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The economy-wide impacts of a large-scale electric fencing intervention in Bhutan

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Abstract

National policy responses towards human-wildlife conflicts (HWC) are becoming increasingly relevant in the light of population growth and dwindling wildlife habitat. Yet, mitigation strategies at (sub-) national level are often resource intensive, particularly for low-income countries. Moreover, the HWC literature largely focused on socio-ecological interactions at the micro-level and there has been no research on how potential benefits from labour savings and reduced crop damages materialize once general equilibrium effects are accounted for. The contribution of this study is to assess the upscaling of HWC mitigation policies using an economy-wide model approach. Bhutan, where more than half of the population relies on agriculture, serves as a case study. Throughout Bhutan, HWCs present the highest ranked farming constraint due to crop raiding herbivores leading to farm abandonment and increasing labour shortages. Investments in low-cost electric fencing have been highly cost-effective and are expanding because of substantial subsidies by the government of Bhutan. The study employs a computable general-equilibrium model to ex-ante simulate the economy-wide effects of a comprehensive, large-scale electric fencing policy scenario in Bhutan in which the percentage of fenced cropland increases from 10% to 35%. The model representation accounts for many peculiarities of the rural economy, e.g., different agro-ecological zones and the seasonality of labour. In all, the results shall give insights on how this policy would impact rural household welfare by changes in agricultural wages and changes in agricultural prices and output. Policy implications and avenues for further research will be highlighted.

Introduction

Human wildlife conflicts (HWC) describe the negative impacts of wildlife on human activities, such as crop raiding or livestock depredation. HWC are *inter alia* a result of the expansion of cropland and human settlement and the decline in natural habitats for wildlife. With one million species on the brink of extinction, urgent action is needed to conserve biodiversity (IPBES 2019). At the same time, humanity is still fighting to eradicate global hunger, as reflected in the sustainable development goals.

HWC mitigation strategies include crop guarding, the use of scarecrows, and hunting, but also include more capital-intensive or innovative strategies like fencing (with or without electricity) or even the use of beehives to deter crop-raiding animals (King *et al.* 2007). Often, farmers resort to crop guarding to protect their fields against wildlife, which is a highly labour-intensive activity. However, time is also a scarce resource for smallholders (Blackden and Wodon 2012) and crop guarding activities even were found to have reduced children's school attendance (Mackenzie and Ahabyona 2012). Time spent on guarding fields has an opportunity cost. The time to deter wildlife could have been used for cash-earning activities off-farm (Blackden and Wodon 2012) and on-farm activities (e.g., cultivating more land that was left fallow due to HWC). Besides these time-use effects, HWC has multiple other impacts on human welfare, such as crop damages, increased social conflicts, stress, exposure to zoonotic and vector-borne diseases like rabies and malaria, and even deaths (Barua *et al.* 2013). These multidimensional impacts of HWC lead to immediate losses in labour productivity (due to stress, diseases, and possibly death) and availability (due to time-use and death). In addition, they impair the accumulation of human capital.

Of the available HWC mitigation strategies, electric fencing (EF) was found to be highly cost-effective in reducing crop losses and guarding time among farmers (Davies *et al.* 2011; Sapkota *et al.* 2014; Feuerbacher *et al.* 2021). It is a strategy that alleviates the direct and indirect pressures on HHs' food security and overall welfare. Compared to crop guarding, EF results in labour savings and lower crop damage from wildlife but requires high upfront investment costs. Moreover, there is a risk that fencing of cropland diverts wildlife to neighbouring unfenced cropland. Such negative spillover effects have been documented in the literature (Osipova *et al.* 2018; Feuerbacher *et al.* 2021).

This paper analyses the economy-wide impacts of a large-scale EF investment scenario. This is a research gap, since HWC impacts and mitigation potentials have so far only been studied at a micro-level scale ignoring adjustments by farmers and markets. The South-Asian country

Bhutan serves as a case study. In Bhutan, HWCs are a widespread constraint to farming (Nima and Gurung 2018). As a matter of fact, for most years, HWCs have been ranked to be the main farming constraint (MoAF 2022). In 2018, about one-quarter of farmers left arable land fallow due to crop-raiding wildlife (MoAF 2019). HWC is also a reason for rural-urban migration (National Statistics Bureau (NSB) of Bhutan 2018), reinforcing negative effects on the wildlife pressure on the farmland that has not yet been abandoned. HWC mitigation is particularly tricky in Bhutan, where hunting is substantially restricted, and the government has made biodiversity conservation a key priority (Feuerbacher *et al.* 2021). These conditions are transferable to many other biodiversity hotspot regions in the world (e.g., farming activities adjunct to protected areas). So far, in Bhutan, crop guarding is still the main HWC mitigation strategy, leading to a significant increase in farmers' labour burden, exacerbating the labour shortage in the agricultural sector, and leading to farmers leaving land fallow (Nima and Gurung 2018; Feuerbacher *et al.* 2021).

