PhD Research Proposal

1 Proposal Title

The impacts of climate change and land degradation on global food production.

2 Background and research questions

In 2014, 50% of global cereal production came from just four countries: China, USA, India and Russia (The World Bank, 2016). By 2050, an increased population and changes to diets mean that food production is likely to have to increase by 60% to meet demand (Bruinsma, 2009).

Yet food production, both now and in the future, is likely to be adversely affected by two interacting processes that are already established and ongoing. One of these processes is land degradation, which is already having a severe impact on food production in some parts of the world and impeding necessary efforts to close the 'food yield gap' between highly productive agriculture in some countries and much less productive agriculture, on land of similar basic productive land potential, elsewhere. The other is climate change, the effects of which are already beginning to bring about the social and economic instability and damage which climate scientists have been warning of for some years. Further climate change is likely to change crop yields in the future.

Land degradation through loss of top-soil reduces crop water availability and increases nutrient requirements, and leads to increased eutrophication and N_2O emissions. It is not considered in the IPCC AR5, except as a note in a case study of the African Sahel. In contrast to climate change, there are few assessments of the impact of land degradation outside of Mid-West USA and Sub-Saharan Africa.

The impacts of climate change and the rate and impacts of land degradation could be reduced by adapting existing farming practices. The IPCC defines adaptation as reductions in risk and vulnerability through the actions of adjusting practices, processes, and capital in response to the actuality or threat of climate change (Porter *et al.*, 2014). Actions include changes in the decision environment, such as social and institutional structures, and altered technical options that can affect the potential or capacity for these actions to be realised. Adaptation options that have co-benefits for both land degradation and climate change would be particularly useful.

The aims of this PhD are to:

1. Understand the potential impacts of climate change on interannual cereal yield variability.
2. Examine the potential impacts of land degradation on interannual crop yields in the principal global crop-growing regions.
3. Identify how the impacts of both climate change and land degradation together compare to the individual impacts of each process, to understand the nature of the interactions between the two processes in the principal global crop-growing regions.

4. Characterise the relative impacts of adaptation options on climate change and land degradation, with a particular focus on identifying options that could substantially reduce the impacts of both climate change and land degradation and climate change.

3 Methodology

Crop models are generally used to examine the impacts of climate change. These complex biophysical models have hundreds of parameters and hence studies tend to only consider a small subset of future scenarios. The EPIC crop model is able to simulate the growth of a wide range of crops, and has a sophisticated representation of land degradation that has been developed over several decades by the USDA and Texas A&M university (Sharpley and Williams, 1990). This model will be the foundation of this PhD.

IIASA and BOKU have carried out a gridded assessment of the impacts of climate change on several crops for 100,000 global locations using EPIC. This assessment examines the impacts of several adaptation options. They have also carried out some separate runs for Europe that consider the impacts of dynamic land degradation (i.e. where land degradation at the end of each year is used as the starting point for the following year, rather than being reset).

Interannual yield variability has not previously been examined using this database. The potential impacts of climate change on yield variability will be examined through statistical analyses. This will require the development of some sophisticated analysis routes using software such as Python or R.

A similar analysis will be carried out on the dataset for land degradation impacts. Additional EPIC crop model simulations will be required to fully investigate this research question. The impacts of several adaptation options will be considered.

The relative impacts of land degradation and climate change can be examined using the same crop modelling system. The analysis will use dynamic land degradation modelling. Crop yields across the principal regions will be aggregated to produce regional production projections in the major global cropping areas.

4 REFERENCES

Bruinsma, J. (2009). The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050? *FAO Expert Meeting on "How to Feed the World in 2050".* Rome.

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Sharpley, A. N. and Williams, J. R. (1990). *EPIC—Erosion/Productivity Impact Calculator: Model Documentation.* Springfield, VA, USA. Available at: http://epicapex.tamu.edu/files/2015/05/EpicModelDocumentation.pdf.

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