AGEC 528

Global Change and the Challenge of Sustainably Feeding a Growing Planet

Spring Semester, 2021

Tuesday/Thursday: 10:30 – 11:45am, BRNG 1238

An interdisciplinary course at Purdue University

Offered by Thomas W. Hertel

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Background and Motivation

Effective functioning of the global food system is critical to human well-being on the planet – providing nutrition, employment, other ecosystem services, and an important source of income for hundreds of millions of people, including a majority of the world's poorest households. However, this same food system is transforming the earth system – often in undesirable ways. These environmental stresses have recently been conceptualized as risks to the 'safe operating space' within the earth's planetary boundaries. Exceedances of these planetary boundaries represent potentially irreversible alterations of the earth system. Conversion of natural lands to farming and the loss of biodiversity, pollution from excess nutrient applications in agriculture, the depletion of groundwater stocks, and the emission of climate-altering greenhouse gases all pose significant risks to the planet. Balancing the critical role of the food system in feeding the world's growing population while respecting these planetary boundaries is one of the grand challenges faced by society today.

This class will explore the trade-offs and synergies arising out of these competing demands on the planet's finite resources, as well as potential pathways for sustainable development in the coming decades. We will do so within the context of an economic modeling framework that has proven amenable to integration of insights and knowledge from a variety of different disciplines, including agronomy, ecology, hydrology, biology, engineering, climate science, as well as a variety of social sciences. We will begin by exploring the drivers of change behind the evolution of the global food system. We will then explore different dimensions of its interactions with the natural environment – focusing specifically on land, water, and natural ecosystem services. We will also explore how infringement on the planetary boundaries, as evidenced through water scarcity or climate change, for example, may, in turn, alter the functioning of the food system.

Textbook **(e-book is free for Purdue Students via Purdue Libraries)**

Hertel, Thomas W. and U.L.C. Baldos, 2016. Global Change and the Challenge of Sustainably Feeding a Growing Planet, New York: Springer.
http://link.springer.com/book/10.1007%2F978-3-319-22662-0

Format for the class

This is a 3-credit class, meeting twice a week for a full semester. The first meeting of each week will introduce a new dimension of global land use, food and environmental security. We will kick off the week's activities with a guest lecture, followed by student-led discussion of the week's readings. The second meeting of each week will emphasize the economics underpinning how this particular dimension of the problem affects the global food system, resource use, environmental quality and nutritional outcomes. This will be motivated by the lab assignments that students undertake. The lab assignments are based on the SIMPLE economic model of global agriculture (a Simplified International Model of agricultural Prices, Land use and the Environment). These assignments will allow students to obtain a hands-on assessment of the relative importance of the forces bearing on the long run supply and demand for food and land resources, key economic mechanisms mediating these adjustments, and the implications for food security and the environment. The capstone event in this course is the student project, which will involve the application of SIMPLE to a problem of the student's choosing. (See the final section of this syllabus for a listing of some of the previous topics pursued by students.)

The structure of each week's module will be as follows:

First meeting of each week *(10:30 am - 11:45 am: Tuesday; Krannert G-5)*

1) 45 minute presentation on the weekly topic led by a faculty member
2) 30 minute student-led discussion of the week's readings

Second meeting of each week *(10:30 am - 11:45 am: Thursday; Krannert G-5)*

1) 30 minute presentation on the economic dimensions of the topic
2) 45 minute discussion of the lab assignment and application to the week's topic

Prerequisites

This is an interdisciplinary course. As such, there are few prerequisites. A prior course in economics will ensure an understanding of the basic aspects of supply, demand and economic equilibrium. A solid grasp of mathematics up to and including differential calculus is also essential to understand the lab assignments. Prior experience with mathematical modeling is also a plus.

Grading

Grades will be based on three factors: lab assignments (50%, 10% for each lab), the quality of student led discussions of readings (10%: students will be asked to submit two discussion questions in advance of Tuesday's lecture, each week, as well as leading the class discussion in one of the weeks), and the final project (40%), which will be the focal point of the second half of the semester. There is no exam in this course.

