, are maize surplus regions whilst the South is frequently deficit for this cereal. In addition, import and export markets are also identified. Thus, impacts of food loss – even at the farm level in the domestic market – are distributed to all the actors involved in the four markets.

The simplified EDM proposed for the maize value chain in Mozambique is represented in Figure 2, taking into account these four markets. The rectangular boxes in this figure represent each market, and the arrows display the maize grain flow. Though in much of the country maize is consumed at the household level by farmers themselves – only 10% of the farmers actually sell their maize (MASA 2011) – the surplus market often supplies almost all the maize demanded by the local industry in the central and northern regions. In addition, (informal) exports to neighbour countries such as

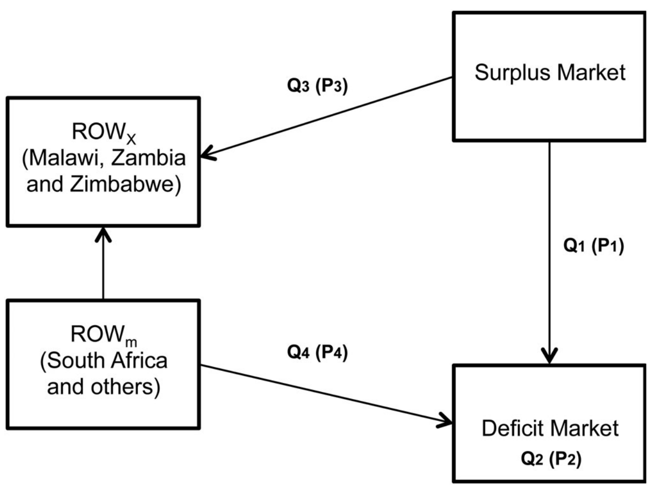



**Figure 2.** Simplified EDM framework for the maize grain sector in Mozambique.

Malawi, Zambia and Zimbabwe are also frequent from this market. For years Malawi has been the main export market, accounting for over 90% of the total maize exported. Conversely, the deficit market relies on maize imports mostly from South Africa due to the cost-efficiency of trade (World Bank 2012). Overall, South African maize prices are more competitive than prices in the surplus market to demanders from the South, particularly if distance and transport costs are accounted for (see Figure 3).

The EDM proposed below is implemented using the Dynamic Research Evaluation for Management (DREAM) software developed by the International Food Policy Research Institute (IFPRI). The variables (and parameters) used in this model are described in Table 1.

Food loss and waste already occurs in the Mozambique maize market, so the prices and quantities that are used to describe the market already have the impact of food loss and waste embedded in there. The current situation represents the "with" loss scenario. The ideal situation is the "without" scenario. Therefore, the impact of food loss at the primary production level for maize in Mozambique is assessed as an outward shift in the supply curve for the surplus market, since it is the most important maize production region. An outward shift is assumed to represent the desired scenario without food loss. The difference between the desired and actual (with food loss) scenarios is the cost of food loss under this EDM approach. The base (actual) scenario is described in Table 2, and the impact of a 3% ($k = 3\%$) of food loss – the minimum percentage of PHL reported by FAO (2018a) – is tested as an increased percentage on maize yield. The resulting relative changes in prices from the supply shift tested are 10% ($K = 10\%$). This allows the measurement of the foregone surplus due to food loss.

### 3.1. Data

As stated earlier, one of the major advantages of EDM over other methods to assess the economic impact of changes is the relatively lower demand for data. Data on prices, quantities and elasticity, along with some assumptions on induced supply shifts, are sufficient to implement the model. In the case of Mozambique, where access to and availability of data is an issue, models with low demand for data are desirable.

Available data for this study includes information from the food balance sheets by FAO and USDA, which are aggregated at a national scale. Disaggregated data on maize production per region of the country are only available for few years (2012, 2014 and 2015) from the Ministry of Agriculture and Food Security (MASA). The data from MASA and evidence from FAO (2014) suggest that the South

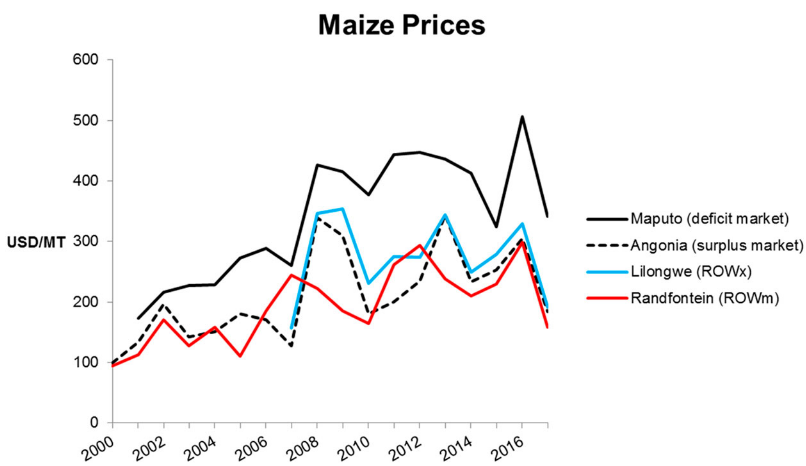



**Figure 3.** Nominal retail prices of maize in Mozambique and Malawi, and wholesale prices in South Africa. Source: Data from FAO (2018b) and MASA.

