

GTAP-RD-InVEST: A forward-looking Earth-economy model to analyze growth and sustainability issues under different climate change, agricultural yield, and policy scenarios

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Abstract

Analyzing sustainability and resilience of economic growth under different climate change, agricultural yield and policy scenarios requires a model that can account for the interaction between economic and ecosystem services. Building on the previous static GTAP-InVEST linkage (Johnson et al. 2021; 2023) framework, this paper describes the development of a recursive dynamic GTAP-InVEST (GTAP-RD-InVEST) model which permits calculation of economic equilibria on an annual basis, coupled with annualized shocks to the economy from ecosystem service impacts (as calculated with InVEST). Compared to Johnson et al. (2021) which included four ecosystem services, the current GTAP-InVEST version extends the coverage of ecosystem services into six, adding Sediment Retention and Coastal Protection to the previously included set of Pollination, Timber Provision, Carbon Storage and Marine Fish Provision.

The GTAP-InVEST model represents an innovative integration of economic and ecosystem service modeling to provide comprehensive insights into the interplay between human economies and natural systems. At the heart of this framework is the coupling of the Global Trade Analysis Project (GTAP) model (Corong et al., 2017), a widely used computable general equilibrium (CGE) model for global economic analysis, with the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model, which assesses ecosystem services. As shown in Figure 1, the GTAP module (on the right side of the figure) simulates economic interactions across sectors, regions, and institutions, capturing feedback loops such as production, household consumption, and government expenditures. The InVEST component (on the left) evaluates key ecosystem services, including sediment retention, climate regulation, timber production, and pollination, which are vital for both human welfare and economic activities. This integration is facilitated by the SEALS module, which predicts land-use changes, thus linking ecosystem service impacts to economic drivers.

The model operates bidirectionally, where economic drivers influence ecosystems (e.g., land-use changes predicted by SEALS that affect sediment retention and pollination), and ecosystem services feedback into the economy by altering welfare and production. This feedback mechanism is represented in the figure by arrows connecting the "Earth" (InVEST) and "Economy" (GTAP) modules. For example, changes in ecosystem services like timber production and coastal protection are quantified and fed into GTAP as alterations in resource availability, shifting supply and demand curves (illustrated at the bottom of the diagram). By combining ecological and economic perspectives, GTAP-InVEST allows for the assessment of trade-offs and synergies between economic development and environmental sustainability, offering policymakers a robust tool for evaluating strategies that balance economic growth with the preservation of ecosystem services.

We analyze the economic impacts of climate change scenarios by implementing four simulation runs that builds upon each other. Initially, a business as usual (BAU) scenario from 2017 to 2050 is

implemented with economic, labor force and population growth projections based on the recently updated SSP2 “middle of the road” scenario from IIASA, along with crop yield changes based on RCP4.5. Note that the BAU scenario only accounts for economic and demographic changes over time and does not take into account any projected changes in biodiversity and ecosystem services (BES). Three climate change scenarios are then implemented and compared relative to the BAU to analyze the interaction between the market-driven economy and ecosystem services.

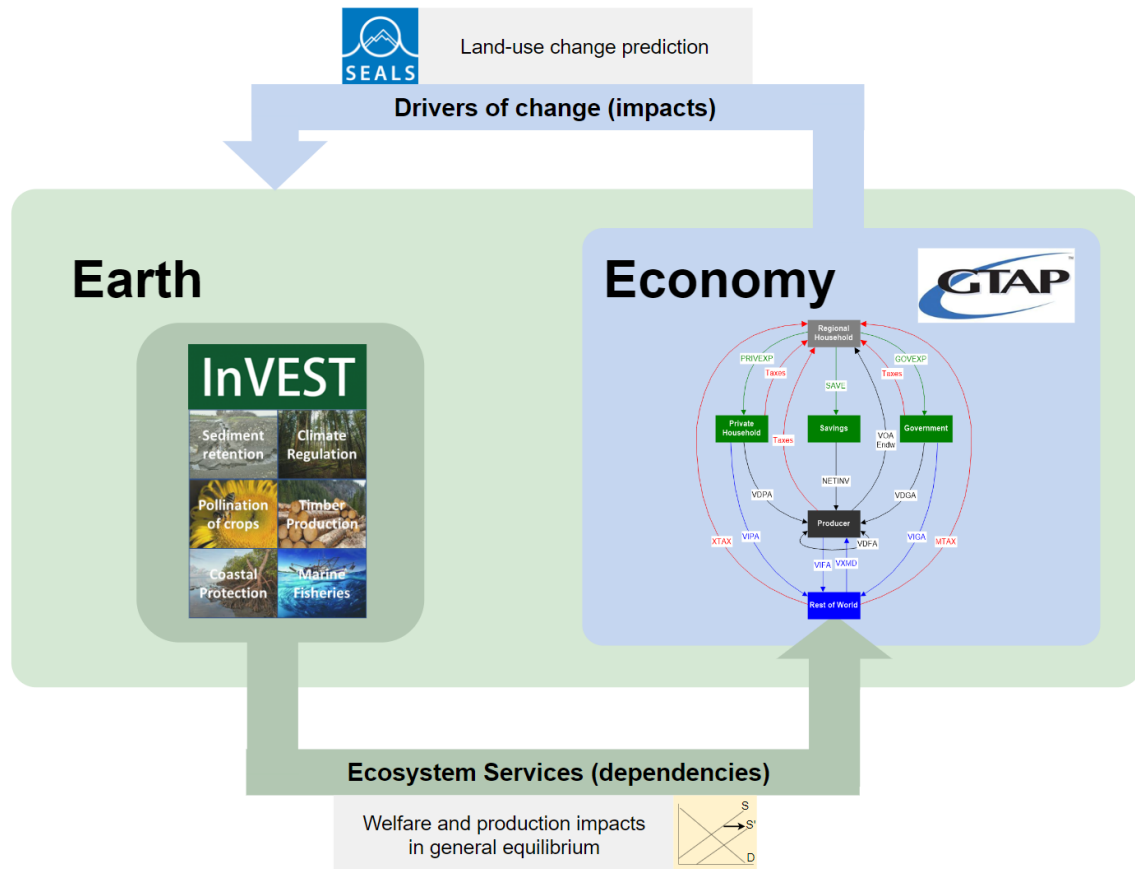


Figure 1: Conceptual Diagram of GTAP-InVEST

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