Learning Outcomes

By the end of the course, students will be well-versed in the current literature on food systems sustainability. They will also be able to use the SIMPLE modeling framework to examine a variety of food security and environmentally sustainability challenges at global scale. Finally, they will have accomplished a deep dive, using this model, into one issue of their own choosing, having written and paper and delivered a presentation to the class on that topic.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email. We will make arrangements for your course participation, based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

Attendance Policy during COVID-19

Students should stay home and contact the Protect Purdue Health Center (496-INFO) if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades, but the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email or by phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via email or phone at 765-494-1747.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask in classrooms and campus building, at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to

investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. More details are available on our course Brightspace table of contents, under University Policies.

Mental Health Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time. **If you need support and information about options and resources**, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm. **If you find yourself struggling to find a healthy balance between academics, social life, stress**, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu. **If you're struggling and need mental health services**: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Detailed Week-by Week Syllabus

Week 1: *Overview: Planetary Boundaries and the Food System in the 21st Century*
Jan. 19 - Lecture by Tom Hertel

During this week, we will obtain an overview of the factors governing the sustainability of the planet – particularly those relating to its land and water resources. We will also trace the long run evolution of agriculture and the challenges of sustainably feeding the world's growing population while respecting the planetary boundaries.

Required Readings:

Will Steffen, Katherine Richardson, Johan Rockstroem et al., (2015) "Planetary Boundaries: Guiding Human Development on a Changing Planet," *Science* 347(6223) DOI: 10.1126/science.1259855

Springmann, Marco, Michael Clark, Daniel Mason-D'Croz, Keith Wiebe, Benjamin Leon Bodirsky, Luis Lassaletta, Wim de Vries, et al. (2018) "Options for Keeping the Food System within Environmental Limits." *Nature* 562, no. 7728 (October): 519. https://doi.org/10.1038/s41586-018-0594-0

Text: Chapter 1: "Overview of Global Land Use, Food Security and the Environment"

Supplementary Reading:

Navin Ramankutty, Jonathan A Foley, and Nicholas J Olejniczak, "People on the Land: Changes in Global Population and Croplands during the 20th Century," *AMBIO: A Journal of the Human Environment* (2002): 251-257

Lab Assignment 0: *Introduction to the modelling software and overview of how to run experiments using the SIMPLE model*

Week 2: *Population growth and global food demand*
Jan. 26 Lecture by Tom Hertel

During this week, we will examine the impact of population and income growth on long run food demand. This debate traces its roots back to the classic publication by Thomas Malthus in 1798 in which he predicted that population would win the footrace between supply and demand for food. As population growth has slowed, the relative importance of dietary upgrading in this footrace has increased. These changes are largely driven by rising per capita incomes and the richer diets are much more land-intensive, hence putting additional pressure on the global resource base. When temporary scarcity arises, it is typically the low income households which experience significant reductions in food consumption in response to rising price. This response is important from the point of view of nutrition as well as the manner in which global supply and demand are balanced in the face of a limited resource base.

Required Readings:
Gerland, P., et al. "World population stabilization unlikely this century" *Science* 346, no. 6206: 234-237.

Keilman, Nico. 2020. "Uncertainty in Population Forecasts for the Twenty-First Century." *Annual Review of Resource Economics* 12 (1): 449–70. https://doi.org/10.1146/annurev-resource-110319-114841.

Textbook: Chapter 2: "Population and Income as Drivers of Global Change"

Supplementary Reading:

Lutz, W., W. Butz, S. KC, W. Sanderson and S. Scherbov. "9 billion or 11 billion: The research behind new population projections" http://blog.iiasa.ac.at/2014/09/23/9-billion-or-11-billion-the-research-behind-new-population-projections/ .

Clements, K. and J. Si, (2018). "Engel's Law, Diet Diversity and the Quality of Food Consumption", American Journal of Agricultural Economics 100(1):1-22.

Lab Assignment 1: *Simulate the impact on global and regional food demands in 2050 of varying assumptions about population growth and the income responsiveness of food demand.*

Scoping of interests: one-on-one meeting with Prof. Hertel to explore possible project topics

Week 3: *Yield Growth and Yield Gaps*
Feb. 2. Guest Lecture by Christopher Kucharik, Proessor and Head, Department of Agronomy, University of Wisconsin-Madison

Over the past 50 years, three-quarters of agricultural output growth came from higher yields. Can this success story be repeated over the next 50 years? There are signs that yield growth is slowing significantly for some key crops. Is this due to underinvestment in technology? Or is it due to looming bio-physical limits on yield increases? We will consider these questions as well as examining why yields are still so low in much of the world, and what it might take to allow farmers to close these yield gaps. The supplementary reading explores the role of risks and regulation in determining the success and adoption of new plant breeding technologies.