**Table 1.** Definitions of variables and parameters in the model.

| | |
|---|---|
| *Endogenous variables* | |
| $Q$ | Total quantity of maize consumed domestically |
| $Q_1$ | Quantity of maize supplied from the surplus market |
| $Q_2$ | Quantity of maize supplied from the deficit market |
| $Q_3$ | Quantity of maize exported |
| $Q_4$ | Quantity of maize imported |
| $P_1$ | Farm gate price of maize in the surplus market |
| $P_2$ | Farm gate price of maize in the deficit market |
| $P_3$ | Retail price of maize in the export market |
| *Exogenous variables* | |
| $P_4$ | Import parity price of maize |
| $K$ | Net supply shifter |
| *Parameters* | |
| $\eta_i$ | Elasticity of demand for maize in market $i$ ($i = 1,2,3$) |
| $\varepsilon_i$ | Elasticity of supply of maize from market $i$ ($i = 1,2,4$). |
| $S_i$ | Price transmission efficiency across markets |

region (deficit market) contributes consistently to around 10% of the total maize production. This information is then used to disaggregate data on maize production available from the food balance sheets. Data on maize consumption is also treated similarly, where consumption per capita – estimated based on the population annual growth rate computed from the disaggregated data (at provincial level) for the last three population census (1997, 2007, 2017) reported by the National Institute of Statistics (INE 2018) – is used to compute the annual total consumption per market (surplus and deficit).

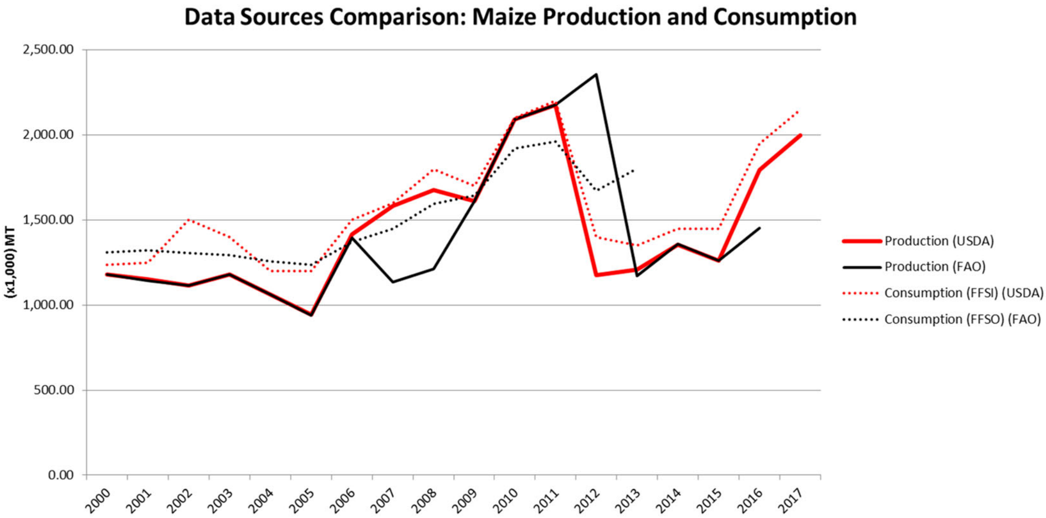
FAO and USDA food balance sheets data display some inconsistencies, as shown in Figure 4. With some exceptions for production, data on other variables differ considerably for every year reported. In Figure 4(a), consumption is estimated as the sum of maize uses reported in each balance sheet: feed, food, seed and industry (FFSI) uses for USDA; and feed, food, seed and other (FFSO) uses for FAO. Though food losses are reported in the FAO food balance sheet, it is not accounted for consumption in Figure 4(a). Food loss reported by FAO (2018a) accounts to 3.69–7.92% of the total production, however, it is worth noting that it is well below the estimates of PHL reported at the farm level by other authors (Cugala et al. 2012; Hugo 2008). FAO estimates of food loss, which is considered in this study, accounts to losses "*at all stages between the level at which production is recorded and the household, i.e., storage and transportation*" (FAO 2019).

As shown in Figure 4(b), the inconsistencies are extended to international trade (import and export) data reported from other sources. These inconsistencies point to the need to consider multiple data sources, and adjustments to balance total supply and demand.

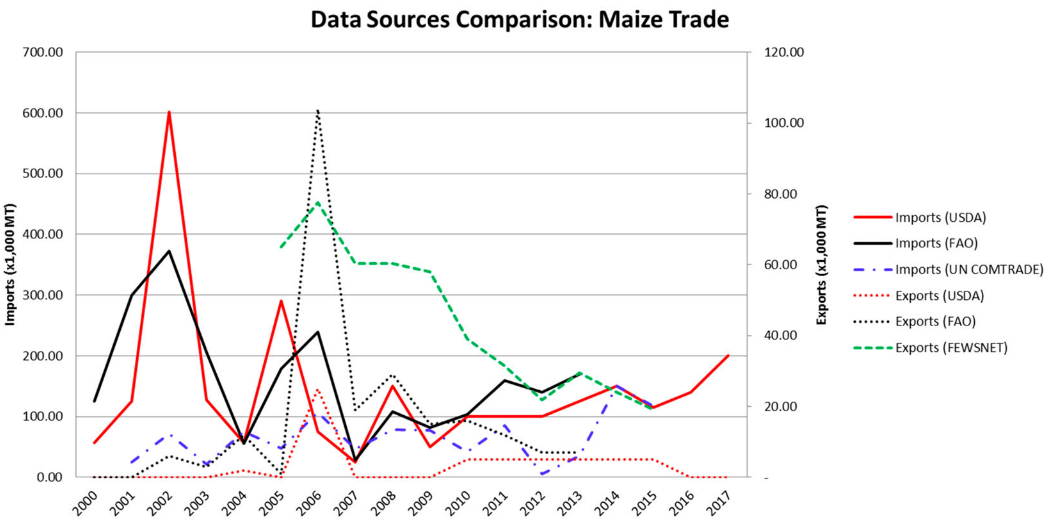
Firstly, data from the USDA food balance sheets is preferred. This is supported from the consistency with data reported from MASA, particularly for 2012 where the USDA and FAO information diverge markedly. For consistency, USDA data on aggregate consumption is also considered. The most up to date food balance sheet information for maize in Mozambique is also available only from USDA. Secondly, trade data from UN COMTRADE and FEWSNET on maize imports and (informal) exports, respectively, are used. It is assumed more accuracy on trade data reported from these entities. Thirdly, for each of the variables – production, consumption, imports and exports – the 2011–

