# *Spodoptera frugiperda* and *Prostephanus truncatus* Biological Invasions' Impacts

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Invasive alien species have environmental, economic and social impacts, disproportionally threatening the livelihood and food security of smallholder farmers in low- and medium-income countries. In most cases, farmers and governments often invest huge sums of money towards synthetic pesticides, the major and first control option used against invading pests, seldom trading off other important sectors, e.g., healthcare and education. Given pesticide resistance, many of these insecticides are often ineffectiv. Furthermore, resource-poor farmers in developing countries usually cannot afford personal protective equipment and lack the knowledge and understanding of chemical pesticides and their safe use, which compromises their proper use and risks exposure to toxic substances, resulting in accidental poisonings. Widespread and indiscriminate use of chemical pesticides also undermine environmental quality (biodiversity loss and pollution of air and water) and the pest control services provided by natural enemies. *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), and the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), two of the most important field and postharvest IAS, respectively, that have invaded Africa.

Keywords: invasive insect species ; Prostephanus truncatus ; Spodoptera frugiperda

## 1. Economic Costs of *S. frugiperda* and *P. truncatus* Invasions

The impacts of *S. frugiperda* and *P. truncatus* can be defined and quantified as economic costs, i.e., expenditures to prevent, reduce or alleviate the losses caused by these pests [1] or the marketing losses resulting from compromised quality. In Africa, IAS generally can cause up to a 35% loss in national gross domestic product (GDP) [2]. Severe maize infestation by *S. frugiperda* can reduce per capita household income by 44% and increase a household's likelihood of experiencing hunger by 17% [3]. Infestation by *S. frugiperda* reduces maize yields by up to 54% [4][5][6] and can cause up to USD 13 billion per annum crop losses across Africa [5]. Various reports have recorded even higher estimated losses per annum see [3][7]. In Ghana and Zambia, the annual loss estimates for 2017 were USD 177 million and USD 159 million, respectively [3]. In Ethiopia, the pest caused an average annual loss of 36% in maize production, reducing yield by 0.225 million tonnes of grain between 2017 and 2019 [8]. In Kenya, *S. frugiperda* caused losses of approximately 33% of the annual maize production, estimated at approximately 1 million tonnes, with large variations across regions [4][9]. Rwomushana et al. [3] extrapolated that the pest had the potential to cause an annual reduction in maize production in Zimbabwe of approximately 264,000 tonnes, translating into revenue loss of USD 83 million. More costs related to *S. frugiperda* damage are highlighted in **Table 1**.

**Table 1.** Summary table showing the estimated costs related to *Spodoptera frugiperda* in some African countries. The costs are related to field damage, cost of control (including pesticides) and related. This list may not be exhaustive but represents significant data obtained at the time of writing.

| Reported Loss/Costs (USD) | Year | Loss/Cost Description | Country | Reference |
|---|---|---|---|---|
| **40.2 million * (134,000 tonnes maize)** | **2017** | **Field damage to crops, amount of food that can feed 1.1 million people.** | **Ethiopia** | [10] |
| **2.5–6.2 million (8.3–20.6 tonnes maize)** | **2022** | **Estimated yield losses.** | **12 African countries** | [5][11] |
| **3 million** | **2017** | **For pesticides and provision for replanting. Cost of pesticides per household was USD 14.20 without subsidies and USD 7.30 with subsidies.** | **Zambia** | [3][11] |
| **159 million** | **2018** | **Value of maize field losses.** | **Zambia** | [11] |

| Reported Loss/Costs (USD) | Year | Loss/Cost Description | Country | Reference |
|---|---|---|---|---|
| **4 million** | | **Procurement of plant protection products.** | **Ghana** | [11] |
| **177 million** | **2018** | **Value of maize field losses.** | **Ghana** | [11] |
| **$25.30** | **2017** | **The amount spent on pesticides per household for those without subsidies. For those who received subsidies, the cost was USD 13.30.** | **Ghana** | [3] |

* Using an average regional price of USD 300 per tonne of maize.

On the other hand, grain damage due to *P. truncatus* can level up to 100% and weight losses between 30 and 50% have been reported in stored maize [12][13][14][15]. Costs related to damage and losses as well as the costs of controlling *P. truncatus* in maize are scarce primarily because the costs cannot be isolated from those of co-occurring pests such as *S. zeamais* and *Tribolium* spp. When *S. frugiperda* and *P. truncatus* occur in the same environment, they have the potential to further disrupt vulnerable Africa's food systems through synergistic interactions. Invasive species also comprise one of the most apparent risks of the globalisation of international trade to both agricultural and related products [16]. This is because IAS can disrupt trade across countries, particularly in developing African regions, where phytosanitary measures are relaxed and ineffective [17]. When the losses caused by the *P. truncatus* became more apparent in the literature, many African countries declared it a quarantine pest and prohibited the importation of maize from infested countries or after transit through these countries [18]. This approach, however justified at that time, not only caused a loss of export markets to African countries that had a surplus of maize (In particular, Tanzania), but also complicated logistics and increased the costs of the provision of 'relief maize' by the international community after the drought in southern Africa in 1991/1992 [19][20]. Combined field and postharvest losses due to *S. frugiperda* and *P. truncatus* led to food shortages by removing part of supply from the market, thus contributing to high food prices [21].