Required Readings:

R.A. Fischer, Derek Byerlee, and G.O. Edmeades (2014), Chapters 1 and 14 in *Crop Yields and Global Food Security,* "ACIAR, Canberra, Australia.

David B. Lobell, Kenneth G. Cassman, and Christopher B. Field, "Crop Yield Gaps: Their Importance, Magnitudes, and Causes," *Annual Review of Environment and Resources* 34, no. 1 (11, 2009): 179-204;

Textbook: Chapter 3: Sections 3.1-3.2: “Productivity Growth and Yields in the Global Crops Sector”

Supplementary Reading:

Qaim, Matin. 2020. “Role of New Plant Breeding Technologies for Food Security and Sustainable Agricultural Development.” *Applied Economic Perspectives and Policy* 42 (2): 129–50. https://doi.org/10.1002/aepp.13044.

Lab Discussion: *Examine the combined impact of population growth, income growth and biofuels on global land use in the context of supply response.*

Week 4: *Total Factor Productivity Growth in the Agricultural System*, February 9 - Lecture by Uris Baldos, Research Assistant Professor, Department of Agricultural Economics

Crop yield is a partial measure of productivity as it only reflects growth in output per unit of land input. Yields can rise due to improvements in technology – or simply due to increased use of fertilizers and other non-land inputs. To assess the overall changes in productivity in the agricultural sector, economists rely on total factor productivity (TFP) which takes into account all inputs used in agricultural production. During this week, we will explore the historical trends in agricultural TFP growth, its drivers, how changes in TFP affect consumers and producers and the implications of TFP growth for cropland use.

Required Readings:
Fuglie, K. 2018. “R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture.” *Applied Economic Perspectives and Policy* 40 (3): 421–44. https://doi.org/10.1093/aepp/ppx045

Baldos, Uris, and Thomas Hertel. 2018. “Productivity Growth Is Key to Achieving Long Run Agricultural Sustainability.” *Purdue Policy Research Institute, Policy Brief* 4 (1). https://docs.lib.purdue.edu/gpripb/ .

Textbook: Chapter 3: Sections 3.3-3.4: “Productivity Growth and Yields in the Global Crops Sector”

Lab Discussion: *Understanding the difference between total and partial factor productivity, and the role of endogenous yield changes.*

Lab Assignment 2: *Economic Responses to Scarcity in the Global Food System*

Week 5: *Supply response: Potential for Cropland expansion* February 16: Lecture by Nelson Villoria, Associate Professor, Kansas State University

Absent sufficiently rapid yield growth, expansion at the extensive margin is inevitable. Many authors have asked the question: How much land is available for cropland expansion? And how productive is this land? If it is available, why is it not presently farmed? How responsive are

producers' area expansion decisions to economic signals? What are the environmental consequences of expanding cropland area?

Required Readings:

Villoria, N., D. Byerlee and J.R. Stevenson. (2014). "The Effects of Agricultural Technological Progress on Deforestation: What Do We Really Know?" *Applied Economic Perspectives and Policy*, doi: 10.1093/aepp/ppu005.

Jonah Busch and Kalifi Ferretti-Gallon, "What Drives Deforestation and What Stops It? A Meta-Analysis," *Review of Environmental Economics and Policy* 11, no. 1 (January 1, 2017): 3–23, https://doi.org/10.1093/reep/rew013

Textbook: Chapter 4: "Economic Response to Scarcity"

Supplementary Reading:

Textbook Appendix B: "Analytical Framework: A Theoretical Model of Long Run Demand and Supply for Agricultural Land"

Lambin, Eric F. 2012. "Global Land Availability: Malthus versus Ricardo." *Global Food Security* 1 (2): 83–87. https://doi.org/10.1016/j.gfs.2012.11.002.