**Table 2.** Equilibrium quantities, prices and elasticity.

| Region | Quantity (× 1000 MT) | | Price (USD/MT) | Elasticity of | | |
|---|---|---|---|---|---|---|
| | Demanded | Supplied | | Supply | Demand | Price transmission |
| Surplus | 1,209.53 | 1294.08 | 207.78 | 0.30 | (0.30) | 0.50 |
| Deficit | 360.47 | 142.44 | 342.40 | 0.30 | (0.10) | 0.50 |
| $ROW_X$ | 25.18 | - | 175.70 | - | (0.49) | 0.50 |
| $ROW_m$ | - | 158.66 | 209.61 | 0.24 | - | 0.05 |




(a)




(b)

**Figure 4.** Data sources comparisons for maize in Mozambique. (a) Data sources comparison: maize production and consumption in Mozambique. (b) Data sources comparison: maize imports and exports in Mozambique.

2015 (5 years) average data is considered as the base information for EDM. This allows some consistency with data available across the sources. Lastly, the (negative) difference between the resulting total supply and demand is incorporated into imports in order to balance supply and demand quantities.

Over the period 2008–2017, the annual volume of maize imports accounted to nearly 123,000 tons valued at about USD 27.8 million (UN COMTRADE 2018; USDA 2018). This is around 7.56% of the domestic production of maize over the same period and much higher than exports. The average (2011–2015) volume of Mozambique informal exports of maize to neighbouring countries, captured by FEWSNET (2018), has been about one-quarter of the volumes of maize imports.

EDM also requires information on prices, (supply and demand) elasticity, as well as an exogenous shifter. Domestic prices for maize in Mozambique are sourced from MASA (through the agricultural markets information system, SIMA) and FAO (2018b). FAO (2018b) is also the source for prices in South Africa (the reference for the imports markets, $ROW_m$) and Malawi (the reference for the exports markets, $ROW_X$).

Whilst farm gate prices are not available for Maputo (the reference for the deficit market), for Angonia (the closest market to Malawi with some available price information, and considered as the reference for the surplus market) wholesale prices are unavailable. Therefore, (real) retail prices for these markets are used in the analysis, which is consistent with the price level reported by FAO (2018b) for Malawi (Lilongwe, assumed as the reference for exports markets due to its importance, size and proximity to Mozambique). For South Africa, however, only wholesale prices from Randfontein are reported by FAO (2018b). These wholesale prices are then used under the assumption that they reflect the price Mozambican importers pay for the South African maize.

Information on supply and demand elasticities in $ROW_m$ and $ROW_X$ are extracted from Shoko, Chaminuka, and Belete (2016) and Ecker and Qaim (2008), respectively. Due to lack of information on supply and demand elasticities for the domestic (surplus and deficit) markets, assumptions are made from the elasticities reported for Zambia by FAO (2010), where demand elasticities are reported for different profiles of consumers.

Information on price transmission elasticity (that expresses the transaction costs such as transport and others among regions) is also required by DREAM (IFPRI 2001). By default, DREAM assumes the maximum value of 1. However, acknowledging the price market integration for maize between markets in the surplus region with markets in the cross borders countries, the poor domestic market integration across the regions in Mozambique, and the Mozambique's weakly maize price transmission to South Africa as reported by several authors (Alemu and Biacuana 2006; Paulo 2011; Penzhorn and Arndt 2002; Van Campenhout 2012), different values on price transmission elasticity are assumed. Data used on the EDM is summarised in Table 2. An extended table with respective sources for this information is provided in the Appendix.

### 3.2. Sensitivity analysis

To account for the uncertainties on the elasticities of supply and demand in the domestic markets, some sensitivity analyses are included. These include testing different values on supply and demand elasticity for each (surplus and deficit) market.

Sensitivity analysis is conducted by testing five different levels (0.2, 0.25, 0.3, 0.35 and 0.4) of supply elasticity at the surplus and deficit markets, as well as same levels for demand elasticity at the surplus market. For the demand market, three levels (0.05, 0.1 and 0.15) of demand elasticity are tested. In total, 375 scenarios are constructed for each group of producer and consumer surplus from both domestic surplus and deficit markets.

## 4. Results

Results from the EDM suggest that the reduction in maize supply has strong negative impacts domestically. As shown in Figure 5, a 3% loss of maize can lead to net economic losses of over $USD 28 million per year for Mozambique. Producers and consumers from the surplus market share the highest proportion of the losses. Together they share over 87% of the total economic losses faced in the country due to food loss in maize at farm level (Figure 6). In contrast, the scarcity of maize in the deficit market provides some benefits to the commercial farmers (traders) there but losses to consumers. Benefits are also extended to suppliers from $ROW_m$.

