

Implementing land supply curves in the GTAP AEZ model

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Analysis of renewable fuels policies, sustainable development targets and environmental issues rely on models that use spatial data on land use and land cover. The GTAP-AEZ model incorporates heterogeneous land use and land cover types classified by agroecological zones (AEZs; (Lee *et al.*, 2009; Baldos and Corong, 2020). In this framework, the competition for land within a given AEZ is constrained to activities that have been observed to take place in a selected AEZ. This facilitates analysis of the competition for land within and across regions. Given this, the GTAP-AEZ model has been used in a wide variety of applications aimed at examining the land-environment-energy nexus (Tyner and Taheripour, 2007; Hertel *et al.*, 2010; Golub and Hertel, 2012; Stevenson *et al.*, 2013; Taheripour and Tyner, 2013; Liu *et al.*, 2014; Taheripour, Hertel and Ramankutty, 2019; Johnson *et al.*, 2023). However, in the standard GTAP-AEZ model, the supply of land in an AEZ is assumed to be fixed, which means that additional land demanded by one sector needs to come from other land-using sectors resulting in the absence of land conversion from natural land cover which is important for the assessment of land use change emissions and biodiversity.

This research seeks to extend the GTAP AEZ model to incorporate land supply curves which accounts for physical information on available land for use at the AEZ level. It extends the work of Johnson *et al.* (2023) which introduced land supply curves in the GTAP-AEZ model following the approach of Eickhout *et al.* (2009), which is used in the MAGNET model (Woltjer and Kuiper 2014). Using this framework, land supply in each AEZ is defined as a function of real land rental rates as well as an asymptote that captures the maximum available land. Land supply increases as land rents rise as long as current land use is below the maximum available land. Likewise, if land rents fall, then the supply of land also declines and it is assumed that any land not being used is allocated back to natural cover.

To illustrate the importance of this research, the GTAP-AEZ model is used to simulate two scenarios, with fixed land endowment and with land supply curves at the AEZ-region level, using GTAPv10 LULC database aggregated for 37 regions (Baldos and Corong, 2020) and adjusted crop sector productivity growth over the period 2014 to 2030 based on the higher R&D spending scenario from Fuglie *et al.* (2022). Maximum available land is calibrated using historical estimates of potentially cultivable lands (circa 1980 to 2009) from Schneider *et al.* (2022) which incorporates information on agricultural suitability for growing 23 major food, feed, fuel and fiber crops.

Figure 1 illustrates the changes in total land endowments given AEZ-region land supply curves under greater crop productivity. On average, regional crop productivity increases by 20.5% which results in a global reduction in total land endowment at around 360.8 million hectares. Regions which have large crop and pasture cover as well as greater productivity growth such as US, China, Brazil and Russia experienced greater reduction of land endowment due to increasing productivity growth. Note that total land area did not change under the fixed land endowment case. Figure 2 compares the changes in cropland, pastureland and forest land under fixed land endowment and with AEZ-region land supply curves. The pastureland and forestland maps show notable differences between the two scenarios. Pastureland cover under the fixed land endowment case generally showed increases in area while pasture area declines in most AEZ-regions when land supply curves are implemented. Globally, pastureland cover increases by 56.0 million hectares when land endowments are fixed but it declines by 156.3 million hectares when land supply curves are implemented. For forests, regions such as USA and Brazil reported increases in forest land under fixed land endowment case but forest areas in these regions decline slightly as more land goes back to natural land cover. Globally, land cover used in forestry sector increased slightly by around 12.0 million hectares when land supply curves are used while it

increased by around 88.4 million hectares under fixed land endowments. Overall reduction in global cropland area is much smaller with AEZ-region land supply curve compared to fixed land endowments (reduction of 144.4 and 216.5 million hectares respectively).