## 2. Direct and Indirect Effects of *S. frugiperda* and *P. truncatus* on Human Health and Nutrition

Economic losses experienced when invasive species affect food production also result in negative effects on human health, directly or indirectly. By contributing to huge losses in maize, both *S. frugiperda* and *P. truncatus* contribute to malnutrition negatively affecting the health of many people across the continent. Tambo et al. [22] found that households affected by *S. frugiperda* were 12% more likely to experience hunger, as measured by the household hunger scale. Farm losses incurred have cascading effects of reducing agricultural production, which is largely menial in Africa [23], thus further compounding food insecurity challenges. Human health is also affected by product contamination in storage, i.e., infestation by *P. truncatus* can increase the moisture content of the stored grains, inadvertently creating a favourable environment for fungal growth, e.g., *Aspergillus flavus* which can produce some carcinogenic aflatoxins in food products [21]. Furthermore, insect feeding also causes nutritional postharvest losses reducing basic access to nutritious food for consumers [24][25]. Cereal grains comprise 30–60% of the daily caloric intake for humans around the globe [26]. Maize, for instance, is central to food and nutrition security for millions of people in Africa, which consists of 54 countries populated by over one billion people and accounts for 73% of the calorific intake within the region [27][28][29][30]. The consumption of insect-damaged grain which potentially has low nutritional value exposes the population to malnutrition [31].

The initial detection of *S. frugiperda* and *P. truncatus* is usually followed by the haphazard use of pesticides, leading also to increased human exposure to pesticides. For example, in 2017, Zimbabwe distributed nearly 102,000 L of pesticide valued at USD 1.97 million to farmers [32]. The continuous and injudicious use of these chemical insecticides poses adverse risks to human and environmental health, including the loss of biodiversity, e.g., natural enemies and pollinators [30][31]. This also increases the costs incurred in mitigating and managing the pest, a feat that is often difficult for resource constrained African farmers [33][34].

## 3. Ecological Costs of Biological Invasions

Biological invasions rank among the most significant threats to biodiversity and ecosystems and are considered the second most serious cause of species extinctions [35][36]. Their ecological impacts can be so severe that they are considered as one of the major drivers of biodiversity loss across the globe [37][38][39]. They are associated with an average of a 25% decline in native species diversity, and increasing abundances of non-native predators are linked to a 44% decline in native species population [40]. Indeed, the impact of invasion by a single non-native species on the function and structure of ecological communities can be devastating as they have detrimental effects on ecosystem functioning and the delivery of ecosystem services [37][41][42]. The interactions among species in an ecological community can be significantly altered as the introduction of an exotic species can influence species composition, richness and abundance; thereby disrupting the structure of local food webs and patterns of interspecific interactions [41][43]. Using data from InvaCost, a repository of costs of invasive alien species [42], estimated the cumulative cost of biological invasions in Africa to a range between USD 18.2 billion and USD 78.9 billion for the period from 1970 to 2020. Worryingly, the reported costs are mostly associated with the damage caused by invasive alien species without considering those of controlling the incursions. Consequently, the actual total costs were grossly under-estimated. The majority of reported costs are, however, skewed towards the agriculture and health sectors, which are considered economic activities compared to ecosystem services [1].

Field studies conducted in Uganda revealed that the invasion by *S. frugiperda* has caused the decline of stemborer incidences in maize and the displacement from the maize crop, as their preferred host plant, to sorghum [30][44]. There is interspecific competition among these species at the larval stage in the utilisation of maize—the preferred host [45][46]. Such interactions are likely to influence community structure of these lepidopteran herbivores in areas where they co-exist [30]. Introduction of species into new environments can trigger rapid evolution, for example, functional responses, and thus increasing the damage potential of alien invasive species [47]. Furthermore, multiple introductions of species from different biogeographical regions can result in cryptic interactions leading to admixture of genetic characteristics leading to changes in genomic structure of the IAS [47][48][49]. Rane et al. [50], for example, associated multiple *S. frugiperda* introductions into Asia and Australia with genetic hybridisation, backcrossing and genome doubling, see also [2], linking these with the introduction of insecticide resistance alleles in established populations. Such genetic hybridisation complicates pest management, leading to increased crop losses.

Similarly, studies have shown that invasive species that occur in postharvest agricultural commodities are often more competitive and can overcome competition and even displace other native species [51][52][53][54]. Quellhorst et al. [52] examined the competition between *S. zeamais* and *P. truncatus* on maize at four varying temperatures and found that increasing temperature resulted in elevated population growth of the invasive *P. truncatus* at the expense of *S. zeamais*. Other impacts noted included direct competition, changes to ecosystem functioning, hybridisation and predation. Phylogenetic studies by [55] revealed significant additive genetic and environmental effects enhancing some traits (e.g., body weight) in strains of *P. truncatus* from different geographical locations, increasing fitness and thus invasiveness in certain populations. Similarly, genetic diversity in *T. nigrescens* characterised by allele insertions and deletions at specific loci may explain the variable success of biological control of *P. truncatus* with predators from different geographical locations [56]. Ecosystem dynamics are altered through a variety of interacting, mutually reinforcing mechanistic pathways, for example, species' resource acquisition traits; population densities and the ability to engineer changes to physical environmental conditions [43]. Impacts to the environment such as pollution and development of pesticide resistance in pests arise through excessive and/or overapplication of synthetic pesticides in response to biological invasions [17]. This has negative implications on ecological services as they can lead to death of non-target organisms, e.g., pollinators, predators and parasitoids [57].

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