Depending on the magnitude of the supply and demand elasticity, the economic losses for each of the actors domestically could even be higher. As shown in Table 3, under the scenarios tested, the maximum total economic losses to producers from the surplus market solely is around $USD 28

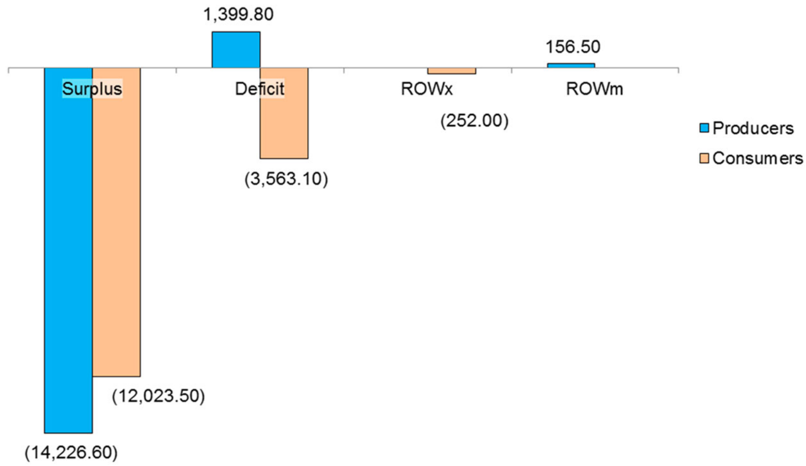



**Figure 5.** Total economic surplus from food loss on maize.

million per year. This is not surprising since changes in the supply elasticity at the surplus market have a direct impact on net changes in price ($K$). In general, the more inelastic is the supply at the surplus market the higher is the net effect on price changes ($K = k/\varepsilon$). This is also evident from Figure 7(a).

Figure 7 shows the impact of individual scenarios of elasticity changes to producers and consumers' surplus in each of the domestic markets of maize. In panel (a) it is shown that different supply elasticity values at the surplus market have a very large impact on producers' surplus at that particular market. Overall, the more inelastic the supply at the surplus market, the larger is the total economic loss for the producers from this market. In panel (b) where different demand elasticity values at the surplus market are tested, the impact to the same group of producers referred to is the opposite. As demand becomes less inelastic, total economic losses for producers from the surplus market gets larger. This is consistent with theory, since when demand becomes more elastic (or less inelastic) an increase in price has a negative effect on producers (or sellers) in the form of reduced revenue and, hence, reduced producer surplus. In both panels (a) and (b) of Figure 7, the effect of different supply and demand elasticity values is almost unaltered to consumers from the surplus market as well as to actors from the deficit market.

Panels (c) and (d) in Figure 7 show the impact of different supply and demand elasticity at the deficit market. In either cases, different elasticity values have almost no impact on economic

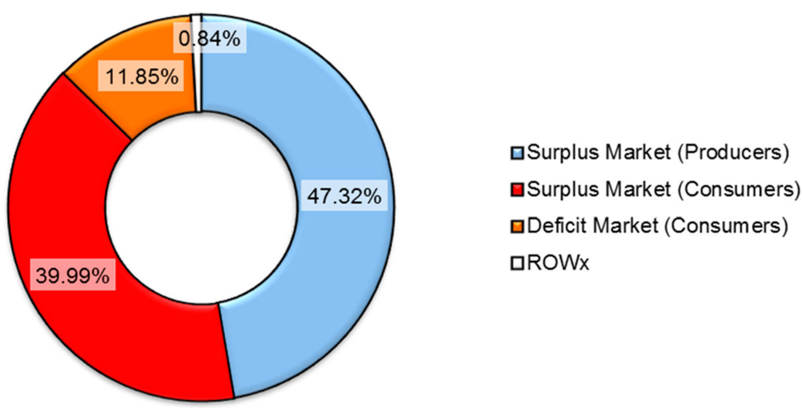



**Figure 6.** Share of total loss.

**Table 3.** Economic surplus (× 1000 USD) for each actor under all scenarios tested.

| | | Min | Max | Mean | St.Dev. |
|---|---|---|---|---|---|
| Surplus Market | Producer | (7255.80) | (28,017.20) | (15,574.42) | 5906.90 |
| | Consumer | (9038.30) | (17,953.00) | (12,324.52) | 1997.37 |
| Deficit Market | Producer | 1052.30 | 2090.30 | 1434.62 | 231.56 |
| | Consumer | (5318.50) | (2678.90) | (3652.56) | 592.91 |

surplus changes. This is shown from the almost flat curves for producers and consumers surpluses in both markets, under different elasticity.

Outcomes from panel (a) of Figure 7 are used to further investigate the impact of different demand elasticity values at the surplus market, given the worst-case scenario of supply elasticity identified. Figure 8 shows that a more inelastic demand at surplus market lead to larger economic losses to consumers and smaller to producers, both from the surplus market. At a 0.2 supply elasticity at the surplus market – and keeping unchanged the supply and demand elasticity values at 0.3 and 0.1, respectively, for the deficit market – economic losses to producers from the surplus market jumps to about twice the value from the base scenario in Figure 5 at a demand elasticity of 0.4, and economic losses to consumers from the same market increases in nearly over $USD 5 million at a demand elasticity of 0.2.

As a lump sum from previous scenarios, Figure 9 shows the impact to surplus when different supply elasticity values for the deficit market are added to the scenarios of 0.2 and 0.4 demand elasticity from Figure 8. As depicted, under this scenario supply elasticity at the deficit market has again a

