AGROECOSYSTEMS AND GLOBAL CHANGE
Agronomy/Environmental Studies/Agroecology 724
Fall Semester 2015

Course Description
Revised 9.02.15 CJK

Course Details

Prof. Christopher J. Kucharik
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(Tel: 890-3021; kucharik@wisc.edu)

Teaching Assistant: Anna Cates (acates@wisc.edu); 3120 Wisconsin Energy Institute

My travel schedule: November 15-18, tri societies annual meeting, MSP.

MEETING TIME: **Tuesday and Thursdays 11:00-12:15 PM** in room 351 Moore Hall
OFFICE HOURS: By appointment and email
LEVEL: Open to graduate students
PREREQUISITES:

- previous coursework in college-level biology or ecology & 1 semester college-level chemistry or physics
- OR consent of instructor

CREDIT HOURS: 3
CLASS SIZE: Limited to 30 students
COURSE WEBSITE: login with your ID at - https://learnuw.wisc.edu/
FINAL COURSE PROJECT: Due Friday, December 18 at 5pm.

Course Description

This course is intended to help students examine how agroecosystems have been impacted by global changes, how agricultural land management has contributed to emerging environmental problems – but is also being viewed as a means to solve new issues (e.g., bioenergy), and how future global change drivers (e.g., climate, atmospheric chemistry, land management, and policy) are likely to impact agroecosystems and the goods and services we derive from them. Sections of the course include: (1) an introduction to the global change drivers that impact the structure and functioning of agroecosystems; (2) how agricultural land use is an important global change driver itself; (3) how land management can impact the climate system and contribute to further global warming or mitigation of it; (4) study of the concept of "ecosystem goods and services" derived from agriculture, and emerging issues related to sustainability and biofuels derived from agricultural landscapes; and (5) a summary of how modeling tools are used to study these complex problems of the soil-plant-atmosphere system. The course lectures conclude with a detailed analysis of case studies of agriculture and environmental issues – related to concepts covered earlier in the course. "Lightning round" type talks (3 slides x 5 minutes) of student research projects will occur during the last few lectures of the course.

Expectations

Students are expected (1) to participate actively in course lectures and discussion; (2) complete all assigned readings prior to the course lectures; (3) take two mid-term exams; (4) complete two homework assignments; (5) complete final project report that will be due during finals week and present your results in a "lightning round" format (3 slides x 5 min format) during the last few lectures of class. Lecture notes/slides and other materials will be provided on-line as PDFs (https://learnuw.wisc.edu; login with your UW ID). Lecture notes will be put on-line in PDF format **after** the lectures have been presented in class.

Reading Assignments

Because there is no single textbook used, this course will rely heavily on readings from the recent scientific literature as well as other handouts and/or postings in PDF format online that I will acquire from various book chapters. It is expected that each student will have completed the reading assignments before each lecture. Exam and homework questions will be taken from both in class lectures and from material covered in the readings that may not necessarily be part of lecture presentations and notes.

Supplemental textbooks (suggested only as references, not required):

Canadell, J.G., D.E. Pataki, and L.F. Pitelka, 2007. Terrestrial ecosystems in a changing world. 336 pp.
Cotton, W.R., and R.A. Pielke Sr., 2007. Human impacts on weather and climate. 308 pp.
Jackson, L.E. 1997. Ecology in Agriculture. 472 pp.
Lal, R. et al., 2005. Climate change and global food security. 778 pp.
Lambin, E.F., and H.J. Geist, eds. 2006. Land-use and land-cover change. 222 pp.
Loomis, R.S. and D.J. Connor, 1992. Crop ecology. 538 pp.
Newton, P.C.D. et al., (eds.) 2007. Agroecosystems in a changing climate. 364 pp.
Pritchard, S.G. and J.S. Amthor, 2005. Crops and Environmental Change. 421 pp.
Rosenzweig. C. and D. Hillel, 1998. Climate change and the global harvest. 324 pp.
Steffen, W., A. Sanderson, P.D. Tyson et al., 2005. Global change and the earth system. 336 pp.

Teaching Philosophy

My overall philosophy in teaching is to challenge students to think in a way that they are often not accustomed to – using the tools and skills they acquire to tackle problems and questions they have never been exposed to. I challenge students to elevate their level of thinking and apply themselves in real-life problem solving exercises as much as possible. The philosophical approach that I take involves the following crucial elements that I believe transcend many disciplines:

- Problem solving in today's society, no matter what job students take on after college or graduate school, will require students to use the tools and skills they have acquired in a combination that may be unfamiliar to their overall thought process. I try to get students to understand that being able to recite important facts, figures, or equations is not how people advance in careers or solve everyday problems. Today, there is an increasing need for **well-trained interdisciplinary scholars** in environmental sciences. To me, interdisciplinary means much more than just acquiring knowledge on a variety of subjects. Instead, I have found that teaching specific "skills" to students for problem solving is almost more important than the subject matter. This includes both quantitative and qualitative assessments.

- I use a "**systems**" perspective in teaching, and emphasize how individual systems interact with one other, often leading to unpredictable and unintended consequences. This is particularly evident in environmental sciences including meteorology, ecology, biology, agronomy, and agriculture. Students should learn to appreciate or have a realization that systems do not function separately from one another.

- I use real-life examples and case studies to allow students to actively engage in discussion with each other about examining problems, or to simply decide what is the question that needs to be answered. In environmental courses I have taught or other guest lectures I have given, I use "**case-studies**" of particular geographic regions that are experiencing some type of problem related to human pressure on natural resources.

Grading

Final grades for the course will be based on the following contributions:

- Participation in class discussion (10%)
- Two midterm exams (20% each) = 40% total
- Two problem set assignments (15% each) = 30% total. I expect that assignments will be turned in on time! Late assignments will not be accepted unless there are extenuating circumstances.
- Final project presentation and report (20%). Project presentation will be peer-reviewed.