Lab Discussion: *Examine the combined impact of population growth, income growth and biofuels on cropland expansion around the world and the interactions between the intensive and extensive margins of supply response.*

Lab Assignment 3: *Examine the impact of economic growth and climate change on undernutrition.*

Week 6: *Environmental Impacts of Agriculture: Water Quality* February 23 – Guest Lecture by Professor Jane Frankenberger, Department of Agricultural and Biological Engineering

Excess nutrient runoff from agricultural lands is arguably the most important environmental impact of farming in the Corn Belt. Nitrogen and Phosphorous loadings have not only polluted groundwater in the region, they has increased the cost of municipal water treatment and resulted in a massive dead zone in the Gulf of Mexico. This had led to calls by the National Hypoxia Task Force to reduce nitrate leaching by 45% in the Mississippi Basin. In light of ongoing pressures to increase food production, this presents a massive challenge. Fortunately, there are potential solutions to this problem involving improved in-field practices designed to increase nitrogen use efficiency, crop rotations which can reduce run-off, as well as edge of field practices such as managed drainage and wetland restoration which have the potential to reduce nutrients ending up in streams and rivers. During this week we will explore the nature of these challenges and how these site-specific measures might feedback to regional, national and global markets.

Required Readings:

Rabalais, Nancy N., and R. Eugene Turner. “Gulf of Mexico Hypoxia: Past, Present, and Future.” *Limnology and Oceanography Bulletin* 28, no. 4 (2019): 117–24. https://doi.org/10.1002/lob.10351.

Diaz, R. J. & Rosenberg, R. (2008). Spreading Dead Zones and Consequences for Marine Ecosystems. *Science* 321, 926–929.

Donner, S. D. & Kucharik, C. J. (2008). Corn-based ethanol production compromises goal of reducing nitrogen export by the Mississippi River. *PNAS*, 105, 4513–4518 (2008).

Supplementary Readings:

Liu, Jing, Thomas Hertel, Laura Bowling, Sadia Jame, Christopher Kucharik, and Navin Ramankutty. 2018. “Evaluating Alternative Options for Managing Nitrogen Losses from Corn Production.” *Purdue Policy Research Institute, Policy Brief* 4 (3). https://docs.lib.purdue.edu/gpripb/ .

Lab Discussion: *Examine the potential for policy interventions to mitigate excess nutrient runoff from agriculture in the US Corn Belt and explore the consequences of these policies for regional and global markets.*

Week 7: *Globalization, and the scope for feeding the world sustainably in 2050*
March 2 – Lecture by Uris Baldos, Research Assistant Professor, Department of Agricultural Economics

Global demands are increasingly driving local sustainability stresses, and responses to those stresses feed back to the global level. However, the extent of these interactions depends critically on international trade and the degree of global market integration. In this week, we will explore these themes, emphasizing the role of globalization in driving local outcomes as well as the consequences of policies put in place to improve food and environmental security.

Required Readings:
Hertel, T.W. and U.L.C. Baldos. (2016) “Attaining Food and Environmental Security in an Era of Globalization”, *Global Environmental Change*, 41:195-205.

Eric Lambin and Partick Meyfroidt, “Global land use change, economic globalization and the looming land scarcity”, *Proceedings of the National Academy of Sciences,* www.pnas.org/cgi/doi/10.1073/pnas.1100480108

Haqiqi, Iman, Laura Bowling, Sadia Jame, Thomas Hertel, Uris Baldos, and Jing Liu. 2018. “Global Drivers of Land and Water Sustainability Stresses at Mid-Century.” *Purdue Policy Research Institute, Policy Brief* 4 (1). https://docs.lib.purdue.edu/gpripb/ .

Text: Chapter 11: “Global Change and the Food System in 2050”

Lab Assignment 4: *Examine the consequences of market segmentation for the effectiveness of sustainability policies.*

Week 8: *Consumer Preferences for Food: Implications for Sustainability*
March 9 – Guest Lecture by Jayson Lusk, Distinguished Professor & Department Head, Agricultural Economics

Up to this point, we have focused on heavily on the supply side of the global sustainability challenge. In this week, we will consider the role of consumer preferences and food policies in shaping the global agricultural landscape and the potential for achieving a more sustainable future.