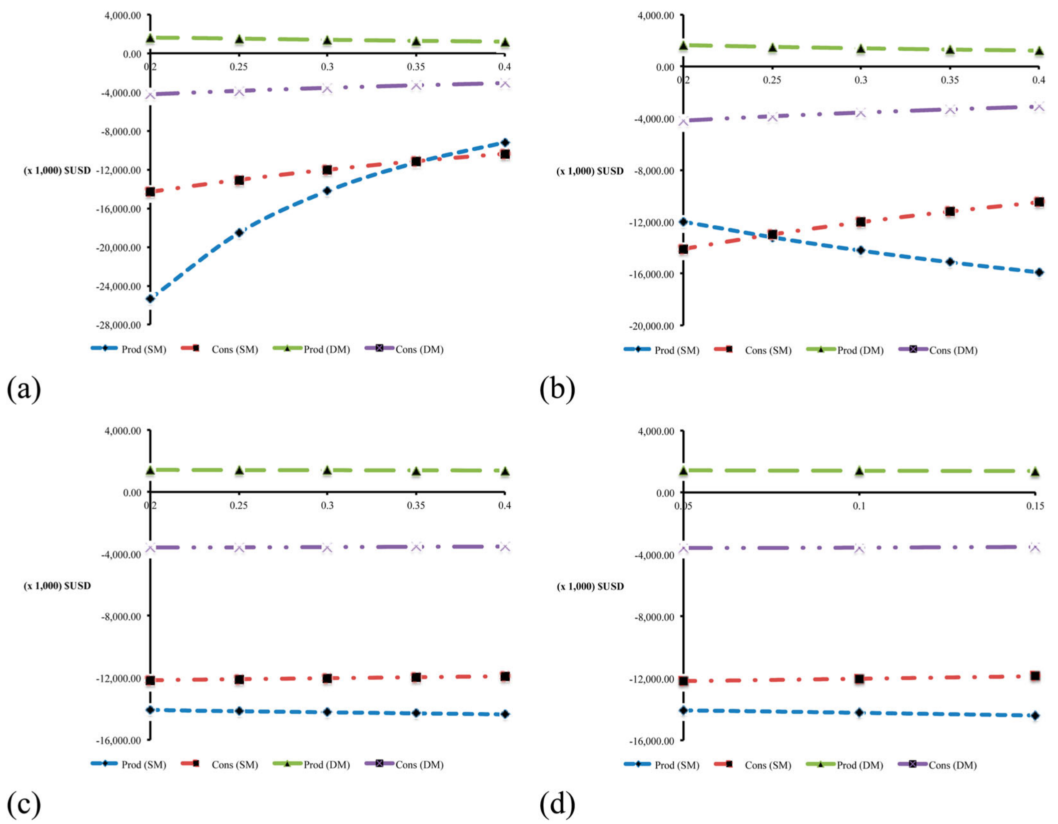



**Figure 7.** Different scenarios of elasticity for (a) supply and (b) demand at the surplus market, and (c) supply and (d) demand at the deficit market.

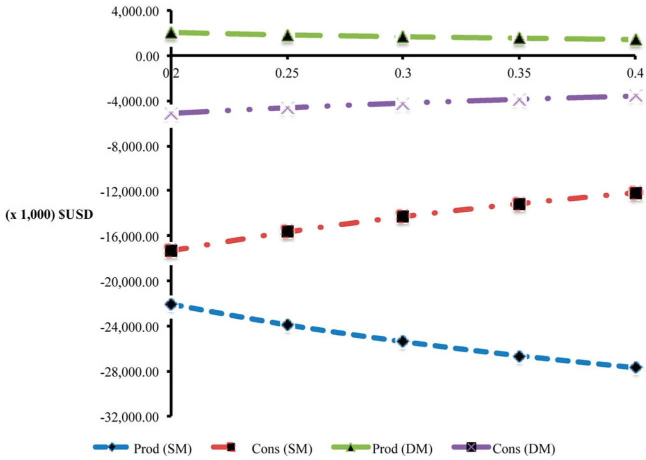



**Figure 8.** Producers and consumers surpluses changes under different demand elasticity values at surplus market, at 0.2 supply elasticity in the same market.

minimum impact to changes in producers and consumers surplus in both markets. The same is true when different demand elasticity values at the deficit market are tested (Figure 10). The maximum economic loss to producers from the surplus market, however, is found from the scenario described in panel (d) of Figure 10 whilst the maximum economic losses for the two groups of consumers are identified in Figure 10(a). Figure 10(a) also depicts the maximum economic gains for producers in the deficit market under the considered scenarios.

## 5. Discussion

Results displayed in Figure 5 as well as from the sensitivity analyses are consistent with economic theory. The resulting scarcity of maize domestically, due to maize loss in the surplus market, could lead to overall higher prices domestically. This is the case of the actual scenario with food loss. From a static and theoretical point of view, the higher prices lead to gains for commercial producers (traders) from the South, assuming that shocks (i.e., food loss) are only observed in the surplus market (see Figure 11). However, in practice such gains may not be realist since maize production in the South is insignificant and the majority of farmers are subsistence-oriented. In contrast, producers

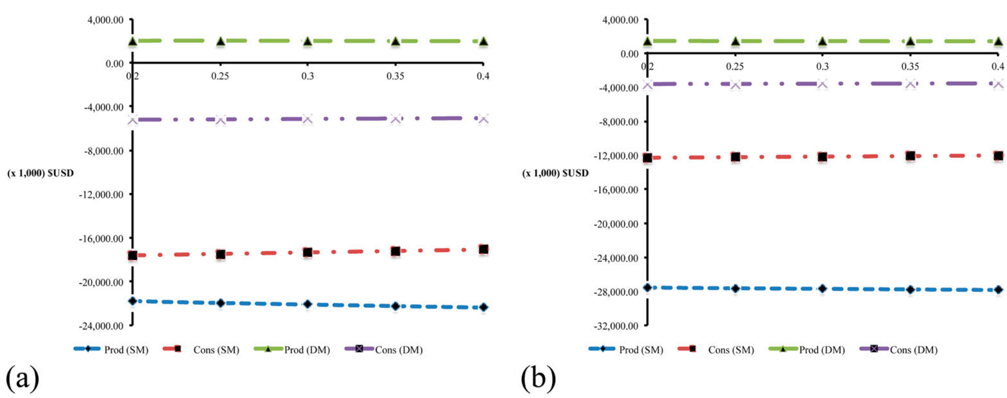



**Figure 9.** Different scenarios of supply elasticity at the deficit market, under 0.2 supply elasticity in the surplus market and (a) 0.2 demand elasticity and (b) 0.4 demand elasticity, both at the surplus market.