Grading will follow the following scale:

- 93 – 100 A
- 88 – 92 A/B
- 83 – 87 B
- 78 – 82 B/C
- 70 – 77 C
- 60 – 69 D
- < 60 F

Cheating

While you might feel unnecessary for me to remind graduate students of this – I've dealt with academic misconduct cases in the past to forego mention of this issue. I expect that a student's work on homework and exams is his or her own, not someone else's, and not a group effort. Cheating and/or plagiarism by students will not be tolerated, and will be treated according to UW Academic Misconduct Guidelines in dealing with the offense. This may range from failure on an assignment or exam, failure in the course, or expulsion from UW-Madison – foregoing your opportunity to receive a degree from here – EVER – in the future. As a note (and fair warning) I have previously caught students cheating on quizzes and a final exam in another course, and several others failed assignments for plagiarism. In a few of these cases, the students ended up failing the course because of their wrongdoing. So, please, please, please don't test the system unless you want to jeopardize your entire academic future here at UW-Madison.

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<u>Course Syllabus</u>
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Dates	**Topic**	**Key readings I will draw from for following lecture**	**Deadlines/ other notes**
Section 1: Drivers of change: population, land-use change, biotechnology, mechanization, climate change & atmospheric chemistry			
Thu Sep 3	Course overview; discussion of agroecosystems; global population growth; environmental changes *IonE video "Feast or Famine"*	Ramankutty et al. 2002a Ramankutty et al. 2002b Foley et al., 2005 Ramankutty et al. 2008	
Tue Sep 8	Historical changes in land-use & land cover: *Farming the planet – what, where, why, and when? Croplands and Pastures*	Cassman et al., 2002 Wollenweber et al., 2005 Sassenrath et al., 2008 Ronald, 2011 Varshney et al., 2011 Ray et al. 2012	*Interesting article on breeding/genetics: "Corn Wars", 2015*
Thu Sep 10	Mechanization and technology: *crop productivity impacted by biotechnology, mechanization, and GMOs; irrigation; fertilizer use/efficiency*	Arbuckle et al., 2013 Hmielowski et al., 2013 Rejesus et al., 2013	*Visit Yale Climate Opinion Maps: http://environment.yale.edu/poe/v2014/*
Tue Sep 15	Perspectives on Climate Change: *The media, politicians, farmer acceptance, and the public's perception* *Oliver video*	Rosenzweig and Hillel, 1998 (<u>Chapter 3</u>) Long et al., 2006 Lobell and Field, 2007 Long and Ort 2010 Hatfield et al., 2011 Lobell and Gourdji 2012	
Thu Sep 17	Part I: Impacts of atmospheric CO_2, O_3 & temperature and precipitation: *plant physiology and crop productivity; soil resources; weeds, insects, and diseases*	Rosenzweig and Hillel, 1998 (<u>Chapter 4</u>) Fiscus et al., 2005 Feng and Kobayashi, 2009 Fishman et al., 2010 Myers et al. 2014	
Tue Sep 22	Part II: Impacts of atmospheric CO_2, O_3 & temperature and precipitation: *plant physiology and crop productivity;*	McPherson, 2007 Anderson-Teixeira et al. 2012 Hungate and Hampton 2012	

	soil resources; weeds, insects, and diseases	Bagley et al., 2014	
Section 2: Agricultural land use and feedbacks on the climate system			
Thu Sep 24	Land use and feedbacks on the climate system: concepts of *biogeochemical & biogeophysical feedbacks; water and energy balance*	Rosenzweig and Hillel, 1998 (Chapter 2) Robertson et al., 2000 Robertson et al. 2011 Gelfand et al. 2013	
Tue Sep 29	Biogeochemical feedbacks: *carbon balance*; *agricultural emissions of CO_2, N_2O, and CH_4; concept of carbon sequestration*	Horton et al., 1996 Lobell et al., 2006 Wolf and Market, 2007 Bonfils and Lobell, 2007 Georgescu et al. 2011 Schatz and Kucharik, 2014	**Problem set #1 handed out**
Thu Oct 1	Biogeophysical: *changes to surface albedo and energy balance from irrigation and tillage practices; case studies of Iowa, California, Madison; Global modeling studies*	Macbean and Peylin, 2014 Gray et al., 2014 Zeng et al. 2014 Luyssaert et al. 2014 Powlson et al., 2014	
Tue Oct 6	Other recent examples of bidirectional feedbacks between agriculture and the climate system	Baldocchi et al., 2001 Verma et al., 2005	**Problem set #1 due beginning of class**
Thu Oct 8	**Observational networks: AmeriFlux**, measurements of carbon, water, and energy balance in agroecosystems – AmeriFlux and Mead, Nebraska		
Tue Oct 13	**MIDTERM EXAM #1: Material covered through Oct 8**	Robertson et al., 2008 Keeney, 2009 McBride et al., 2011 Davis et al., 2013 Robertson et al., 2014	
Section 3: Agroecosystems, biofuels, and environmental sustainability			
Thu Oct 15	Sustainability and bioenergy: *overview of ecosystem goods and services derived from agroecosystems*	Pimentel, 2003 Hill et al., 2006 Farrell et al., 2006 Wald, 2007 Wang et al. 2012	
Tue Oct 20	Corn grain ethanol vs. cellulosic	Fargione et al., 2008	

