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Summary of Methods for:

Implications of the 30x30 biodiversity conservation targets: quantifying uncertainty in local and global food system projections

Iman Haqiqi*, Jonathan Doelman, Thomas Hertel, Elke Stehfest, Hermen Luchtenbelt

Abstract

This manuscript briefly describes methods used to examine the potential implications of the 30x30 biodiversity conservation targets for local and global food systems. These targets call for protecting 30% of the Earth's land and ocean resources by 2030. There are concerns about the likely impact of implementing these targets on food prices, food security, and spillover to other locations. We developed a gridded economic model to quantify the complex interactions between land-use changes driven by 30x30 and global food security. Our analysis focuses on the critical uncertainties arising from different implementations of land supply elasticities and land use specification, a key factor influencing land-use change dynamics in future scenarios. We examine these variations across global, regional, and local (grid cell) scales. Preliminary findings suggest land supply elasticities significantly influence the magnitude and geographic distribution of potential spillover effects, highlighting the importance of considering these uncertainties when evaluating the overall impact on food systems. This study sheds light on possible unintended consequences associated with 30x30 implementation, urging careful consideration of land-use change dynamics during policy development.

Keywords:

Unintended consequences, spillover effects, global-to-local analysis, sustainability, food security

* Department of Agricultural Economics, Purdue University,
Address: KRAN#642, 403 Mitch Daniels Blvd., West Lafayette, IN 47906, USA.
Email: ihaqiqi@purdue.edu

1 Introduction

The alarming rate of loss of the worlds' biodiversity along with increasing pressure on land and water resources has resulted in calls for area-based targets for protecting nature. The 30x30 targets seek to protect 30 percent of earth's land and sea resources by 2030 as well as to increase funding for biodiversity protection. In addition to sustainable use, conservation, restoration, and improved management, the target is "to bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero by 2030" (United Nations, 2022).

Achieving the 30x30 goal requires large changes in global land and sea uses and ensuring that "areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, including through a substantial increase of the application of biodiversity friendly practices'' and "significantly increase the area and quality and connectivity". This implies prevention of further agricultural land-use expansion and changes in the management of current agricultural and cultivated land. This will have consequences for local and global food security. In addition, it will cause changes in the extent of agricultural land as well as the intensive use of inputs. It also is expected to result in spillovers to non-targeted lands through market price changes and the ensuing changes in exports, imports, and location of agricultural and economic activities.

The goal of this study is to improve our quantitative understanding of the impacts of land use changes implied by 30x30 on food security and land use at the global, regional, and local (grid cell) scales. Specifically, we assess the variation that arises from different implementations of land supply elasticities, a key determinant of land-use dynamics in scenario projections. In addition, we investigate how different distributions of protected areas in line with the 30x30 biodiversity conservation target affect land-use dynamics. We analyze the likely market responses through international trade, land use change, and cropland changes in targeted and non-targeted areas. Specifically, we like to see how US might be influenced by the 30x30 targets in different locations such as in Sub-Saharan Africa or in Brazil. We will also provide some estimation of impacts and some insights for those communities that highly depend on natural resources. Finally, we will discuss how does the land rights, enforcement of conservation areas, and international collaboration could impact the goal. We do this with the SIMPLE-G model which is uniquely suited to assessing this as it combines local, regional and global agro-economic dynamics in a single model framework.

2 Background and contributions

Global consequences of land use change have been the center of many studies over the last two decades (Foley, et al., 2005; Hertel, 2011; Nelson, et al., 2014; Willett, et al., 2019; Stehfest, et al., 2019). Different global frameworks have been employed to project the future global changes and evaluation of policies including MAgPIE (Lotze-Campen, et al., 2008), GCAM (Calvin, et al, 2019), SIMPLE (Hertel and Baldos, 2016), GLOBIOM (Havlik, et al., 2013) and IMAGE (Doelman et al., 2018; de Vos et al., 2021).

This study will build on current global quantitative frameworks but will explore the critical role of spatially gridded land supply elasticities based on metrics of land suitability. Also, we will draw on a recent empirical study (Van Vuuren, et al., 2021; Cengic, et al., 2020) to parameterize a quantity-preserving CET (constant elasticity of transformation) function (Zhao, et al., 2020) to model land supply behavior on over a million grid-cells worldwide. We will consider three different methods for estimating the spatially disaggregated land supply elasticities based first on downscaled regional elasticities, secondly using empirically estimated elasticities based on biophysical data, and finally using empirical estimates informed by both economic and biophysical data.