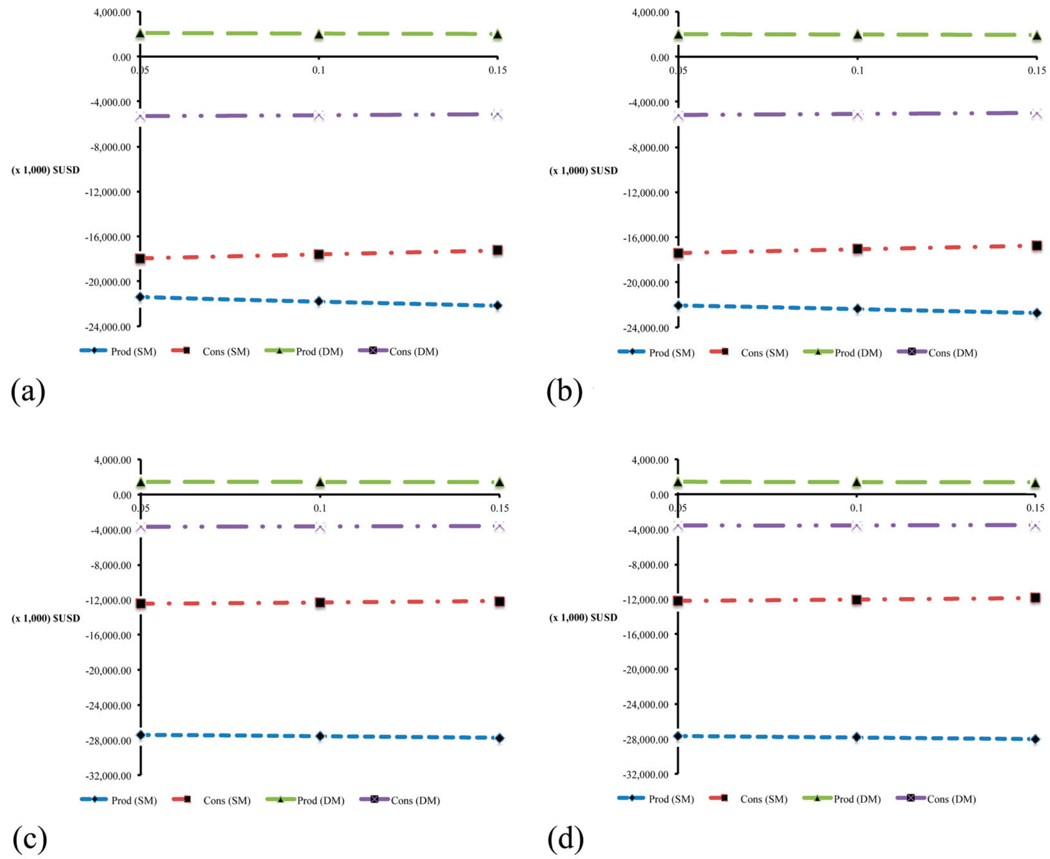



**Figure 10.** Different scenarios of demand elasticity at the deficit market. (a) $\varepsilon_1 = \eta_1 = \varepsilon_2 = 0.2$, (b) $\varepsilon_1 = \eta_1 = 0.2$ and $\varepsilon_2 = 0.4$, (c) $\varepsilon_1 = 0.2$, $\eta_1 = 0.4$ and $\varepsilon_2 = 0$, (d) $\varepsilon_1 = 0.2$ and $\eta_1 = \varepsilon_2 = 0.4$.

(and/or traders) from the surplus region and overall domestic consumers are the most prone to facing financial losses due to resulting deadweight losses.

Figure 11 displays the theoretical impact of food loss on maize for farmers from the surplus market. In this figure, *S* and *D* represent maize supply and demand, respectively, in the domestic surplus (*A*) and deficit (*B*) markets, as well as in the $ROW_x$ and $ROW_m$ markets. *C*, *Q*, and *QT* are used to represent consumed, supplied and traded quantities, respectively. *ED* represents exclusively the excess demand (imports) curve, and the subscripts *0* and *1* associated with the different letters

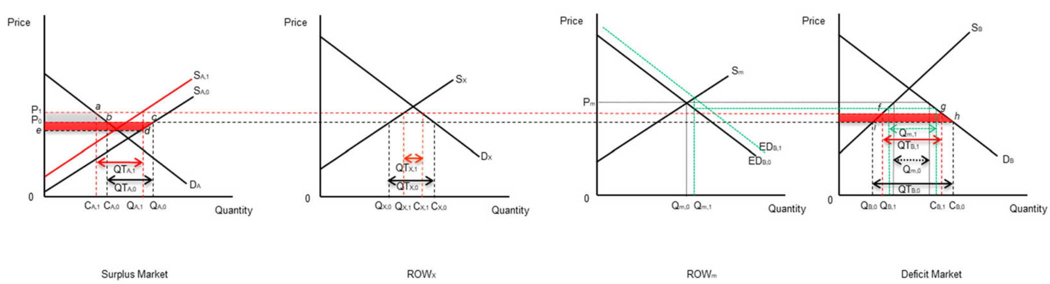



**Figure 11.** Theoretical impact of food loss at the surplus market of maize in Mozambique.

are used to represent the “desired” (without food loss) and “actual” (with food loss) scenarios, respectively.