Required Readings:
Lusk, J. (2017). "Evaluating Policy Proposals of the Food Movement", *Applied Economic Perspectives and Policy*, Volume 39, Issue 3, 1 September 2017, Pages 387–406, https://doi.org/10.1093/aepp/ppx035

Clark, Michael A., Marco Springmann, Jason Hill, and David Tilman. 2019. "Multiple Health and Environmental Impacts of Foods." *Proceedings of the National Academy of Sciences* 116 (46): 23357–62. https://doi.org/10.1073/pnas.1906908116 .

Supplementary Reading:
Lusk, J. (2013). Lunch with Pigou: Externalities and the "Hidden" Cost of Food. *Agricultural and Resource Economics Review, 42*(3), 419-435. doi:10.1017/S1068280500004913

Lab Discussion: *Analysis of the impact of reducing food waste on global food and environmental security.*

Week 9: *Nutrition: The Triple Burden*
March 16 - Guest Lecture by Nilupa Gunaratna, Assistant Professor of Public Health (TBC)

Nutrition and food security are closely linked to developments in the agricultural sector. With obesity eclipsing undernourishment in many developing countries, the nutrition challenge has become much more complex. Adding to this the pervasive micro-nutrient deficiencies that are now being identified, and it is clear that global nutrition now faces a triple-burden. Innovative interventions will be required to improve nutritional outcomes.

Required Readings:

Gómez, Miguel I., Christopher B. Barrett, Terri Raney, Per Pinstrup-Andersen, Janice Meerman, André Croppenstedt, Brian Carisma, and Brian Thompson. "Post-green revolution food systems and the triple burden of malnutrition." Food Policy 42 (2013): 129-138.

Black, R.E., L.H. Allen, Z.A. Bhutta, L.E. Caulfield, M. de Onis, M. Ezzati, C. Mathers and J. Rivera. (2008). "Maternal and Child Under-nutrition: Global and Regional Exposure and Health Consequences", *Lancet* (371):243-260.

Textbook: Chapter 10: "Food Security and Nutrition"

Supplementary Reading:

Behrens, P. et al. (2017). “Evaluating the Environmental Impacts of Dietary Recommendations”. *PNAS* 114(51):13412-13417.

Lab Discussion: *The evolution of global and regional undernutrition under alternative future scenarios.*

Begin outlining ideas for class project

READING DAY: MARCH 18

Week 10: *Water Availability: Constraints and Opportunities*
March 23: Guest Lecture by Danielle Grogan, Research Scientist, University of New Hampshire

Presently two-fifths of global crop production comes from irrigated areas that, when combined, account for just one-fifth of total cropland. This is a reflection of the very high productivity of irrigated agriculture. However, this irrigation activity accounts for 70% of freshwater withdrawals, and projections indicate that 50% of global river basins will be experiencing severe shortages by 2030. This will inevitably translate into water scarcity and ultimately to reductions in the water available for farming. Thus, water will be an increasingly key limiting factor for agricultural production in the coming decades.

Required Readings:
Jacob Burke and Karen Villholth, “Groundwater: a global assessment of scale and significance,” in *Water for Food, Water for Life*, ed. David Molden (London and Colombo: Earthscan and International Water Management Institute, 2007), 395-423;

Baldos, U. L. C., I. Haqiqi, T. Hertel, M. Horridge, and J. Liu. 2020. “SIMPLE-G: A Multiscale Framework for Integration of Economic and Biophysical Determinants of Sustainability.” Environmental Modelling & Software, August, 104805.

Textbook: Chapter 5: “Water, Food and Environmental Security”

Supplementary Reading:

Laura C. Bowling and Keith A. Cherkauer (2018). “The Green, Blue and Gray Water Rainbow”, Chapter 2 in *How to Feed the World*, J. Eise and K. Foster (eds.), Washington: Island Press.

Perry, Chris J. Video discussion of Jevon’s Paradox: https://youtu.be/BiLEjPgSoXc

Lab Assignment 5: *Analyzing the impacts of improvements in irrigation efficiency at the level of individual grid cells.*

Class project: one-on-one meeting with Prof. Hertel to finalize topic

Week 11: *Post-Harvest Losses and Food Waste*
March 30 – Guest Lecture by Jake Ricker-Gilbert, Professor of Agricultural Economics

Goal 12.3 of the United Nations' Sustainable Development Goals aims to cut in half the global food waste and post-harvest losses by 2030. How large are these losses? What are the barriers to achieving this goal? The global food system is extremely diverse, so we will focus attention this week on on-farm, post-harvest storage losses in Sub-Saharan Africa. The Purdue Improved Crop Storage (PICS) Project has developed technologies that have been widely recognized as being valuable in lowering losses. But there remain important barriers to widespread adoption and we will explore these issues and the potential impacts of reducing post-harvest losses on food and environmental security.