3 Model

To estimate the impacts of land-use changes implied by 30x30 targets, we employ SIMPLE-G, a gridded economic equilibrium model of land use, agricultural production, and global trade. The SIMPLE-G Global is one of the members of the SIMPLE-G model family (Liu, et al., 2017; Baldos, et al., 2020; Haqiqi, et al., 2022; Haqiqi et al., 2023a). It is the gridded version of SIMPLE (a Simplified International Model of agricultural Prices, Land use and the Environment) developed for global analysis of sustainability and food security (Baldos and Hertel, 2013; Baldos and Hertel, 2016; Kabir et al., 2023). The gridded version is employed for the spatial analysis of conservation policies (Loduca et al., 2020), the interaction of conservation policy and labor market (Ray et al., 2023), land use implications of biofuels (Villoria et al., 2022), water quality implications of cofiring (Sun et al., 2020), complex systems interactions (Woo et al., 2022), compound environmental-pandemic stress (Haqiqi et al., 2023b), and classroom teaching of sustainability (Fraysse et al., 2023).

SIMPLE-G is a computable multi-scale gridded partial equilibrium framework focused on production, consumption, and trade of crops. The original model includes regional markets for composite commodities such as crops, livestock, processed food, and non-food. It also includes gridded markets for production inputs such as land, water, and other manufactured and human inputs. The grid cell sizes are 5 arc-min that are called 10km nominal resolution. In summary, SIMPLE-G models the consumption and production of food at the global level with gridded production and aggregating all the crops in a single composite commodity. The consumption and production of food are modeled at 17 global regions, while the crop production is modeled within over 1.3 million grid cells. Each grid cell has its specific production function that determines the input demand and crop supply.

