SIMPLE-G In the Classroom and the Cloud

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***Abstract*— SIMPLE-G serves as a significant tool for researchers to address sustainability challenges, serving as a Convergence Catalyst for issues related to the global-local-global connections affecting land, water, and food security. This paper explores the pedagogical path of SIMPLE-G in the classroom setting, highlighting its key benefits in interdisciplinary education. Furthermore, we explore the future development of SIMPLE-G for facilitating collaborations between economists and other disciplines as well as increasing accessibility to users through cloud computing.**

Keywords—Sustainability, SIMPLE-G, global-local-global connections, land, water, food security, pedagogy, interdisciplinary education

I. Motivation for SIMPLE-G

The United Nations Sustainable Development Goals (SDGs) highlight the overarching sustainability challenges facing the world today. Of these 17 goals, half bear directly on the world's land, water, and food systems and none of these SDGs sit alone. We are faced with planetary boundaries and resource constraints that necessarily link any individual SDG to the others, through positive synergies and negative tradeoffs. For example, SDG2 sets the goal of having zero hunger by the year 2030. Eliminating poverty (SDG1) will facilitate the achievement of SDG2 (a positive synergy), but meeting SDG2 also requires more food production, which may have adverse environmental impacts, thereby presenting challenges for SDGs 12, 14 and 15. In this context, cropland expansion is a major source of biodiversity loss, which limits attainment of SDG15 (a negative tradeoff). Addressing these challenges, and quantifying the associated tradeoffs and synergies requires new modeling frameworks and tools. The Simplified International Model of agricultural Prices, Land use and the Environment – Gridded version (SIMPLE-G) [1] is one such tool that has been successfully deployed in the classroom as well as in peer-reviewed publications.

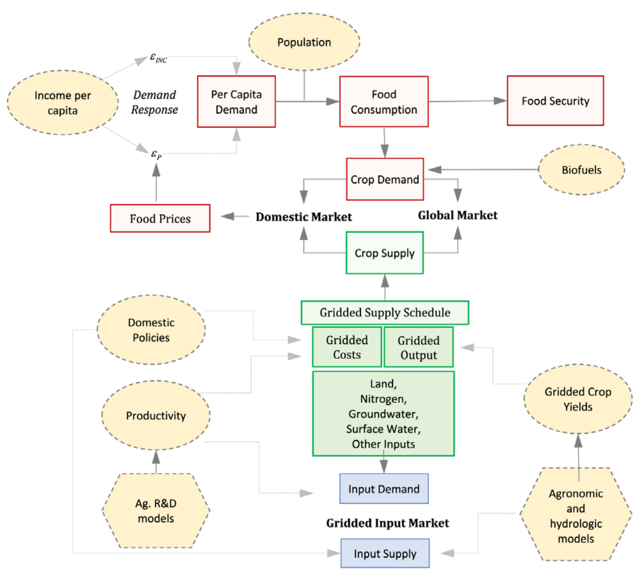
The most important challenge facing researchers seeking to assess the SDGs related to land and water sustainability is effectively capturing the Global-Local-Global nature of the problem [2]. Sustainable use of these resources varies by location, according to hydrology, soils, weather, and socioeconomic conditions, as well as local laws and practices. So, one cannot avoid taking a high-resolution approach to the modeling of these SDGs. However, many of the local stresses are driven by global forces, including population and income growth, as well as climate change. The Global-Local-Global framework starts by looking at the global drivers and their influence on the sustainability of food, energy, and water issues at a local level. These issues are then evaluated by the local responses and how they feedback to the regional, national, and then global level. Sustainability issues are a local challenge, but they cannot be successfully addressed without global context and accounting for spillover effects from changes in local policies to adjacent regions. Taking climate change, for example, as global temperatures rise, this not only shifts agricultural production, but also induces heat stress for agricultural laborers depending on their location, the crop being grown and the labor conditions as well as weather. Lima et al. (2021) find that climate change reduces the number of hours that agricultural laborers can work in the face of severe heat stress, and this requires additional workforce in agriculture, leading to global changes in farm and nonfarm work as well as production [3].

Issues like this cannot be addressed by a single academic discipline; a more holistic framework is necessary. By combining the insights from agronomy, public health, climate science and others within the framework of economics, we are able to see the significance of a multidisciplinary approach to the grand challenges we face today. This desire to allow room for contribution from other disciplines is what gave rise to SIMPLE-G. SIMPLE-G [1] aims to keep economics simple, so as to leave room for other disciplines. Furthermore, by keeping economics simple this opens the door to researchers that can utilize this tool and allow for other scientists to incorporate it into their own research. There are a number of opportunities for researchers or graduate students to learn about SIMPLE-G including the SIMPLE-G short course, offered by the Center for Global Trade Analysis Project (GTAP) at Purdue University (https://www.gtap.agecon.purdue.edu/events/gtap-u/index.aspx).