	bioenergy: *net energy balance of corn grain ethanol, biodiesel, and cellulosic ethanol from switchgrass*	Searchinger et al., 2008 Holzman, 2008 Mathews and Tan, 2009 Gelfand et al., 2011	
Thu Oct 22	Land use change to support bioenergy I: GHG emissions; *carbon debts; direct vs. indirect impacts of land use change*	Tilman et al., 2006 Vavrel et al., 2008 Cruse and Herndl, 2009 Delgado 2010 Liska et al., 2014 Qin et al., 2015	
Tue Oct 27	Land use change to support bioenergy II: *Soil organic matter/carbon sequestration: impacts of grassland biodiversity and crop residue impacts*	Groom et al., 2008 Hill et al., 2009 Dominguez-Faus, 2009 Dale et al., 2010 Meehan et al., 2012	
Thu Oct 29	Land use change to support bioenergy III; *water quantity and quality; air pollution and human health; biodiversity*	Johnston et al., 2009 Lobell et al., 2009 Licker et al., 2010 Mueller et al. 2012 Foley et al., 2011	
Tue Nov 3	Global crop yields & yield gaps; *why do they exist; global expectations of future bioenergy production*	Van Loocke et al. 2010 Nair et al., 2012 Kucharik et al., 2013 Bagley et al. 2014 (review)	**Final Project Assignment given** **Problem set #2 handed out**
Thu Nov 5	Modeling *bioenergy cropping systems*	Slater et al. 2010 Oates et al. 2015 Hamilton et al., 2015 Werling et al., 2013	
Tue Nov 10	Overview of Sustainability Research as part of the Great Lakes Bioenergy Research Center (GLBRC)	Kraft et al., 2012	Anna Cates Lecture **Problem set #2 due beginning of class**
Section 4: Case studies: This year's themes are water and carbon			
Thu Nov 12	**Case Study 1:** *Agricultural land use and water issues in the Wisconsin: Central Sands water resources*		
Tue Nov 17*	**MIDTERM EXAM #2: Oct 15 through Nov. 12**	Qiu and Turner, 2013 Gillon et al., 2015 Carpenter et al. 2015 Wardropper et al. 2015	Readings for lectures on Nov 19 and Nov 24
Thu Nov 19	**Case Study 2:** *Agricultural land use*		

	and water issues in Wisconsin: Yahara Watershed *Yahara 2070 – pathways for the future*		
Tue Nov 24	**Case Study 2 cont.** Yahara Watershed and Yahara 2070 Scenarios and Model Output	DeLuca and Zabinski, 2011 Schmidt et al., 2011	
Thu Nov 26	**THANKSGIVING BREAK – NO CLASS**		
Tue Dec 1	**Case Study 4:** *Soil C sequestration: past results and looking towards the future*	Sanford et al., 2012 Prescott, 2010	Anna Cates lecture
Thu Dec 3	**Case study 4 continued:** *Soil C sequestration*		Anna Cates lecture
Tue Dec 8	**Course project presentations**	3 slides / 5 minute format	
Thu Dec 10	**Course project presentations**	3 slides / 5 minute format	
Tue Dec 15	**Course project presentations**	3 slides / 5 minute format	*In class evaluations of course*
Fri Dec 18	**FINAL PROJECT WRITTEN REPORT DUE 5PM – emailed to CJK**		

- Tue Nov 17 I will be away
- Course project presentations will be evaluated by peers as well as myself and Anna Cates

***Class readings – PDFs available for download;** others for your reference

<u>SEP 3: Historical changes in land-use and land cover</u>

***Foley, J.A., R. DeFries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, M.T. Coe, G.C. Daily, H.K. Gibbs, J.H. Helkowski, T. Holloway, E.A. Howard, C.J. Kucharik, C. Monfreda, J.A. Patz, I.C. Prentice, N. Ramankutty, and P.K. Snyder (2005). Global consequences of land use. Science 309, 570-574.**

***Ramankutty, N., J.A. Foley, and N.J. Olejniczak (2002). People on the land: Changes in global population and croplands during the 20th century. Ambio 31(3), 251-257.**

***Ramankutty, N., J.A. Foley, J. Norman, and K. McSweeney (2002). The global distribution of cultivable lands: current patterns and sensitivity to possible climate change. Global Ecology and Biogeography 11, 377-392.**

***Ramankutty, N., A.T. Evan, C. Monfreda, and J.A. Foley (2008), Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. Global Biogeochemical Cycles 22, GB1003, doi:10.1029/2007GB002952.**

Monfreda, C., N. Ramankutty, and J.A. Foley (2008). Farming the planet. Part 2: Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. Global Biogeochemical Cycles 22, GB1022, doi:10.1029/2007GB002947.

Steffen et al., 2004. The Anthropocene Era: How Humans are Changing the Earth System (Chapter 3, book, use as reference in lecture – JPGs are available on CD)

<u>SEP 8: Mechanization and technology</u>

***Sassenrath et al., 2008. Technology, complexity, and change in agricultural production systems. Renewable Agriculture and Food Systems: 23, 285-295.**

***Wollenweber et al., 2005. Need for multidisciplinary research towards a second green revolution. Plant Biology, 8, 337-341.**

***Cassman, K.G., A. Dobermann, and D.T. Walters, 2002. Agroecosystems, nitrogen-use efficiency, and nitrogen management. Ambio, 31, 132-140.**

***Ronald, P. 2011. Genetically engineered crops – what, how and why. Scientific American, http://blogs.scientificamerican.com/guest-blog/2011/08/11/genetically-engineered-crops/**

***Varshney et al., 2011. Agricultural biotechnology for crop improvement in a variable climate: hope or hype? Trends in Plant Science, 16: 363-371.**

***Ray et al. 2012. Recent patterns of crop yield growth and stagnation. Nature communications, DOI: 10.1038/ncomms2296.**

Genoways, T. 2015. Corn wars. The farm-by-farm fight between China and the US to dominate the global food supply. New Republic, online.

Frink, C.R., et al., 1999. Nitrogen fertilizer: retrospect and prospect. Proc. Natl. Acad. Sci., 96: 1175-1180.

Mann, C.C., 1999. Crop scientists seek a new revolution. Science, 283, 310-314. Available online: http://www.sciencemag.org/cgi/content/full/283/5400/310.

Galloway, J.N. and E.B. Cowling, 2002. Reactive nitrogen and the world: 200 years of change. Ambio, 31: 64-71.

Kucharik, C.J. and N. Ramankutty (2005). Trends and Variability in U.S. Corn Yields Over the 20th Century. Earth Interactions 9, 1-29 (irrigation and yields).

Ruttan, V.W., 1999. Biotechnology and agriculture: a skeptical perspective. AgBioForum – Vol 2, 54-60.

