NRE 501.039: LAND USE AND GLOBAL CHANGE
Fall 2013

Professor Dan Brown
School of Natural Resources and Environment
Office Hours: 3-5 pm Mondays in 3505 Dana

Course Description
This course explores the interactions between land use, land cover, and environmental processes at multiple scales. The emphasis is on understanding the interactions between land-use changes and climate change. These interactions are bi-directional: global land-use changes have been a significant source of carbon to the atmosphere, while climate change and variability requires adaptation and modification of land-use practices. Land-use modification provides one means of mitigating increases in atmospheric carbon due to fossil fuel burning. Land-use change takes place in the context of a wide range of social, economic, and environmental processes. Understanding how land uses are, or should be, allocated to achieve multiple goals, including food and fiber production, space for human settlement, provision of ecosystem services, and access to renewable energy sources, requires consideration of these multiple objectives and of the various factors driving land-use decisions at multiple scales.

The course will involve readings, lectures and discussions on current scientific literature about the interactions between land-use change at multiple scales and global climate change. We will meet twice weekly to discuss the implications of the literature, and evaluate contemporary approaches to monitoring, modeling and managing land use.

Class Meetings
The class will meet Mondays and Wednesdays from 1 to 2:30 pm, 2024 Dana

Assignments and Grading
The assignments for the course center around an overall group assignment to prepare a proposal that addresses one of two types of problems that your team proposes to address: a) a research problem or b) a practical land use planning, management, or policy problem. This assignment will unfold in four steps: 1) group definition of a problem/system; 2) group production of a map and narrative for the selected system; 3) individual review of an article; and 4) a final proposal in response to one of two RFPs (i.e., requests for proposals) will be completed in both written and presented form. In addition, your group will produce analyses based on two exercises that make use of data and modeling to explore land use systems. Finally, two exams/quizzes and class participation will round out the graded work in the course.

Grade Calculation

Group proposal concept	5%
Maps	10%
Individual Article Review	10%
Simulation game	10%
Adaptation analysis	10%
Final Proposal	20%
Presentation	10%
Midterm	10%
Final	10%
Participation	5%

Outline (subject to change – check CTools for updates)

I. Land Change Science

a. Definitions and Scope

Sept 4 – Introduction and class preliminaries

Sept 9 – Definitions and links between land use and global change

Lambin, E.F., Geist, H., and Rindfuss, R.R. 2006. Chapter 1: Introduction: Local processes and global impacts. In Lambin, E.F., and Geist, H. (eds.), *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. Berlin: Springer, pp. 1-8.

Brown, D.G., Polsky, C., Bolstad, P. Brody, S.D., Hulse, D., Kroh, R., Loveland, T.R., and Thomson, A. Forthcoming. Chapter 13. Land Use and Land Cover Change. In National Climate Assessment and Development Advisory Committee, Editors. National Climate Assessment Report, Washington, DC: US Global Change Research Program.

b. *History* – How have land uses changed?

Sept 11 – Long-term global dynamics

Ramankutty, N., Graumlich, L., Achard, F., Alves, D., Chhabra, A., DeFries, R.S., Foley, J.A., Geist, H., Houghton, R.A., Goldewijk, K.K., Lambin, E.F., Millington, A., Rasmussen, K., Reid, R.S., Turner, B.L. 2006. Chapter 2: Global land-cover change: Recent progress, remaining challenges. In Lambin, E.F., and Geist, H. (eds.), *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. Berlin: Springer, pp. 9-40.

Rudel, T.K., Coomes, O.T., Moran, E., Achard, F., Angelsen, A., Xu, J., and Lambin, E. 2005. Forest transitions: towards a global understanding of the land use change. *Global Environmental Change*. 15(1): 23-31

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. 2011. A meta-analysis of global urban land expansion. *PloS one*, *6*(8), e23777.

Assignment: Form groups and define a land-change system/problem (Due Sept 23)

Sept 16 – Methods: Mapping land use and land cover

Homer, C., Huang, C., Yang, L., Wylie, B. K., & Coan, M. 2004. Development of a 2001 national land-cover database for the United States.