II. SIMPLE-G Overview

SIMPLE-G is a partial equilibrium model of agricultural production, trade and consumption which allows one or more regions to be represented at the individual grid cell level. It stems from the original non-gridded regional version of model (SIMPLE) which is used for teaching and research into sustainability issues at the global food-water-environment nexus. Figure 1 below shows the interaction between variables within SIMPLE-G. Food demand is driven by population and income, along with biofuel production. Supply is determined at the grid cell level and then aggregated to the region where equilibrium is obtained. Traded products are differentiated by place of origin, following the approach of Armington [4]. The gridded nature of SIMPLE-G allows for researchers to accurately represent the heterogeneity across individual grid cells, particularly around land, water, crop production, environmental impacts, and constraints.

Fig. 1. SIMPLE-G Flowchart



III. HOW IS SIMPLE-G DEPLOYED?

There are two main approaches to the deployment SIMPLE-G models for the classroom: on PCs and in the cloud. When deployed on PCs, SIMPLE-G models can be used with the GEMPACK software suite [5] to run simulations and generate data that can be used in class discussions and assignments. This facilitates students' understanding of the foundational economic concepts and how they are affected by global change. The students need to install GEMPACK and obtain a free course license. The model codes and data are provided by the instructor. A brief introduction to GEMPACK is necessary to be able to understand how the model works and how to read the outputs. This is typically done in the context of the first lab assignment.

There are multiple benefits for PC deployment. Perhaps the most important is the access to Analyse-GE, a powerful software interface for investigation and interpretation of model results [7]. This approach is also the most flexible for innovative class projects requiring a change in the SIMPLE-G source code. The students and instructors have complete control over the model and data. In other words, they can customize the model and experiments to fit the specific needs of the multidisciplinary students. The drawback is that non-Windows users may need additional steps to use the GEMPACK tools on their machines. And the technical expertise to deploy the model on the constantly-changing Operating Systems can be difficult to maintain.

These drawbacks have led to the deployment of SIMPLE-G 'in the cloud'. With cloud deployment, SIMPLE-G models can be accessed by students from anywhere in the world through a browser. This can help students to collaborate on projects and share data and model outputs with each other. It can also help students to access the models even if they do not have a PC and have not installed the GEMPACK software. These cloud-based platforms typically include a graphical user interface (GUI) that allows students to visualize the model outputs and explore different features [6].

Cloud deployment is more reliable and sustainable than traditional methods of model deployment. However, the drawback is that the users have limited or no control over the source code and are limited to the embedded features of the model. This means that they cannot modify the model to fit their specific needs. However, if the model set up is done well, users will be able to make significant modifications through changes to the model closure (exogenous/endogenous variable split), parameters, and shocks (e.g., groundwater conservation, nitrogen leaching tax, population growth rate, etc.). As such, it can be quite general, making this an excellent option for reaching out to a wider range of users around the world and generating a broader impact on sustainability and food security research. It is also reliable, sustainable, and easy to use. Nonetheless, it is important to be aware of the limitations of cloud deployment before embarking on this path.

IV. HOW DO WE TEACH SIMPLE-G?

SIMPLE-G is taught currently taught via a short course offered through the GTAP Center at Purdue University. The course starts with the SIMPLE model, before adding the complexity of the grid cell resolution. Prior to the in-person course component, participants complete a three-week on-line session. The three, weekly lab assignments completed during this section of the course allow participants to gain a fundamental understanding of the economics behind the model and to build expertise with the software. These lab assignments also highlight different ways that SIMPLE can be applied to complex issues. By showing different types of shocks (technology, population, income, climate change) we are able to highlight where other disciplines can deepen our analysis and inspire them to think of their own applications.

Following the on-line component of the course, participants spend a week in person to learn about the gridded application. We start them on the simplest gridded model, SIMPLE-G1 which was developed to serve as a bridge between the SIMPLE model and the rapidly proliferating versions of SIMPLE-G which involves more complex production functions. In the spirit of SIMPLE, SIMPLE-G1 has just two inputs: land and nonland factors and one Constant Elasticity of Substitution (CES) nest in its production function. This section also introduces students to a mini-version of SIMPLE-G ("mini-model") which allows users to hone in on a dozen grid cells of special interest which are typically chosen to maximize the variation in results, as determined by the underlying parameters such as cost shares and elasticities. By examining how these heterogeneous grid cells respond to an exogenous crop price increase, we can enrich our understanding of what drives the heterogenous outcomes when we solve the model with tens of thousands of grid cells.