Cassman, K.G., A. Dobermann, D.T. Walters, and H. Yang. 2003. Meeting cereal demand while protecting natural resources and improving environmental quality. Annu. Rev. Environ. Resour. 28: 315-58.

Conway, G. and Toenniessen, G., 1999. Feeding the world in the 21st century. Nature, 402, C55-C58.

Howarth, R.W., et al., 2002. Nitrogen use in the U.S. from 1961-2000 and potential future trends. Ambio, 31: 88-96.

Ozdogan, M., and G. Gutman (2008). A new methodology to map irrigated areas using multi-temporal MODIS and ancillary data: An application example in the continental US. Remote Sensing of Environment 112, 3520-3537.

Siebert, S., Doll, P, et al., 2005. Development and validation of the global map of irrigation areas. Hydrology and Earth System Sciences, 9, 535-547.

SEP 10: Perspectives on Climate Change

***Arbuckle et al., 2013. Climate change beliefs, concerns, and attitudes toward adaptation and mitigation among farmers in the Midwestern United States. Climatic Change: DOI 10.1007/s10584-013-0707-6.**

***Hmielowski et al., 2013. An attack on science? Media use, trust in scientists and perceptions of global warming. Public Understanding of Science: 0: 1-18.**

***Rejesus et al., 2013. U.S. agricultural producer perceptions of climate change. J. Agricultural Appl. Econ., 45: 701-718.**

SEP 15: Part I: Crop response to climate & CO_2

***Hatfield, J.L. K.J. Boote, B.A. Kimball, et al., 2011. Climate impacts on agriculture: implications for crop production.**

***Rosenzweig, C. and D. Hillel, 1998. Carbon dioxide, climate change, and crop yields. In Climate Change and the Global Harvest. Pg 70-100.**

***Lobell, D.B., and C.B. Field, 2007. Global scale climate-crop yield relationships and the impacts of recent warming. Environ. Res. Lett., 2: 014002, 7 pp.**

***Long, S.P., et al., 2006. Food for thought: lower than expected crop yield stimulation with rising CO2 concentrations. Science, 312, 1918-1921.**

***Long, S.P. and D.R. Ort, 2010. More than taking the heat: crops and global change. Current opinion in Plant Biology, 13: 241-248.**

***Lobell, D.B. and S.M. Gourdji, 2012. The influence of climate change on global crop productivity. Plant Physiology, 160: 1686-1697.**

Leakey, A.D.B., et al. 2009. Elevated CO2 effects on plant carbon, nitrogen, and water relations: six important lessons from FACE. J. Exp. Bot., 60: 2859-2876.

Heagle, A.S., 1989. Ozone and crop yield. Annu. Rev. Phytopathol. 27:397-423.

Rosenzweig, C. and D. Hillel. 1998. The role of soil resources. In Climate Change and the Global Harvest. Pgs. 123-139.

SEP 17: Part II: Crop response to ozone; effects of climate/CO2 change on weeds, insects, disease

***Myers et al., 2014. Increasing CO2 threatens human nutrition. Nature, 510:139-143.**

***Fiscus, E.L., F.L. Booker, and K.O. Burkey, 2005. Crop responses to ozone: uptake, modes of action, carbon assimilation and partitioning. Plant, Cell and Environment, 28: 997-1011.**

***Feng, Z. and K. Kobayashi, 2009. Assessing the impacts of current and future concentrations of surface ozone on crop yield with meta-analysis. Atmospheric Environment, 43: 1510-1519.**

***Rosenzweig, C. and D. Hillel. 1998. Effects on Weeds, Insects, and Diseases. In Climate Change and the Global Harvest. Pgs. 101-122.**

***Fishman J, Creilson JK, Parker PA, Ainsworth EA, Vining GG, Szarka J, Booker FL, Xu X (2010) An investigation of widespread ozone damage to the soybean crop in the upper Midwest determined from ground-based and satellite measurements. Atmospheric Environment 44: 2248-2256**

Davis, A.S. and E.A. Ainsworth. Weed interference with field-grown soyabean decreases under elevated CO2 in a FACE experiment. Weed Research, 52: 277-285.

Betzelberger AM, Gillespie KM, McGrath JM, Koester RP, Nelson RL, Ainsworth EA (2010) Biochemical, physiological and yield variation in soybean cultivar responses to chronic elevated ozone concentration. Plant, Cell Environment 33: 1569-1581

Gray SB, Dermody O, DeLucia EH (2010) Spectral reflectance from a soybean canopy exposed to elevated CO2 and O3. Journal of Experimental Botany 61, 4413-4422

Percy KE, Matyssek R, King JS (2010) Facing the future: evidence from joint Aspen FACE, SoyFACE and SFB 607 meeting. Environmental Pollution 158, 955-958

Eastburn DM, Degennaro MM, DeLucia EH, Dermody O, McElrone AJ (2010) Elevated atmospheric carbon dioxide and ozone alter soybean diseases at SoyFACE. Global Change Biology 16, 320-330

Nemani et al., 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999. Science, 300: 1560-1563.

Ashmore, M.R., 2005. Assessing the future global impacts of ozone on vegetation. Plant, Cell and Environment, 28: 949-964.

Reilly, J. et al., 2007. Global economic effects of changes in crops, pasture, and forests due to changing climate, carbon dioxide, and ozone. Energy Policy, 35, 5370-5383.

SEP 22: Land use and feedbacks on the climate system

***McPherson, R.A., 2007. A review of vegetation-atmosphere interactions and their influences on mesoscale phenomenon. Progress in Physical Geography, 31: 261-285.**

***Anderson-Teixeira, K.J et al., 2012. Climate-regulation services of natural and agricultural ecoregions of the Americas. Nature Climate Change, DOI: 10.1038/NCLIMATE1346.**

***Hungate, B. and H.M. Hampton, 2012. Valuing ecosystems for climate. Nature Climate Change, 2: 151-152.**

***Bagley, J. et al. 2014. The biophysical link between climate, water, and vegetation in bioenergy agro-ecosystems. Biomass and Bioenergy, 71: 187-201.**

Adegoke et al., 2007. Observational and modeling studies of the impacts on agriculture-related land use change on planetary boundary layer processes in the central U.S. Agricultural and Forest Meteorology, 142: 203-215.