Required Readings:

Kaminski, Jonathan, and Luc Christiaensen. 2014. "Post-Harvest Loss in Sub-Saharan Africa—what Do Farmers Say?" *Global Food Security*, SI: GFS Conference 2013, 3 (3–4): 149–58. doi:10.1016/j.gfs.2014.10.002

Omotilewa, O., J. Ricker-Gilbert, J.H. Ainembambazi, and G. Shively. 2018. "Does improved storage technology promote modern input use and food security? Evidence from a randomized trial in Uganda." *Journal of Development Economics* 135:176-198.

Supplementary Reading:

Lopez Barrera, Emiliano, and Thomas Hertel. 2020. "Global Food Waste across the Income Spectrum: Implications for Food Prices, Production and Resource Use." *Food Policy*, March, 101874. https://doi.org/10.1016/j.foodpol.2020.101874.

Lab Discussion: *Evaluate the impact of reducing post-harvest food losses in Africa. Also evaluate the impact of reducing food waste in the OECD.*

Continue work on class projects

Week 12: *Biodiversity and Ecosystems Services*
April 6: Guest Lecture by Professor Jeff Dukes, Director of the Purdue Climate Change Research Center (TBC)

There are many dimensions of biodiversity. Here, we will focus on those that affect agricultural production and sustainability. This is often termed 'natural capital' and it can play an important role stimulating agricultural output (e.g., natural pollinators) or aiding in achieving sustainability goals (e.g., sequestering carbon and reducing GHG emissions).

Required Readings:
Chaplin-Kramer, Rebecca, Richard P. Sharp, Charlotte Weil, Elena M. Bennett, Unai Pascual, Katie K. Arkema, Kate A. Brauman, et al. 2019. "Global Modeling of Nature's Contributions to People." *Science* 366 (6462): 255–58. https://doi.org/10.1126/science.aaw3372 .

Rieb, Jesse T., Rebecca Chaplin-Kramer, Gretchen C. Daily, Paul R. Armsworth, Katrin Böhning-Gaese, Aletta Bonn, Graeme S. Cumming, et al. 2017. “When, Where, and How Nature Matters for Ecosystem Services: Challenges for the Next Generation of Ecosystem Service Models.” *BioScience* 67 (9): 820–33. https://doi.org/10.1093/biosci/bix075 .

Text: Chapter 7, Sections 7.1, 7.3, 7.4: “Land-based Environmental Services”

Supplementary Reading:

T.H. Ricketts and E. Lonsdorf, (2013) “Mapping the Margin: Comparing Marginal Values of Tropical Forest Remnants for Pollination Services”, *Ecological Applications* 23(5):1113-1123.

Lab Discussion: *Analysis of the impacts of pollinator losses on sustainability of the food system.*

Continue work on class projects

READING DAY: APRIL 13

Week 13: *Climate Change as a factor influencing global agriculture* April 15 - Guest lecture by Matt Huber, Professor of Earth and Atmospheric Sciences

The question of meeting global food, fiber and fuel demands in 2050 is greatly complicated by the prospect of climate change which is likely to alter temperature and precipitation as well as the frequency and intensity of extreme events. How will climate change affect land use? This will depend not only on the absolute impacts, but also on the relative impacts – the changes in comparative advantage of competing land using activities across regions of the world.

Required Readings:

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Schlenker, W. and M. Roberts, 2009. “Nonlinear temperature effects indicate severe damages to US crop yields under climate change”, *Proceedings of the National Academy of Sciences*, 106:37: 15594-15598.

