Extended Abstract
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Paper/Poster Title	**The impact of UK food and bioenergy imports on global land use under future socioeconomic scenarios (UK-SSPs)**

Abstract prepared for presentation at the 97th Annual Conference of the Agricultural Economics Society, The University of Warwick, United Kingdom

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Abstract	***200 words max***

Food imports are a critical part of the UK's food supply, accounting for nearly half of all food consumed domestically. Reliance on imports raises concerns about food security as well as environmental impacts due land-use associated with imported commodities (the land footprint). Previous studies estimate that ~10 Mha of agricultural land is used globally outside the UK to produce food destined for the UK. However, previous methods fail to account for marginal yield effects and feedbacks between food demand, production, and international trade. Using a global land use modelling framework, LandSyMM, we produce estimates of the global land use impact of UK food and bioenergy imports. We simulate food demand, agricultural production, and trade under a range of global and UK-specific socioeconomic and climate scenarios. We estimate that 43 Mha of agricultural land could be currently linked to UK food and bioenergy imports, trending towards 22-45 Mha by 2080-2089. Given 9 Mha of agricultural land in the UK, our results suggests that UK food imports could have a disproportionate impact on global land use compared to domestic production. Further work is needed to quantify the environmental consequences of the UK's global land footprint.

Keywords	Land footprint, food imports, land use models
JEL Code	Agriculture in International Trade Q17 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

The United Kingdom is a net importer of food with imports accounting for 46% of total food consumption (Defra 2021). The UK's reliance on food imports leaves the country's food system vulnerable to potential global food system shocks including climate change, international conflict, and market shocks (Macdiarmid et al. 2018; Defra 2021). Another concern is the global environmental impact of food imports associated with agricultural production abroad. Land use and land cover change (LULCC), the additional use of fertilizer and irrigation have all been linked to international food trade.

Previous studies primarily use one of two approaches to estimate land footprints – biophysical accounting and multi-region input output (MRIO) analysis. While differences in estimates for land use footprints are to be expected from different

methodologies, some case studies have produced contradictory and inconsistent results (Kastner et al. 2014). This lack of consensus calls for a re-evaluation of existing methodologies. The approaches described above ignore the marginal effects of land footprints by assuming that the land use intensity of good exported internationally is the same as that of goods consumed domestically.

Interactions between trade flows, domestic production, commodity markets, and consumer demand add further layers of complexity which cannot easily be captured by simpler land footprint models. Considering these interactions is particularly important when attempting to project land footprints into the future as feedback effects may amplify with time.

Methodology	***100 – 250 words***

The Land System Modular Model (LandSyMM) is a spatially explicit model of the global land system which couples a number of sub-component models of land use decision making, vegetation growth, food demand and international trade. The model explicitly simulates yield responses of a range of crop types, allowing us to directly estimate the marginal land footprint of trade flows. Food demand, trade and commodity prices are modelled endogenously thus allowing for potential feedbacks between trade, consumption, and production. Future bioenergy demand is taken from the IIASA SSP database (Riahi et al. 2017).

Using LandSyMM, we explore the global land use impact of UK food and bioenergy imports under a range of socioeconomic and climate scenarios. We chose six SSP-RCP combinations to represent a range of plausible future socio-economic trajectories, both in the UK and globally. This includes one scenario for each of the five SSPs/UK-SSPs with corresponding RCPs (SSP1-RCP2.6, SSP2-RCP4.5, SSP3-RCP6.0, SSP4-RCP4.5, SSP5-RCP8.5) and an additional SSP2 scenario with a high RCP (SSP2-RCP8.5).

For each scenario, we produced a series of baseline and counterfactual runs. Input parameters were sampled using Monte Carlo methods from distributions consistent with each scenario. In counterfactual runs, the UK was removed from the simulation. We estimate the impact of UK food and bioenergy imports by comparing corresponding baseline and counterfactual runs within each scenario.

Results	***100 – 250 words***

We estimate that in the period 2010-2019, 19.0 Mha (IQR: 15.3, 21.7) of cropland and 23.7 Mha (IQR: 19.6, 25.9) of pasture could be linked to UK food and bioenergy imports. This was further associated with 36 km^3 (IQR: 5.2, 68.6) of additional irrigation and -1.2 Mt (IQR: -2.6, 0.2) nitrogen fertilizer used compared to counterfactual scenarios. It is important to note that these figures do not represent the actual land area and inputs used to produce food imported to the UK. Instead, they represent the marginal impact that UK food imports have on global land use.

Under SSP5-RCP8.5, the UK's global cropland impact will increase to 26.3 Mha (IQR: 8.5, 33.4) in the period 2090-2089. Under SSP1-RCP2.6 and SSP2-RCP4.5, the cropland impact decreases to 11.2 Mha (IQR: 4.9, 29.2) and 11.5 Mha (IQR: 1.1, 19.5) respectively. In other scenarios, the cropland impact remains steady. However, considering only food and feed crops (i.e. excluding bioenergy), the UK's cropland impact remains stable or decreases in all scenarios.