Food loss in the surplus market represents a reduction in the supply (from $S_{A,0}$ to $S_{A,1}$) of maize from this market, which results in relatively higher prices (from $P_0$ to $P_1$) and, hence, reduced quantities of maize consumption domestically (from $C_{A,0}$ to $C_{A,1}$ and from $C_{B,0}$ to $C_{B,1}$ in the surplus and deficit markets, respectively) as well as maize exports (from $QT_{x,0}$ to $QT_{x,1}$). For maize famers (and traders) from the deficit and imports markets, this actually represents an opportunity for gains from increased sales. Traders from the deficit market also benefit from increased prices. As Figure 11 suggests, the resulting outcome of food loss in the domestic market is a net loss for producers (area $P_0cde$) and consumers (area $P_1abP_0$) in the surplus market, as well as to consumers in the deficit market (area $P_1ghP_0$). In contrast, the opportunity of gains for producers (traders) in the deficit market is equivalent to the area $P_1fiP_0$. Nevertheless, and as the results show, overall gains are less than losses.

The results shown in Figure 5 represent a proxy to the overall direct impacts of food loss of maize at the farm level and should not be taken as accurate measurements of benefits and losses to producers or consumers. Effective disaggregation of producers and consumers surpluses for both markets is quite complex for at least three major reasons. Firstly, retail prices are used instead of farm gate prices. Producers’ surplus is then a measure of surpluses to all actors up to the retail stage. Secondly, maize producers are simultaneously the major consumers of this cereal. According to official statistics, only 10% of farmers actually trade their maize. Therefore, consumers’ surpluses can be overestimated whilst producers’ surpluses underestimated. Thirdly, due to a lack of information on maize flow quantities, a vertical disaggregation of the supply chain seems impractical for effective measurement of surpluses for each actor across the supply chain stages. Even if disaggregated information on maize quantities were available, it would add much complexity to a multiple horizontal market scenario, which would arise from the part of the maize consumed in the deficit market being sourced from producers in the surplus market, usually through the small and medium-scale assemblers (FAO 2014). DREAM is also limited in such cases, as it doesn’t allow for a vertical disaggregation and development of an EDM specific to Mozambique’s maize industry. Despite these limitations, and as pointed by Alston, Norton, and Pardey (1995), the change in total welfare is still effective to assess the overall direct economic impact.

The magnitude of the resulting impact from food loss of maize is a massive direct economic loss (of $USD 28.41 million) per year for Mozambique, valued at more than the yearly average value of maize imports. Such loss is equivalent to over 1% of the national budget reported for 2017 and 2018 (GoM 2017).

The magnitude of the total economic losses, however, is sensitive to the elasticities tested. As shown from Figures 8–10, supply elasticity at the surplus market is the key of the total economic losses estimated. A more inelastic supply from the surplus market results in a large economic loss, mainly from the increased losses to producers from this market. Other elasticity values have a minimum impact on surplus changes. Since the supply elasticity from the surplus market is used to estimate the net supply shift (price shift) on this market, this outcome is consistent in theory. However, at a more inelastic supply, the magnitude of the total economic loss may be somehow inflated due to EDM’s limitations as referred to earlier.

Overall, the negative impacts of food loss are even higher if secondary impacts such as the prevalence of high levels of undernourishment and food insecurity are accounted for. Recent data point to nearly 25% of the population in the country suffering from undernourishment or food insecurity (GoM 2015; World Bank 2018b). Between 2016 and 2018, the cost of food aid to the country by the United States Agency for International Development (USAID 2018) have been around $USD 22.2, 13.4 and 3.6 million, respectively. This, on average, is relatively low compared to what could be saved yearly if maize losses could have been avoided.

Minimising food loss should also be seen under the country’s commitments to agricultural development. In 2003, under the Maputo declaration, Mozambique and other African Union (AU) members have agreed to increase to at least 10% of their national budget to investments in agriculture, aiming at accelerating agricultural growth in the continent (AU 2006). However, in the maize sector in particular, since 2011 production has declined significantly and imports are rising (Figure 4).

Overall, domestic policies for agriculture are very limited and food loss and waste reduction is not clearly targeted. This is also highlighted by the Food, Agriculture & Natural Resource Policy Analysis Network (FANRPAN 2017) in their study on postharvest management innovations in Mozambique. In the maize sector in particular, the main Government commitments are limited to seed and fertiliser subsidy provisions. Other non-specific policies referred to in the National Plan for Investments in the Agricultural Sector (PNISA 2013–2017) include improvements on infrastructure facilities and promotion of technology transfer to producers (FAO 2017). The current trade policies in place include Mozambique's agreements at the World Trade Organisation's (WTO), which include the free trade agreements (FTAs) for maize seed, grain and other forms of maize within the SADC region (excluding maize meal) as well as with the European Union. The only prevailing tariff is the 2.5% *ad valorem* for maize imported from other WTO members (FAO 2017).

These trade policies are perceived as a short-term measure to satisfy local demand for maize, and hence the development of the domestic milling industry. However, there is a need to acknowledge food loss as an important issue that restricts domestic supply and, simultaneously, contributes to high levels of undernourishment.

Reducing food loss, along with other interventions to facilitate and promote domestic trade, has also the potential to minimise dependency on maize imports whilst simultaneously improving farmers and consumers welfare. Since 2015 Mozambique has been experiencing some decelerated economic growth (World Bank 2018c). Despite the actual cost efficiency from maize imports, and considering the country's potential competitive advantage (over a number of countries in the Southern African region) on maize production, medium and long-term alternatives to reduce external dependency on maize (and other commodities) seem appealing to promote sustainable economic growth. As shown from Figure 3, overall retail prices of maize from the surplus market are comparable to wholesale prices from South Africa, though productivity levels are much lower domestically. If investments can be made towards exploiting economies of scale – by increasing production, productivity and reducing food loss – along with improved transportation networks, excessive transaction costs between the surplus and deficit markets are likely to be offset by reduced prices. This can also lead to additional gains from increased access to food by the lowest income households, as well as increased exports.