Scenarios

This paper explores the potential of large-scale investment scenarios in EF infrastructure. A business-as-usual scenario, in which – as currently – only 10% of agricultural land is fenced serves as a reference scenario to compare against the impacts of the policy scenario. The policy scenario is referred to as "EF35". It assumes that 35% of Bhutan's cropland is fenced, which results in no negative spillover effects. Here we are interested in exploring the impacts of mitigating HWC in the whole country on the agricultural labour market (as a substantial amount of labour is released that was previously used for crop guarding) and the impact on agricultural markets (as the crop damage due to wildlife is decreasing).

Data and Methods

The study uses a 2012 social accounting matrix (SAM) for Bhutan with satellite accounts for labour quantities. The SAM includes social reproduction and leisure that are outside the SNA production boundary (Pyatt 1990; Landefeld and McCulla 2000). The SAM disaggregates agricultural activities by three agroecological zones[1] (AEZs) to account for variations in climate and altitude and differences in growing conditions and agricultural labour is disaggregated by months.

[1] AEZ1 is the humid subtropical zone below 1,200m; AEZ2 is the dry subtropical zone between 1,200 and 1,800m; AEZ3 is the temperate zone above 1,800m

This analysis employs a single-country computable general equilibrium (CGE) model. The model is run in recursive dynamic mode, i.e., after solving for each year, the model uses current period data to update parameters relevant for production technologies, household demand, factors endowments, etc. There are various features that make the model particularly suitable to study the economy-wide impacts of electric fencing investments on rural farm households. The model captures the seasonal nature of rural livelihoods by incorporating both the seasonal demand for labour and leisure. Smallholders' labour-leisure trade-off is accounted for by explicitly accounting for the time use for leisure and social reproduction activities outside the production boundary. A land supply curve is used to capture the high degree of land left fallow. And lastly, factor markets clear at the level of factor owners.

Preliminary results

The preliminary results of the analysis show that the expansion of fenced agricultural land results in substantial labour savings. Based on the assumption of rigid labour market segmentation, the drop in labour demand results in an overall decline in agricultural shadow wages (Figure 1).

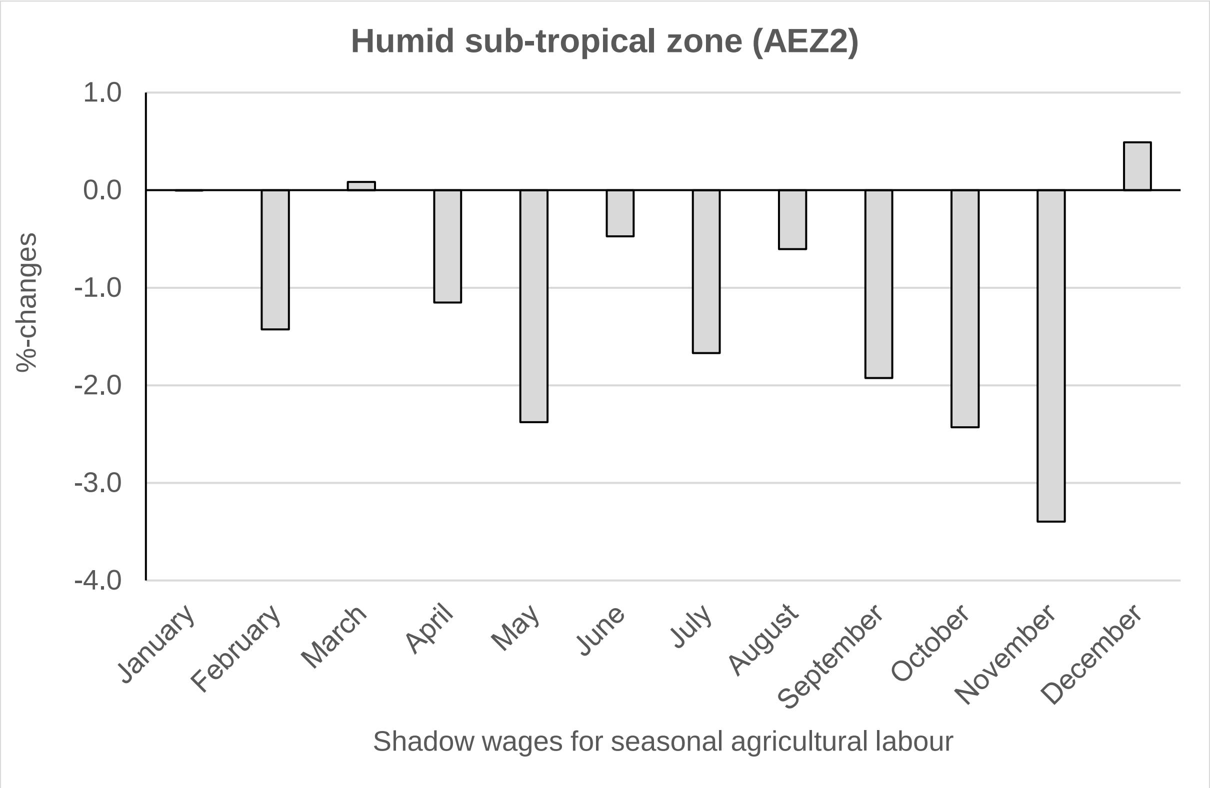

Figure 1 - Changes in agricultural shadow wages for the humid sub-tropical zone (AEZ2)

The electric fencing investments particularly benefit crops like rice, maize and potatoes, which are primarily targeted by crop raiding wildlife. Fencing these crops substantially reduces the labour demand for crop guarding and increases the land productivity. Other crops as vegetables, spices and fruits, in contrast, do not benefit from electric fencing. This is reflected in the changes in agricultural output and prices as shown in Figure 2.