The UK's pasture impact shows a slight negative trend across all scenarios, falling to 14.8 Mha (IQR: 9.0, 31.4) under SSP2-RCP8.5. Nitrogen fertilizer use shows the strongest trend, increasing to 4.2 Mt (IQR: 2.0, 5.2) by 2080-89 under SSP5-RCP8.5. Irrigation shows a slight positive trend albeit with large year to year variation and considerable spread between scenarios.

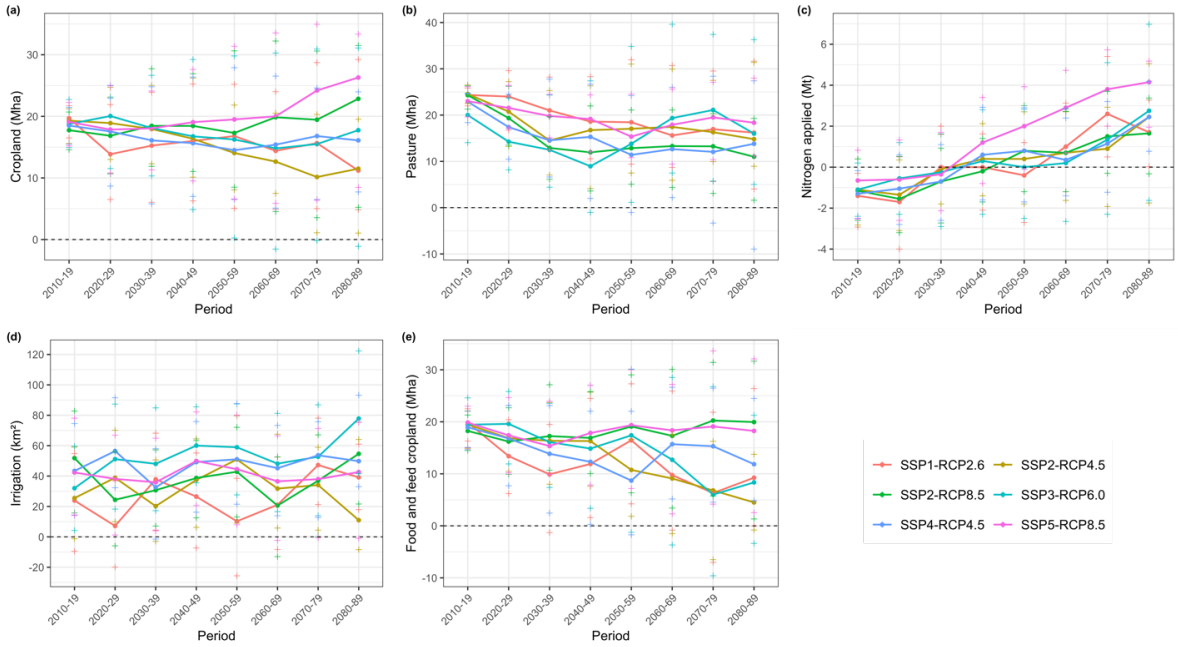

Figure 1 – Global land use and agricultural inputs linked to UK food and bioenergy imports from 2010 to 2089 under different socioeconomic and climate scenarios. Median values are shown by solid lines and interquartile ranges are indicated by crosses.

Discussion and Conclusion

100 – 250 words

The environmental impact of food consumed in the UK reaches far beyond the UK's borders. We estimate that food and bioenergy commodities imported into the UK are currently linked with 43 Mha of additional agricultural land globally. To our knowledge, our study is the first to evaluate the UK's global land use impact under a range of future socioeconomic scenarios. Our results suggest that the UK's total global land use impact will remain stable or decline by 2080-2089 to 22-45 Mha.

Despite a large degree of uncertainty, our estimates are considerably higher than those reported in previous studies. de Ruiter et al. (2017) estimate the UK's global land footprint due to food imports to be 10.2 Mha in 2010, composed roughly in equal

parts cropland and pasture. Analyses of land footprints in other countries have previously shown large differences depending on the methodology used (Kastner et al. 2014). Unlike previous studies, our work explicitly attempts to estimate the UK's marginal land use impact while allowing for feedbacks between food demand, production, and trade. We believe this represents a more complete picture of the UK's impact on global land use.

In conclusion, we find that an area nearly twice the UK's land area could be linked to agricultural commodities imported into the UK. We predict that under most socioeconomic scenarios, the UK's total global land use impact will remain broadly stable or decreasing, albeit with increases in nitrogen fertilizer use. Further work should use our estimates to examine the environmental impact of the UK's land footprint.

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