Ellis, E.C. and Ramankutty, N. 2008. Putting people in the map: Anthropogenic biomes of the world. *Frontiers in Ecology and Environment*, 6(8): 439-447.

Sept 18 – Land use change in Michigan and the Upper Midwest

Brown, D.G., Johnson, K.M., Loveland, T.R., and Theobald, D.M. 2005. Rural land use change in the conterminous U.S., 1950-2000. *Ecological Applications*, 15(6): 1851-1863.

Robinson, D.T. 2012. Land-cover fragmentation and configuration of ownership parcels in an exurban landscape. *Urban Ecosystems*, 15: 53-69.

Sept 23 – Introduction to ArcGIS and land-use-related information on line

Assignment: Group publishes a map with a narrative (Due Oct 7)

c. *Drivers* – What drives land-use changes?

Sept 25 – Overview of drivers

Geist, H.J., McConnell, W., Lambin, E.F., Moran, E., Alves, D., and Rudel, T. 2006. Chapter 3: Causes and trajectories of land-use/cover change. In Lambin, E.F., and Geist, H. (eds.), *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. Berlin: Springer, pp. 41-70.

Lambin, E.F. and Meyfroidt, P. 2010. Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy*, 27(2): 108-118.

Sept 30 – Markets and policy drivers

Bucholtz, S., Claassen, R., Roberts, M. J., Cooper, J. C., Gueorguieva, A., & Johansson, R. 2006. *Environmental effects of agricultural land-use change*. Washington, DC, USA: US Department of Agriculture, Economic Research Service. (CHAPTERS 1, 2, 3, and 5)

Oct 2 – Methods: Multiple methods for analyzing land-use drivers

Cheong, S., Brown, D.G., Lopez-Carr, D., and Kok, K. 2012. Mixed methods in land-change research: Towards integration. Transactions of the Institute of British Geographers, 37(1):8-12.

Tian, Q., Brown, D.G., Zheng, L., Qi, S., Liu, Y., and Jiang, L. Manuscript In Review. Spatial, temporal and household variations in land-use drivers in the Poyang Lake Region of China. *Annals of the Association of American Geographers*.

II. Land Use Effects on the Carbon Cycle

a. *Land Use and Carbon* – global changes in land use and contributions to global carbon cycle

Oct 7 – Land use and carbon cycle

Churkina, G. 2013. An Introduction to the Carbon Cycle. In D.G. Brown, D.T. Robinson, N.H.H. French, and B.C. Reed, eds., *Land Use and the Carbon Cycle: Science and Applications in Coupled Natural-Human Systems.* New York: Cambridge University Press. Pp. 24-51.

Houghton, R.A. 2013. The contribution of land use and land-use change to the carbon cycle. In, D.G. Brown, D.T. Robinson, N.H.H. French, and B.C. Reed, eds., *Land Use and the Carbon Cycle: Science and Applications in Coupled Natural-Human Systems.* New York: Cambridge University Press. Pp. 52-76.

Assignment: Individual article review (Due Oct 28)

Oct 9 – Land use and the carbon cycle (cont.)

Hartman, M.D., Merchant, E.R., Parton, W.J., Gutmann, M.P., Lutz, S.M. and Williams, S.A. 2011. Impact of historical land-use changes on greenhouse gas exchange in the U.S. Great Plains, 1883–2003. *Ecological Applications* 21:1105–1119.

Oct 14 – FALL BREAK

Oct 16 – Midterm (Brown in Brussels)

Oct 21 – Methods: Modeling carbon in human-dominated landscapes (SLUCE2)

Robinson, D.T., Filatova, T., Sun, S., Riolo, R.L., Brown, D.G., Parker, D.C., Hutchins, M., Currie, W.S., and Nassauer, J.I. Manuscript In Press. Integrating land markets, land management and ecosystem function in a model of land change. *Environmental Modelling and Software.*

b. *Managing Land Carbon* –Land-based mitigation

Oct 23 – Managing Carbon: Policy and Markets

Izaurralde, R.C., Post, W.M. and West T.O. 2013. Managing carbon: Ecological limits and constraints. In D.G. Brown, D.T. Robinson, N.H.H. French, and B.C. Reed, eds., *Land Use and the Carbon Cycle: Science and Applications in Coupled Natural-Human Systems.* New York: Cambridge University Press, pp. 329-358.