To improve on this preliminary set of results, the latest GTAP LULC database will be used. Sensitivity tests on the parameters governing the land supply curves will also be conducted. Furthermore, land use change results from the GTAP AEZ model will be linked to the AEZ-EF model (Plevin *et al.*, 2014) to generate emissions from land cover change as well as to land transformation characterization factors (Chaudhary and Brooks, 2018) to calculate potential biodiversity losses from converting natural land into economic use. Alternative data for specifying maximum available land in each AEZ and region will also be explored.

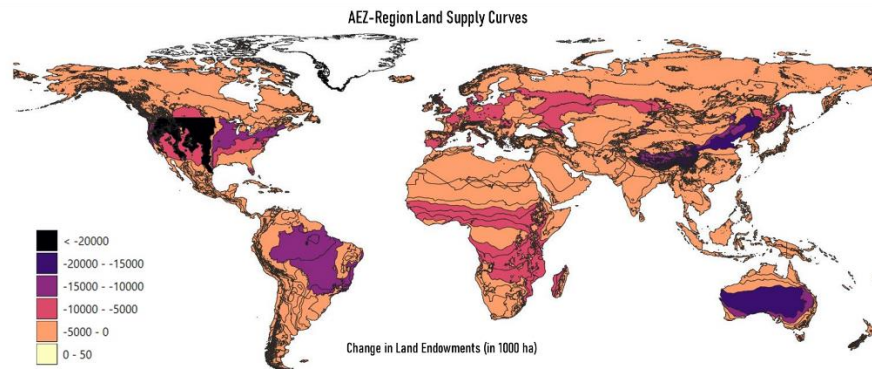


Figure 1. Changes in Total Land Endowments given AEZ-Region Land Supply Curves

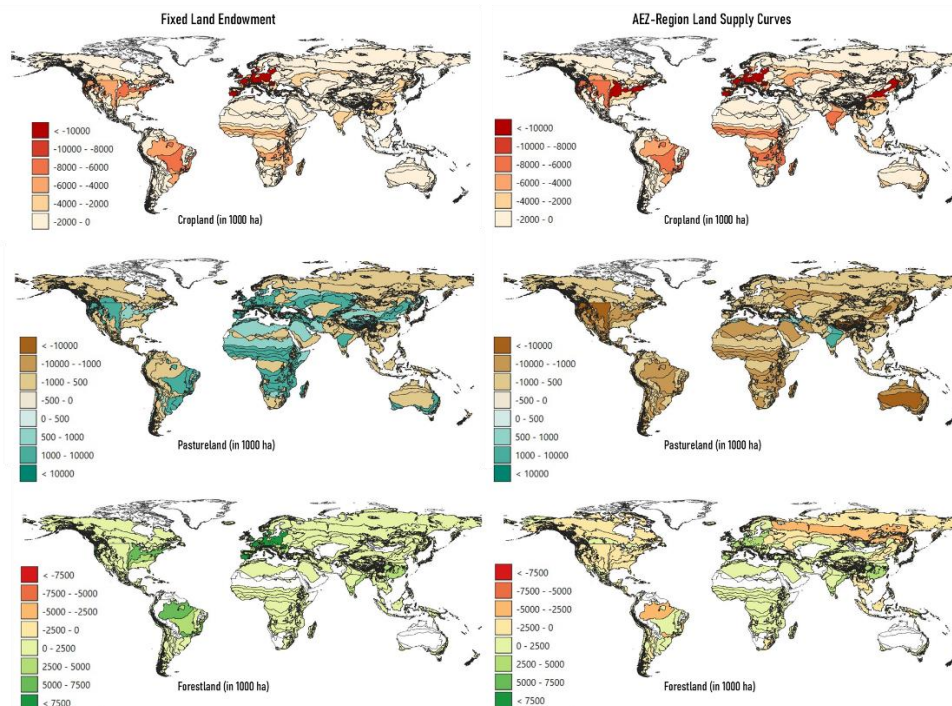


Figure 2. Changes in Cropland, Pastureland and Forestland Cover under Fixed Land Endowment and with AEZ-Region Land Supply Curves

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