Pielke et al., 2002. The influence of land-use change and landscape dynamics on the climate system: relevance to climate-change policy beyond the radiative effect of greenhouse gases: Phil. Trans. R. Soc. Lond. A, 360: 1705-1719.

Pielke et al., 2008. A broader view of the role of humans in the climate system. Physics Today, S-0031-9228-0811-230-3. Pg 54-55.

Pielke et al., 2007. A new paradigm for assessing the role of agriculture in the climate system and in climate change. Agricultural and Forest Meteorology, 142: 234-254.

Ramankutty et al., 2006. Feedbacks between agriculture and climate: an illustration of the potential unintended consequences of human land use activities. Global and Planetary Change 54: 79-93.

SEP 24: Biogeochemical: agricultural emissions of CO_2, N_2O, and CH_4.

***Robertson et al., 2000. Greenhouse gases in intensive agriculture: contributions of individual gases to the radiative forcing of the atmosphere. Science, 289: 1922-1925.**

***Rosenzweig, C. and D. Hillel. 1998. Agricultural emissions of greenhouse gases. In Climate Change and the Global Harvest. Pgs. 38-69.**

***Robertson, G.P., S.K. Hamilton, S.J. Del Grosso, and W.J. Parton, 2011. The biogeochemistry of bioenergy landscapes: carbon, nitrogen, and water considerations. Ecol. Appl., 21: 1055-1067.**

***Gelfand, I. et al., 2013. Sustainable bioenergy production from marginal lands in the US Midwest. Nature, DOI:10.1038/nature11811.**

Grassini P. and K.G. Cassman, 2012. High yield maize with large net energy yield and small global warming intensity. PNAS, DOI:10.1073/pnas.1116364109.

Jansson, C., S.D. Wullschleger, U.C. Kalluri, and G.A. Tuskan, 2010. Phytosequestration: Carbon biosequestration by plants and the prospects of genetic engineering. Bioscience, 60: 685-696.

Post, W.M., and K.C. Kwon, 2000. Soil carbon sequestration and land-use change: processes and potential. Global Change Biology, 6: 317-327.

World Resources Institute, 2007. Charting the Midwest: An inventory and analysis of greenhouse gas emissions in America’s heartland (Wisconsin case study).

Rosenberg, N.J. and R.C. Izaurralde, 2001. Storing carbon in agricultural soils to help head-off a global warming. Climatic Change, 51: 1-10.

Schlesinger, W.H., 2000. Carbon sequestration in soils: some cautions amidst optimism. Agric. Ecosystems, and Environment, 82: 121-127.

Buyanovsky, G.A., and G.H. Wagner, 1998. Changing role of cultivated land in the global carbon cycle. Biol. Fertil. Soils, 27: 242-245.

Guo, L.G. and R.M. Gifford, 2002. Soil carbon stocks and land use change: a meta analysis. Global Change Biology: 8, 345-360.

Matson, P.A., et al. 1998. Integration of environmental, agronomic, and economic aspects of fertilizer management. Science, 280: 112-115.

Lal. R., 2004. Soil carbon sequestration and impacts on global climate change and food security. Science, 304: 1623-1626.

SEP 29: Biogeophysical feedbacks Part I: changes to surface albedo and energy balance examples; irrigation, tillage, and evidence.

***Schatz J. and C.J. Kucharik, 2014. Seasonality of the urban heat island in Madison, WI USA. Journal of applied meteorology and climatology: DOI: 10.1175/JAMC-D-14-0107.1**

***Horton, R., et al. 1996. Crop residue effects on surface radiation and energy balance – review. Theoretical and Applied Climatology. 54: 27-37.**

***Bonfils, C., and D. Lobell, 2007. Empirical evidence for a recent slowdown in irrigation induced cooling. PNAS, 104: 13582-13587.**

***Lobell, D.B., Bala, G., and P.B. Duffy, 2006. Biogeophysical impacts of cropland management changes on climate. Geophysical research letters, 33: L06708.**

***Wolf, R.A. and P.S. Market, 2007. On the impact of corn and soybeans to the local moisture budget in Iowa. National Weather Digest, July 1.**

***Gorgescu et al., 2011. Direct climate effects of perennial bioenergy crops in the United States. PNAS, DOI:10.1073/pnas.1008779108.**

Georgescu, M., D.B. Lobell and C.B. Field. 2009. Potential impact of US biofuels on regional climate. Geophys. Res. Let., 36, L21806. doi:10.1029/2009GL040477.

Sacks et al., 2009. Effects of global irrigation on the near-surface climate. Climate Dynamics, DOI 10.1007/s00382-008-0445-z.

Changnon, D., et al. 2003. Relating changes in agricultural practices to increasing dew points in extreme Chicago heat waves. Climate Research, 24: 243-254.

Bonan, G.B., 2001. Observational evidence for reduction of daily maximum temperature by croplands in the Midwest United States. Journal of Climate, 14: 2430-2442.

Mahmood et al., 2006. Impacts of irrigation on 20th century temperature in the northern Great Plains. Global and Planetary Change, 54: 1-18.