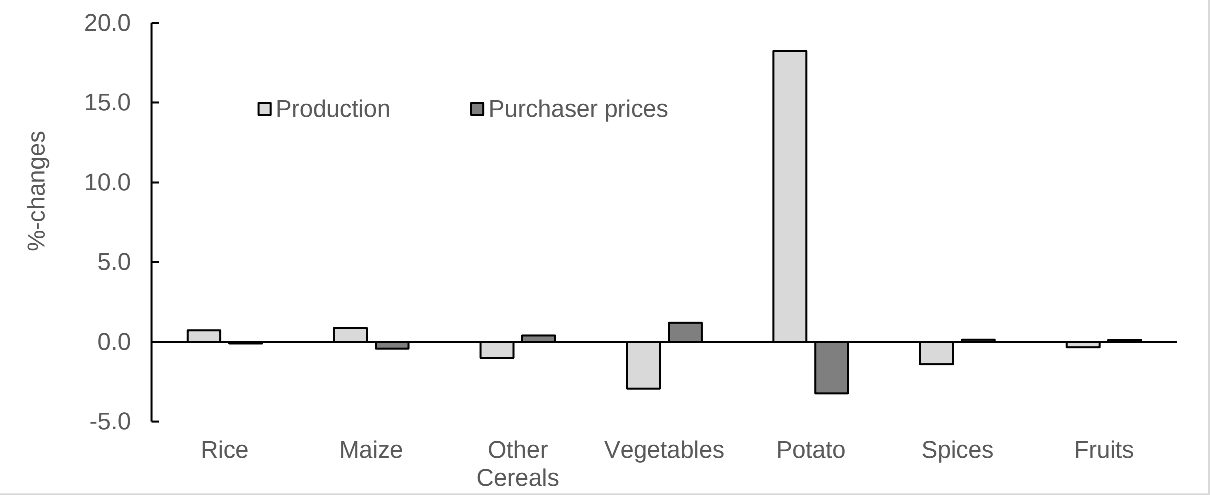

Figure 2 - Changes in production and prices of agricultural commodities

The strong increase in potato production is largely due to the rise in exports. Potatoes from Bhutan are mostly exported to India. Trade linkages for export of rice and maize are very low, which partially explains their low output response.

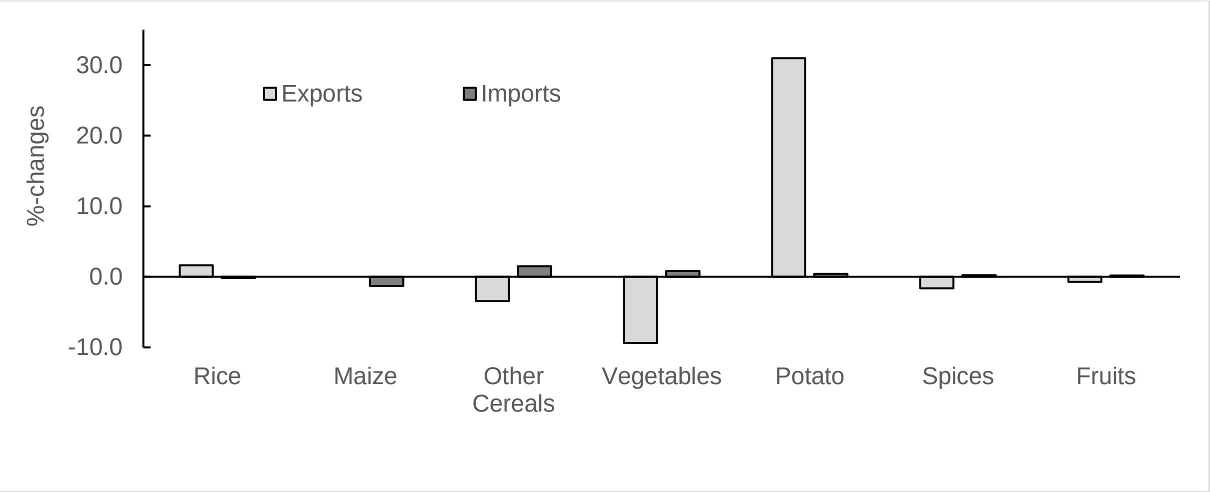

Figure 3 - Changes in exports and imports of agricultural products

Note: These results are preliminary. The changes in macro-level indicators, welfare and other results will be added in time for the conference.

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