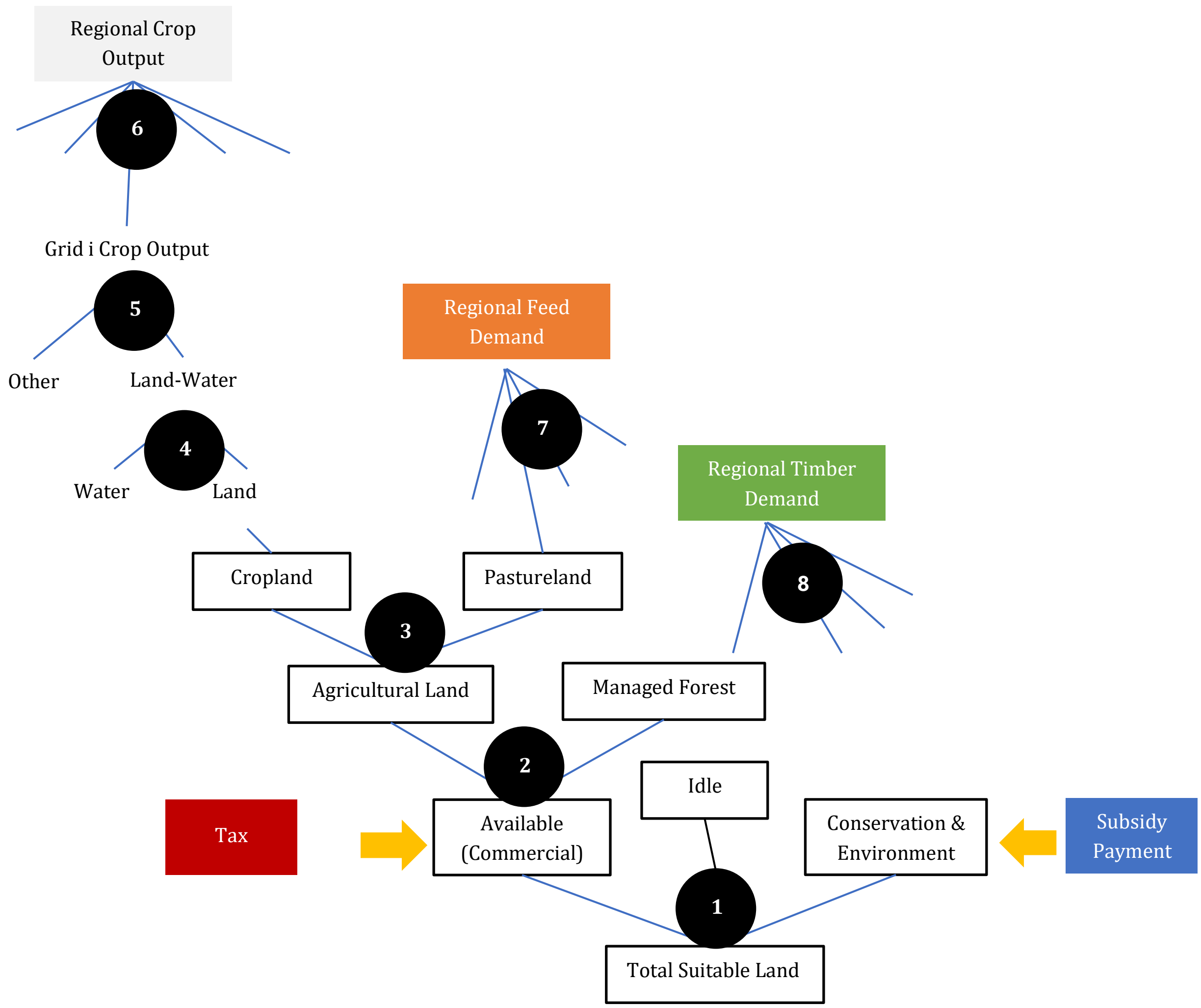

Figure 1. Illustration of gridded agricultural production and land allocation. (1) Total suitable land for agriculture allocated to commercial, conservation, or idle assuming a quantity-preserving constant elasticity of transformation (QCET) function. (2) Commercial land is allocated to managed forest or agriculture with a QCET structure. (3) Agricultural land is allocated to pastureland or cropland with a QCET function. (4) Land and water are combined to create a composite land-water input with a constant elasticity of substitution (CES) function. (5) All other inputs are combined with land-water composite in a CES production function to generate gridded output. (6) Gridded outputs are combined to shape sub-regional and regional production assuming product differentiation. (7) The gridded pastureland is considered imperfectly substitutable within a region from one location to another. (8) The regional timber demand assumes imperfect spatial substitutability. Environmental tax and subsidy are defined at the grid cell level and may represent different local incentives for land conversion. For each commodity (output, intermediate, or input), the equilibrium prices and quantities are determined with interaction of demand and supply of each input at different scales.

This study shows an example application of SIMPLE-G framework but also illustrates new developments. In previous versions of the SIMPLE-G model, the connection between livestock production and land use was through crop markets. In this study we consider pastureland as direct input to livestock production. In addition, we consider a market for timber for each region which provides more comprehensive competition between different land uses.

3.1 Gridded crop production

For crops, the production is at grid cell level where millions of production units produce differentiated products. The production function is a nested CES (constant elasticity of substitution) function of land, water, and a composite of all other inputs. This function is calibrated and parameterized based on multiple geospatial datasets.

3.2 Gridded land allocation and cropland supply

Land supply follows a spatially heterogeneous approach allocating land to different land uses. It is modeled using a nested quantity-preserving constant elasticity of transformation function. This function determines the allocation to cropland, pastureland, managed forest, environment, or idle land cover.

3.3 Local pastureland and regional livestock production

For livestock, there is one regional production function where the pastureland input is a composition of many locations within each region.

3.4 Local forests and regional Timber demand

For timber, there is a regional demand for many timber products differentiated by location. In other words, we assume imperfect spatial substitutability between the gridded managed forests.

3.5 Regional processed food production

For processed food, production and consumption are modeled at regional level at which markets are cleared. There is a CES production function for processed food where crops are one of the major inputs and are purchased from domestic or global markets.

3.6 Regional consumption

We assume consumption decisions are a function of prices and income. Total regional consumption is then determined considering per capita consumption and population. The crops are either purchased from domestic markets or an international pool of commodities.

3.7 International trade

The import decisions follow an Armington structure with imperfect substitutability between imported and domestically produced commodities. Total production of each region is either exported to the global market or supplied to the domestic market following a constant elasticity of transformation function.

4 Database

The model requires gridded data on value of production, yields, physical area, and water withdrawals. It also requires regional data on income, prices, consumption, exports, and imports. For a complete list if variables look at Haqiqi et al. (2023).

5 Scenarios

The following scenarios will be evaluated. The BAU baseline includes future projections with no new protection. To assess how different conservation strategies may differently affect the food system and land-use change dynamics, we consider two sets of strategies for reaching the 30% protection goal of the 30x30 target. The first set includes predetermined local targets based on various criteria like highest biodiversity value or proximity to important agricultural areas. Second, we impose regional targets and determine the required level of tax or subsidy to reach the goals.

6 Expected Results

In this study, we seek to answer to the following questions in a globally gridded multi-scale economic framework:

- What is the likely impact of the 30x30 policy on global land use patterns? How big is the land use change in non-targeted locations? (relocation)
- What is the impact on local and regional food prices and undernourishment? (food security)
- What is the impact on intensification of production? (fertilizer and water)
- Which regions are likely to be most affected by this policy? For example, we will examine how much of the change in the US is due to the 30x30 goal in Sub-Saharan Africa.

The findings demonstrate the critical role of land supply elasticities in driving the spillover effects and overall impacts. This study will highlight the unintended consequences and spillover effects of the land-use changes implied by 30x30 targets. In addition, it will evaluate how different protection strategies may differently affect local, regional and global land-use change dynamics. This will inform local and regional policy makers about the broader consequences of their policies, so they can avoid unintended environmental impacts while addressing this global biodiversity target.

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