<u>OCT 1: Recent examples of agroecosystems and land use impacting the climate system.</u>

***Macbean N. and P. Peylin, 2014. Agriculture and the global carbon cycle. Nature, 515:351-352.**

***Gray, J. et al., 2014. Direct human influence on atmospheric CO2 seasonality from increased cropland productivity. Nature, 515: 398-401.**

***Zeng et al., 2014. Agricultural Green Revolution as a driver of increasing atmospheric CO2 amplitude. Nature, 515: 394-397.**

***Luyssaert et al., 2014. Land management and land-cover change have impacts of similar magnitude on surface temperature. Nature Climate Change, DOI: 10.1038/NCLIMATE2196.**

***Powlson et al., 2014. Limited potential of no-till agriculture for climate change mitigation. Nature Climate Change: DOI:10.1038/NCLIMATE2292**

<u>OCT 6: Observational Networks: tillage and observational evidence of C, water, and energy exchange in agricultural systems</u>

***Baldocchi et al., 2001. FLUXNET: A new tool to study the temporal and spatial variability of ecosystem-scale carbon dioxide, water vapor, and energy flux densities. Bulletin of American Meteorological Society, 82: 2415-2434.**

***S.B. Verma, A. Dobermann, K.G. Cassman, D.T. Walters, J.M. Knops, T.J. Arkebauer, A.E. Suyker, G.G. Burba, B. Amos, H. Yang, D. Ginting, K.G. Hubbard, A. Gitelson and E.A. Water-Shea, Annual carbon dioxide exchange in irrigated and rainfed maize-based agroecosystems, *Agric. For. Meteorol.* 131 (2005), pp. 77–96.**

Bavin et al., 2009. Impact of reduced tillage and cover cropping on the greenhouse gas budget of a maize/soybean rotation system. Agric. Ecos. And Environ., 134: 234-242.

Arkebauer T., et al. 2009. Scaling up of CO2 fluxes from leaf to canopy in maize-based agroecosystems. Agric. For. Meteor., 149: 2110-2119.

Suyker, A.E., and S.B. Verma, 2007. Interannual water vapor and energy exchange in an irrigated maize-based agroecosystem. Agric. For. Meteor., 148: 414-427.

Doraiswamy, P.C., et al. 2004. Crop condition and yield simulations using Landsat and MODIS. Remote Sensing of Environment, 92: 548-559.

Gupta et al., 1983. Tillage and surface residue effects on soil upper boundary temperatures. Soil Sci. Soc. Am. J. 47:1212-1218.

Leakey et al., 2009. Elevated CO2 effects on plant carbon, nitrogen, and water relations: six important lessons from FACE. J. Exp. Botany, 60: 2859-2876.

Hatfield, J.L. and J.H. Prueger, 1996. Microclimate effects of crop residues on biological processes. Theoretical and Applied Climatology. 54: 47-59.

Hayes, M.J. and W.L. Decker, 1998. Using satellite and real-time weather data to predict maize production. Int. J. Biometeorology, 42:10-15.

Verma et al., 2005. Annual carbon dioxide exchange in irrigated and rainfed maize-based agroecosystems. Agricultural and Forest Meteorology, 131: 77-96.

OCT 8: No readings

OCT 13: Sustainability, ecosystem services, and biofuels

***Robertson, G.P. et al. 2014. Farming for ecosystem services: an ecological approach to production agriculture. BioScience, 64: 404-415.**

***Robertson, G.P., 2008. Sustainable biofuels redux. Science, 322: 49-50.**

***Keeney, D., 2009. Ethanol USA. Environ. Sci. Technol., 43: 8-11.**

***McBride, A. et al., 2011. Indicators to support environmental sustainability of bioenergy systems. Ecological Indicators, 11: 1277-1289.**

***Davis, S.C., C.J. Kucharik, S. Fazio, and A. Monti. 2013. Environmental sustainability of advanced biofuels. Biofuels, Bioproduces and Biorefining, in press.**

Robertson, G.P., S.K. Hamilton, S.J. Del Grosso, and W.J. Parton, 2010. Growing plants for fuel: predicting effects on water, soil, and the atmosphere. Ecological Society of America Biofuels and Sustainability Report. 8pp.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., and S. Polasky, 2002. Agricultural sustainability and intensive production practices. Nature, 418: 671-677.

Firbank, L.G., 2008. Assessing the ecological impacts of bioenergy projects. Bioenerg. Res., 1: 12-19.

Rodriguez, J.P., et al., 2006. Trade-offs across space, time, and ecosystem services. Ecology and Society, 11:28.

Williams, P.R., et al., 2009. Environmental and Sustainability factors associated with next-generation biofuels in the U.S.: What do we really know? Environmental Science and Technology, 43: 4763-4775.

Daily, G.C., et al., 2009. Ecosystem services in decision making: time to deliver. Front. Ecol. Environ., 7:21-28.

Naylor, R., et al., 2007. The ripple effect: biofuels, food security, and the environment. Environment, 49:31-43.
Robertson, G.P., et al., 2008. Sustainable biofuels redux. Science, 322: 49-50.

Tilman, D., 1999. Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. Vol 96: 5995-6000.

OCT 15: Corn grain ethanol vs. cellulosic ethanol; energy balance, environmental goals

***Farrell, A.E., 2006. Ethanol can contribute to energy and environmental goals. Science, 311:506-508.**

***Hill, J., et al., 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proc. Natl. Acad. Sci., 103: 11206-11210.**

***Pimental, D., 2003. Ethanol Fuels: Energy Balance, Economics, and Environmental Impacts are Negative. Natural Resources Research, 12(2), 127-134.**

***Wald, M.L., 2007. Is ethanol for the long haul? Scientific American, Jan. 2007, 42-49.**

***Wang, M. et al., 2012. Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use. Environ. Res. Lett. 7: 045905 (13pp).**

Pimental, D. and T. Patzek, 2005. Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. Nat. Resour. Res., 14: 65-76.

Dias de Oliveira, M.E., et al. 2005. Ethanol as fuel: energy, carbon dioxide balances, and ecological footprint. BioScience, 55: 593-602.

Granda et al., 2007. Sustainable liquid biofuels and their environmental impact. Environ. Prog., 26: 233-250.

Scharlemann, J.P.W., and W.F. Laurance, 2008. How green are biofuels. Science, 319: 43-44.

Schmer, M.R., et al., 2008. Net energy of cellulosic ethanol from switchgrass. Proc. Natl. Acad. Sci., 105: 464-469.