With SIMPLE-G1 and the mini-model under their control, students are introduced to increasingly complex versions and applications of the model such as groundwater scarcity and nitrate leaching affecting water quality. Finally, students take what they have learned from SIMPLE, the mini model and SIMPLE-G and apply it to their own capstone project through the replication and an extension of an existing, published application. This course material, plus a number of additional contents, is being turned into a book under contract with Springer Publishing. The book will provide further content, including theoretical and modeling background, short PowerPoints, as well as nine applications, including all the files needed for replication and extension. This book will provide structure and content for future short courses, as well as for professors seeking to incorporated SIMPLE-G into their teaching and research programs.

A shortened version of the course has recently been offered through the Institute for Geospatial Understanding through an Integrative Discovery Environment (I-GUIDE) Summer School where students from various institutions were selected to work on a SIMPLE-G project. In summer, 2023, the SIMPLE-G team completed a project titled "Margins of Adaptation to Human Heat Stress: Local, National, and Global Socioeconomic Responses". The team came from a variety of disciplines with significantly different depths of experience with economics. Over the course of 18 hours of teaching, hands-on lab and group work, they completed their project and were honored to present their findings at the I-GUIDE Conference after winning the "People's Choice Prize". Their project analyzed the impact of severe heat stress, due to climate change, on agricultural production during the peak production season where farmworkers can face temperatures above 100 degrees Fahrenheit. They found that not only were there direct effects on labor productivity, but also indirect spillover effects through commodity and input markets.

V. What has been the experience to date?

The GTAP University (GTAP-U) SIMPLE-G short course has been offered twice so far, in 2019 and 2022, and will be offered again in the Spring of 2024. It was modeled after the highly successful GTAP-U short course which has been offered for 30 years at Purdue University. In a recent survey of SIMPLE-G short course participants, respondents particularly appreciated the deep dive into the spatial nature of SIMPLE-G and the collaboration opportunities with like-minded peers. Participants said that the course gave them the opportunity to learn new models and to investigate research questions in the economic-agricultural-environmental domains at fine spatial resolution. After the course, many of the participants report continued engagement with SIMPLE-G and/or the ability to engage with researchers that use SIMPLE-G. They particularly valued their enhanced capability to bridge the gap between disciplines.

The SIMPLE model, along with some exposure to SIMPLE-G, is taught at the graduate level at Purdue University through a course called 'Global Change and the Challenges of Sustainably Feeding a Growing Planet'. Students from many different disciplines take this course including agricultural economics, political science, agronomy, horticulture and earth, atmospheric, and planetary science. This course gives students the tools to address sustainability issues and help students build economic intuition around these issues. Furthermore, some of this course material has been adopted by Prof. Daniel Mueller at the Humboldt University in Berlin as part of a course for geography master's students. These applications focus on understanding the complex forces determining global land use change.

VI. Future Directions for SIMPLE-G in the Classroom and the Cloud

The SIMPLE-G modeling framework, as a spatially gridded economic model, is a powerful tool for teaching students to understand the global-local-global connections in land and water sustainability and food security. These models are becoming increasingly important as the scientific world becomes more interested in the socioeconomic perspective of the sustainability and food security and as the effects of global-local-global linkages on economic and environmental outcomes become more apparent.

There are several future directions for improving on the use of SIMPLE-G models in the classroom and in the cloud. One direction is to develop PC visualization tools that make it easier for students to view and explore the spatial outputs. Another direction is to develop a more flexible Jupyter Notebook that captures the full range of possibilities for scenario and experiment design.

In addition to the technical challenges, there are also a number of pedagogical challenges in teaching spatially gridded economic models like SIMPLE-G. One challenge is to find ways to communicate the spatial aspects of these models to students who may not have a strong background in spatial analysis. Similar challenges confront those students with limited background in economics. For both groups, remedial lectures need to be developed to ensure that they have the necessary knowledge to be successful. Another challenge is to develop engaging exercises and assignments that allow students from different backgrounds to apply their field knowledge within these models to address real-world problems.

As geospatial software platforms and models become more user-friendly, and as pedagogical materials are developed to address the challenges of teaching these models, we can expect to see an increase in the number of students who are exposed to them. In the future, we hope to expand access to this course material through increased cloud computing, bringing the material to more universities and research institutions, as well as introducing this material to a broad range of disciplines. The availability of the new SIMPLE-G book, YouTube videos, and subsequent voice-over PowerPoint presentations will establish a well-structured course outline for professors to adopt in the classroom or for established researchers to follow on their own. Access to this material will help bridge the gap between disciplines focusing on global-local-global analysis of the food-energy-land-water nexus. We believe it can also play an important role in expanding future collaborations between economists and their counterparts in the physical and social sciences seeking to address the emerging sustainability challenges that face local communities within the context of rapidly evolving global forces.

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