Textbook: Chapter 6: “Climate Change Impacts in Agriculture”

Lab Discussion: *Analysis of the impacts of pollinator losses on sustainability of the food system.*

Continue work on class projects

Week 14: *Mitigating Greenhouse Gas Emissions: The Role of Emissions Trading*
April 20 - Lecture by Leigh Raymond

Most land management policies aimed at curbing GHG emissions and mitigating the effects of climate change are directed toward restoring and preserving natural forests. However, these policies will have unintended consequences for the availability of farmlands in the future. Some studies also point out the potential for GHG mitigation in the agricultural sector by reverting current croplands to natural land cover. During this week, we will explore the potential for emissions trading to contribute to the mitigation of GHG emissions and the effect of these land-based climate mitigation policies on global crop production and food prices.

Required Readings:

Griscom et al. (2017). "Natural Climate Solutions". *Proceedings of the National Academy of Sciences*.

Golub, A.A., B.B. Henderson, T.W Hertel, P. Gerber, S.K. Rose and B. Sohngen (2012). "Global Climate Policy Impacts on Livestock, Land Use, Livelihoods and Food Security", *Proceedings of the National Academy of Sciences*.

Text: Chapter 7, Sections 7.2, 7.5: "Land-based Environmental Services"

Supplementary Readings:

Brent Sohngen, "An Analysis of Forestry Carbon Sequestration as a Response to Climate Change" (*Copenhagen Consensus on Climate*, 2010)

Lab Discussion: *Examine the impact of land use change on GHG emissions. Explore exogenous shifts in the supply of land to agriculture in response to climate mitigation policies. 0*

Finalize class projects for presentation

Week 15: Presentation of Class Projects, April 27 and 29

Each individual will briefly present highlights from their class project, with time for Q&A with the rest of the class. A full write-up, in the form of a short research paper, will be submitted at the end of the semester. A menu of project ideas from previous years follows.

Ideas for Class Projects

(These are based on past class projects. We expect that many more ideas will emerge from our discussions during class):

1. ***Food Waste and Post-Harvest Losses:*** The UN-FAO estimates that one-third of global food production is lost or wasted so that only two-thirds of production is actually consumed. What are the implications of such losses for crop prices? How would a reduction in post-harvest losses affect nutritional outcomes?
2. ***Changing Nutrition Guidelines:*** The USDA is in the process of formulating a new set of nutrition guidelines. For the first time they are considering adding environmental impacts to these guidelines. How would such considerations change the pattern of food consumption? How would changing consumption patterns alter the pattern of global land use and GHG emissions?
3. ***Regulating non-point source pollution from agriculture:*** Arguably the most important environmental problem surrounding agricultural production in the Midwestern United States if the run-off of excess nutrients into streams, rivers and coastal ecosystems. The resulting incidence of hypoxic 'dead zones' has led to calls to greatly restrict nutrient use in agriculture as well as investing in conservation policies. How will such regulations affect production, prices and food security? Which are the most effective policies?
4. ***Economic impacts of biodiversity loss:*** Cropland expansion and intensification have been shown to result in biodiversity loss. One source of biodiversity that is important for agriculture is the presence of natural pollinators. What are the impacts of pollinator loss on agricultural yields, and hence the need for further cropland expansion?
5. ***Empowerment of Women: Implications for Global Food Security:*** Women comprise a large share of the agricultural labor force and female-headed farms represent a large share of agricultural enterprises worldwide. Women are also key decision makers when it comes to household nutrition and fertility. As such, they are in a unique position to influence local, regional and global food security outcomes. However, lack of education and limited access to credit and other inputs currently limit the impact which women can have on these outcomes. How would greater empowerment of women change the global food security landscape?
6. ***Migration and Global Food Security:*** The migration of individuals across national borders is a global phenomenon which is currently on the rise. It affects for the supply of, and the demand for, food. What is the net impact on global food security of trends in international migration?
7. ***Virtual Trade in Water:*** Scientists have recently identified 'virtual trade in water' as an important element of the global sustainability puzzle. Virtual water exports arise when one country exports water intensive goods to another country. The water embodied in the production of this commodity for export is termed 'virtual water' and recent studies have documented the extent of such 'trade'. In light of the trends in population, income, productivity and biofuels alter virtual water trade between the present day and 2050?
8. ***Constraints on irrigated agriculture****:* Almost 40% of the world crop production is coming from irrigated lands. However, growing scarcity of water threatens to limit the potential of irrigated agricultural production to feed the world. Excessive water withdrawals also threaten to increase soil salinity and soil productivity. What are the potential impacts of constraints in irrigated agriculture on the global farm and food system.
9. ***Africa as the Sleeping Giant of Agriculture:*** In 2009, the World Bank published a report suggesting that the Guinea Savannah Zone of Africa could become the next breadbasket for the world. What would be the implications of such a development?