Tilman, D., 2008. Minnesota Ecologist Pushes Prairie biofuels. Science, 322: 1044-1045.

OCT 20: Land-use change to support bioenergy I: GHG emissions & carbon debt

***Fargione, J. et al., 2008. Land clearing and the biofuel carbon debt. Science, 319: 1235-1238.**

***Holzman, D.C., 2008. The carbon footprint of biofuels: can we shrink it down to size in time. Environ. Health Perspect., 116: A246-A252.**

***Searchinger T., et al., 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science, 319: 1238-1240.**

***Mathews, J. and H. Tan, 2009. Biofuels and indirect land use change effects: the debate continues. Biofuels, bioproducts, and biorefining. DOI: 10.1002/bbb.**

***Gelfand, I. et al., 2011. Carbon debt of Conservation Reserve Program (CRP) grasslands converted to bioenergy production. PNAS, 108. DOI:10.1073/pnas.1017277108**

Gibbs, H.K., M. Johnston, J.A. Foley, T. Holloway, C. Monfreda, N. Ramankutty, and D. Zaks. (2008). Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology. Environmental Research Letters 3 034001 doi:10.1088/1748-9326/3/3/034001.

OCT 22: Land-use change to support bioenergy II: Soil SOM; C sequestration, corn stover, prairie diversity/productivity.

***Qin et al., 2015. Soil carbon sequestration and land use change associated with biofuel production: empirical evidence. Global Change Biology Bioenergy: DOI: 10.1111/gcbb.12237.**

***Liska, A.J. et al., 2014. Biofuels from crop residue can reduce soil carbon and increase CO2 emissions. Nature Climate Change, DOI: 10.1038/NCLIMATE2187.**

***Tilman, D., et al., 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science, 314: 1598-1600.**

***Varvel, G.E., K.P. Vogel, et al., 2008. Comparison of corn and switchgrass on marginal soils for bioenergy. Biomass and Bioenergy, 32: 18-21.**

***Cruse, R.M. and C.G. Herndl, 2009. Balancing corn stover harvest for biofuels with soil and water conservation. Doi:10.2489/jswc.64.4.286.**

***Delgado, J. 2010. Crop residue is a key for sustaining maximum food production and for conservation of our biosphere. J. Soil Water Cons. DOI: 10.2489/jswc.65.5.111A.**

Sheehan, J. et al., 2004. Energy and environmental aspects of using corn stover for fuel ethanol. J. Indust. Ecol, 7: 117-146.

Post et al., 2004. Enhancement of carbon sequestration in US Soils. Bioscience, 54: 895-908.

Tilman D., et al., 2009. Beneficial biofuels – the food, energy and environment trilemma. Science, 325: 270-271.

Matson et al., 1997. Agricultural intensification and ecosystem properties. Science, 277: 504-509.

Cassman, K.G. 1999. Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. Proc. Natl. Acad. Sci., 96: 5952-5959.

Jordan, N., et al., 2007. Sustainable development of the agricultural bio-economy. Science, 316: 1570-1571.
Wilhelm, W.W., et al. 2007. Corn stover to sustain organic carbon further constrains biomass supply. Agron. J., 99: 1665-1667.

OCT 27: Land use change to support bioenergy III: Water, health, and biodiversity.

***Dale, V.H., K.L. Kline, J. Wiens, and J. Fargione, 2010. Biofuels: implications for land use and biodiversity. Ecological Society of America Biofuels and Sustainability Report. 13pp.**

***Dominguez-Faus, R., et al., 2009. The water footprint of biofuels: A drink or drive issue? Environ. Sci. Technol. 43: 3005-3010.**

***Groom, M.J., et al., 2008. Biofuels and biodiversity: principles for creating better policies for biofuel production. Conservation Biology, 22: 602-609.**

***Hill, J. et al., 2009. Climate change and health costs of air emissions from biofuels and gasoline. PNAS, 106: 2077-2082.**

***Meehan, T. et al., 2012. Pest-suppression potential of Midwestern landscapes under contrasting bioenergy scenarios. PLOS ONE, 7(7): e41728. doi:10.1371/journal.pone.0041728.**

Davis, A., et al., 2012. Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. PLoS ONE 7(10): e47149. doi:10.1371/journal.pone.0047149.

National Research Council, 2008. Water implications of biofuels production in the U.S. The National Academemis press, Washington D.C.

Engelhaupt, E., 2007. Biofueling water problems. Environmental Science and Technology, 41: 7593-7595.

Berndes, G., 2002. Bioenergy and water – the implications of large-scale bioenergy production for water use and supply. Global Environmental Change 12: 253-271.

Diaz, R.J. and R. Rosenberg, 2008. Spreading dead zones and consequences for marine ecosystems. Science, 321:926-929.

Roth, A.M., et al. 2005. Grassland bird response to harvesting switchgrass as a biomass energy crop. 28: 490-498.

OCT 29: Global crop yields and yield gaps:

***Johnston, M., J.A. Foley, T. Holloway, C. Kucharik, and C. Monfreda (2009). Resetting global expectations from agricultural biofuels. Environmental Research Letters 4, 014004.**

***Lobell, D.B. et al., 2009. Crop yield gaps: their importance, magnitudes, and causes. Annu. Rev. Environ. Resources, 34: 4.1-4.26.**

***Foley et al., 2011. Solutions for a cultivated plantet. Nature. Doi:10.1038/nature10452.**

***Licker, R., M. Johnston, J.A. Foley, C.L. Barford, C.J. Kucharik, C. Monfreda, and N. Ramankutty, 2010. Mind the Gap: How do climate and agricultural management explain the "yield gap" of croplands around the world? Global Ecology and Biogeography, DOI: 10.1111/j.1466-8238.2010.00563.x.**

***Mueller, N.D., et al., 2012. Closing yield gaps through nutrient and water management. Nature, DOI:10.1038/nature11420.**

Nov 3: Modeling bioenergy cropping systems

***Nair S.S., et al., 2012. Bioenergy crop models: descriptions, data requirements, and future challenges. GCB Bioenergy (2012), doi: 10.1111/j.1757-1707.2012.01166.x**