Reduction of food loss is also particularly important in the context of the Sustainable Development Goals (SDG) for 2030. Under these goals, Mozambique is committed to eradicate hunger, achieve food security and improved nutrition and promote sustainable development (SDG 2), and improve standards of production and sustainable consumption (SDG12) by reducing food loss and waste along supply chains (GoM 2016; UN 2018).

## 6. Conclusion

Globally there is a consensus that food loss and waste is a worldwide issue. In this study, the focus was on food loss from the perspective of developing economies, drawn from the example of maize in Mozambique. Empirical findings show that food loss (looked at solely from the perspective of farmers) leads to a massive direct economic loss estimated at over $USD 28 million per year, shared mostly by farmers from the surplus market and consumers. Added to this, there are also the secondary impacts of food loss particularly related to the undernourishment and food insecurity levels in the case of small-economies. Between 2016 and 2018 the average cost of food aid programmes to Mozambique was less than the yearly direct cost of food loss in maize. This suggests that mid- and long-run sustainable investments to minimise food loss, along with other interventions, are required to promote sustainable economic growth and to achieve the global commitment goals, particularly the SDGs 2 and 12.

Under the current scenario of minimal interventions towards food loss minimisation, it is likely that further government interventions to increase production and productivity will result in more food being lost mainly at the farm level. Priority interventions should target improvements to market linkages and postharvest management practices. These may include further investments on road infrastructures to facilitate trade between producers and buyers (domestically and regionally), training to farmers in best postharvest management practices as well as promotion of the BMM services to sellers and buyers. For the cost-effectiveness assessment of such interventions, however, further assumptions would be needed for the model used in this study.

## Notes

1. This figure is reported for the year 2012. Data on improved seeds use for the years 2013 and 2014 is not reported by MASA (2015).
2. FAO defines food loss as the decrease in quality or quantity of edible food mass intended for human consumption that occurs at early stages of the food supply chain (from production to processing) due mainly to logistics and infrastructure inefficiencies, while food waste is an issue that arises at late stages of the food supply chain and is attributed to retailer and consumer behaviour (FAO 2011; Segré et al. 2014).
3. FEWSNET dataset beyond 2015 could not be accessed.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Appendix

Data and parameters used to EDM for maize in Mozambique.

| Variable/Parameter | Market | Value | Adjusted value | Unit | Source | Notes |
|---|---|---|---|---|---|---|
| Production | Surplus (1) | 1,294.08 | | MT (x1000) | USDA | Average value (2011–2015) |
| | Deficit (2) | 142.44 | | MT (x1000) | | |
| Consumption | Surplus (1) | 1,209.53 | | MT (x1000) | USDA | Average value (2011–2015) |
| | Deficit (2) | 360.47 | | MT (x1000) | | |
| Exports | SA region (3) | 25.18 | | MT (x1000) | FEWSNET | Average value (2011–2015) |
| Imports | Worldwide (4) | 78.76 | 158.66 | MT (x1000) | UN COMTRADE | Average value (2011–2015). Adjustment to balance supply and demand from reported values |
| Total Supply | | 1,515.28 | 1,515.28 | MT (x1000) | | |
| Total Demand | | 1,595.18 | | MT (x1000) | | |
| Supply - Demand | | (79.90) | | MT (x1000) | | |
| Prices[a] | $P_1$ | 207.78 | | USD/MT | FAO (2018b) | Retail (Angonia). Average price (2011–2015) |
| | $P_2$ | 342.40 | | USD/MT | MASA | Retail (Maputo). Average price (2011–2015) |
| | $P_3$ | 175.70 | | USD/MT | FAO (2018b) | Retail (Lilongwe). Average price (2011–2015) |
| | $P_4$ | 209.61 | | USD/MT | FAO (2018b) | Wholesale (Randfontein). Average price (2011–2015) |
| Supply Elasticity | $\varepsilon_1$ | 0.30 | | | FAO (2010) | Supply elasticity for maize in Zambia |
| | $\varepsilon_2$ | 0.30 | | | FAO (2010) | Supply elasticity for maize in Zambia |
| | $\varepsilon_4$ | 0.24 | | | Shoko, Chaminuka, and Belete (2016)Shoko, Chaminuka & Belete (2016) | Short-run maize supply elasticity in South Africa |
| Demand Elasticity | $\eta_1$ | (0.30) | | | FAO (2010) | Demand elasticity for maize in Southern Zambia (poor farms and rural non-farms) |
| | $\eta_2$ | (0.10) | | | FAO (2010) | Demand elasticity for maize in Southern Zambia (middle and rich urban) |
| | $\eta_3$ | (0.49) | | | Ecker and Qaim (2008)Ecker & Qaim (2008) | Demand elasticity for maize in Malawi |
| Supply Shifter | $k_1$ | 6 | | % | FAO (2018a) | National average (2000–2013) |
| Net shift | $K_1$ | 10 | | % | Calculation | $K_1 = k_1/\varepsilon_1$ (IFPRI, 2001) |
| Pricing transmission efficiency | $S_1$ | 0.5 | | | | Assumption |
| | $S_2$ | 0.5 | | | | |
| | $S_3$ | 0.5 | | | | |
| | $S_4$ | 0.05 | | | | |

[a]Adjusted to real prices based on GDP deflator reported by the International Monetary Fund (IMF 2018).