10. ***Urbanization:*** In one of our lab discussions, we explored urbanization's impacts on demand for land. However, one could dig deeper by looking at the quality of land that is being displaced. What are the implications for global land use, food security and the environment.
11. ***REDD:*** Similar to **Urbanization**, students explore the impact of efforts to dedicate additional land to the production of environmental services. This is implemented through adjustments to the regional conversion factors of land in environmental services to cropland.
12. ***Climate change:*** We also explored in our lab discussions the impacts of different types of climate shocks on agricultural productivity and land use. A deeper dive might entail converting existing studies of the impacts of climate change into shocks or parameter adjustments within our own model and exploring the results. It is also possible to consider the impact of elevated heat and humidity on labor capacity in agriculture and the consequences for food prices.
13. ***Jevon's paradox:*** Jevon's paradox reflects a situation in which increased efficiency in the use of a resource results in greater use of that resource. In the case of land, for example, farm productivity growth might lead to greater land conversion. A deeper exploration of the conditions under which we might expect such a result would be interesting. What is the demand elasticity required to generate this outcome? How do yield differentials across regions affect the likelihood of this outcome? Can these results tell us anything about the probability of experiencing Jevon's paradox in the real world?
14. ***Impacts of shifting population and income on global demand elasticity:*** Economists have ascertained that wealthier consumers tend to be less responsive to changes in income and prices. Regional differences in demographics and income growth will shift the balance of global demand. How do these shifts change the aggregate global demand elasticity? How does this compare to evolving demand elasticities within regions? What impact does this have in moderating/amplifying the response of food prices to supply side shocks such as drought and heat waves?
15. ***Biophysical/economic interaction:*** Relative yields (local yields versus the global maximum) might be indicative of how close a particular region is to the biophysical limits of intensification given current technologies. What do these limits imply for future projections of crop supplies and long run prices?
16. ***Impacts of different types of technology growth:*** In our model, we can simulate land augmenting, land dis-augmenting and technology neutral productivity. What are the realistic ranges of these types of productivity growth going forward? If yield growth outpaces non-land technology growth, what would be the impact on prices and extensification? Under different scenarios, does the clear relationship between land prices and extensification begin to break down?
17. ***Globalization:*** We have spent relatively little time in the labs relating global processes to local outcomes. However, it can be shown analytically that the *effective* elasticity of demand for a local market depends on the rest of the world's supply elasticity, the local production's share of the global market as well as the global demand elasticity. Among other possibilities, an analysis of globalization's impact might compare the extensification impacts of productivity changes in small markets (share of world supply is small) to large markets.
18. ***Changing productivity of livestock and food processing:*** We've spent a fair amount of time evaluating the impacts of changing agricultural productivity. However, one could also assess the implications of changes in the TFP of livestock production or food processing. Contradictory effects of these downstream productivity changes (less crops required to produce a good, but demand is now increasing) may lead to interesting results depending on the assumed parameter values.

19. ***Market mediated responses:*** Hertel (2011) highlights the importance of considering economic factors when estimating the land use implications of changes in biofuels demand. A similar analysis could assess to what scale biophysical estimates of the impacts of demand shocks (e.g. population growth, income expansion) are moderated through economic processes such as intensification and demand reduction.
20. ***Cost-benefit analysis of productivity growth:*** Several papers provide estimates of the cost and scale of historical TFP growth. Using these estimates, one could estimate the consumer surplus generated by the yield growth to evaluate the cost effectiveness. Similarly, estimates of the cost per hectare saved would be possible for land-sparing technologies.
21. ***Water quality trading in the Chesapeake Basin:*** We have examined the impact of fertilizer use in agriculture, as well as the consequences of excess nutrients for water quality. This is a particularly important problem in the Chesapeake Bay region. Using the gridded version of SIMPLE-G, it is possible to develop nitrate leaching mitigation cost curves to explore the potential for profitable pollution trading with industrial and municipal point-sources of pollutants.