***Kucharik CJ, VanLoocke A, Lenters JD, Motew MM (2013) Miscanthus Establishment and Overwintering in the Midwest USA: A Regional Modeling Study of Crop Residue Management on Critical Minimum Soil Temperatures. PLoS ONE 8(7): e68847. doi:10.1371/journal.pone.0068847**

***VanLoocke, A. et al., 2010. The impacts of Miscanthus x giganteus production on the Midwest US hydrologic cycle. Global Change Biology Bioenergy 2, 180-191.**

Nov 5: GLBRC overview

***Slater, S. et al., 2010. The US Department of Energy Great Lakes Bioenergy Research Center: Midwestern Biomass as a Resource for Renewable Fuels. Bioenerg. Res. (2010) 3:3–5. DOI 10.1007/s12155-009-9075-5**

***Oates, L.G. et al. 2015. Nitrous oxide emissions during establishment of eight alternative cellulosic bioenergy cropping systems in the North Central United States. Global Change Biology Bioenergy, DOI:10.1111/gcbb.12268.**

***Hamilton et al., 2015. Comparative water use by maize, perennial crops, restored prairie, and poplar trees in the US Midwest. Env. Res. Lett. 10(064015).**

***Werling, B. et al., 2013. Perennial grasslands enhance biodiversity and multiple ecosystem services in bioenergy landscapes. Proc. Natl. Acad. Sci., 111: 1652-1657.**

NOV 10: Case Study 1: Agricultural land use and water issues in the Wisconsin: Central Sands

***Kraft, G. et al., 2012. Irrigation effects in the northern lake states: Wisconsin central sands revisited. Vol. 50, No. 2–GROUND WATER–March-April 2012 (pages 308–318)**

<u>NOV 12:</u>

No readings

<u>Nov 17 and Nov 19: Case Study 2: Agricultural land use and water issues in WI: Yahara Watershed</u>

***Qiu J., and M. Turner, 2013. Spatial interactions among ecosystem services in an urbanizing agricultural watershed. PNAS, doi/10.1073/pnas.1310539110.**

***Gillon, S., Booth, E. G., and Rissman, A. R., "Shifting drivers and static baselines in environmental governance: challenges for improving and proving water quality outcomes", Regional Environmental Change, pp. 1-17, 2015.**

***Carpenter S. R., Booth, E. G., Gillon, S., Kucharik, C. J., Loheide, S., Mase, A. S., Motew, M., Qiu, J., Rissman, A. R., Seifert, J., Soylu, E., Turner, M., and Wardropper, C. B., "Plausible futures of a social-ecological system: Yahara watershed, Wisconsin, USA", Ecology and Society, vol. 20, no. 2, 2015.**

***Wardropper C.B., Chang, C., and Rissman, A. R., 2015. "Fragmented water quality governance: Constraints to spatial targeting for nutrient reduction in a Midwestern USA watershed", Landscape and Urban Planning, vol. 137, pp. 64 – 75.**

<u>NOV 24 Case Study 3: Soil carbon cycling and carbon sequestration:</u>

***DeLuca T.H., and C. A. Zabinski, 2011. Prairie ecosystems and the carbon problem. Front Ecol Environ 2011; 9(7): 407–413, doi:10.1890/100063 (published online 15 Mar 2011).**

***Schmidt et al., 2011. Persistence of soil organic matter as an ecosystem property. Nature, 478: 49-56.**

Fissore, C., J. Espeleta, E. Nater, S.E. Hobbie, and P.B. Reich, 2009. Limited potential for terrestrial carbon sequestration to offset fossil-fuel emissions in the upper Midwestern US. Front. Ecol. Environ., doi: 10.1890/090059.

Kucharik, C.J. (2007). Impact of Prairie age and soil order on carbon and nitrogen sequestration. The Soil Science Society of America Journal. 12 March 2007; doi,10.2136/sssaj2006.0074, 2007 71: 430-441.

Pineiro, G., et al. 2009. Set-asides can be better climate investment than corn ethanol. Ecol. Applications, 19: 277-282.

Explore Chicago Climate Exchange website. http://www.chicagoclimatex.com

Read about Farmer's Union Carbon Credit program: http://www.carboncredit.ndfu.org/

Post, W.M., et al. 2001. Monitoring and verifying changes of organic carbon in soil. Climatic Change, 73-99.

Kucharik, C.J., J.A. Roth, and R.T. Nabielski (2003). Statistical assessment of a paired-site approach for verification of C and N sequestration on Wisconsin Conservation Reserve Program (CRP) land. Journal of Soil and Water Conservation 58, 58-67.

Jelinski, N.A., and C.J. Kucharik (2009). Land-use effects on soil carbon and nitrogen on a Midwestern floodplain. Soil Science Society of America Journal 73:217-225, DOI: 10.2136/sssaj2007.0424

Brye, K.R., and C.J. Kucharik (2003). Carbon sequestration in two prairie topochronosequences on contrasting soils in southern Wisconsin. American Midland Naturalist 149, 90-103.

Marland, G., et al., 2001. Soil carbon: policy and economics. Climatic Change, 101-117.

Metting, F.B., et al. 2001. Science needs and new technology for increasing soil carbon sequestration. Climatic Change, 51: 11-34.

Rosenberg, N.J. and R.C. Izaurralde. 2001. Storing carbon in agricultural soils to help head-off a global warming. Climatic Change, 51: 1-10.

NOV 26

No CLASS - Thanksgiving

DEC 1: Case study 3 cont. Soil carbon cycling

***Sanford GR, et al. (2012) Soil carbon lost from mollisols of the North Central U.S.A. with 20 years of agricultural best management practices. Agriculture, Ecosystems & Environment 162:68-76.**

***Prescott, C.E. 2010. Litter decomposition: what controls it and how can we alter it to sequester more carbon in forest soils. Biogeochemistry, 101:133-149.**