Jones, C.A., Nickerson, C., and Cavallaro, N. 2013. U.S. agricultural policies and greenhouse gas emissions. In D.G. Brown, D.T. Robinson, N.H.H. French, and B.C. Reed, eds., *Land Use and the Carbon Cycle: Science and Applications in Coupled Natural-Human Systems.* New York: Cambridge University Press, pp. 403-430.

Oct 28 – Managing carbon offsets

Pearson, T. and Brown, S. 2013. Opportunities and challenges for offsetting greenhouse gas emissions with forests. In D.G. Brown, D.T. Robinson, N.H.H. French, and B.C. Reed, eds., *Land Use and the Carbon Cycle: Science and Applications in Coupled Natural-Human Systems.* New York: Cambridge University Press, pp. 431-454.

Oct 30 – Exploring REDD in local context – REDD simulation game

Assignment: Write up on REDD simulation (Due Nov 13)

Nov 4 – Methods: Measurement, reporting and verification for REDD+.

Goetz, S.J., Baccini, A., Laporte, N.T., Johns, T., Walker, W., Kellndorfer, J., Houghton, R.A., and Sun, M. 2009. Mapping and monitoring carbon stocks with satellite observations: a comparison of methods. *Carbon Balance and Management*, 4(2): http://www.cbmjournal.com/content/4/1/2

Grainger, A. and Obersteiner, M. 2010. A framework for structuring the global forest monitoring landscape in the REDD+ era. *Environmental Science and Policy*, 14: 127-139.

Huettner, M., Leemans, R., Kok, K., and Ebeling, J. 2009. A comparison of baseline methodologies for 'reducing emissions from deforestation and degradation.' *Carbon Balance and Management*, **4**(4): http://www.cbmjournal.com/content/4/1/4

Nov 6 – Biofuels: Solution or Problem?

Hertel, T. W., Golub, A. A., Jones, A. D., O'Hare, M., Plevin, R. J., & Kammen, D. M. (2010). Effects of US maize ethanol on global land use and greenhouse gas emissions: estimating market-mediated responses. *BioScience*, *60*(3), 223-231.

III. Climate, Land Use, and Human Well-Being

a. *Land Use, Livelihoods, and Vulnerability* – relationships between land-use activities, human well-being and vulnerability to climate change

Nov 11 – Vulnerability within sustainability framework

Turner B.L., Kasperson R.E., Matson P.A., McCarthy J.J., Corell R.W., Christensen L., Eckley N., Kasperson J.X., Luers A., Martello M.L., Polsky C., Pulsipher A., Schiller A. 2003a. A framework for vulnerability analysis in sustainability science. *Proc. Nat. Acad. Sci.*, 100(14): 8074-79.

Turner, B.L., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Hovelsrud-Broda, G.K., Kasperson, J.X., Kasperson, R.E., Luers, A., Martellow, M.L., Mathiesen, S., Naylor, R., Polsky, C., Pulsipher, A., Schiller, A., Selin, H., and Tyler, N. 2003b. Illustrating the coupled human-environment system for vulnerability analysis: Three case studies. *Proc. Nat. Acad. Sci.*, 100(14): 8080-8085.

Nov 13 – Examples

Alessa, L.N., Kliskey, A.A., Busey, R., Hinzman, L., White, D. 2008. Freshwater vulnerabilities and resilience on the Seward Peninsula: Integrating multiple dimensions of landscape change *Global Environmental Change*, 18(2):256-270.

McGranahan, G., Balk, D., and Anderson, B. 2007. The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, 19:17-37.

b. *Adaptation* – What role does land use play in climate change adaptation?

Nov 18 – Adaptation in cities: Case of Ann Arbor

Assignment: Analysis of urban adaptation in Great Lakes region (Due Dec 4)

Nov 20 – NO CLASS (Brown in DC)

Nov 25 – Linking land use and adaptation

World Bank 2010. Chapter 3: Managing and water to feed nine billion people and protect natural systems. In Bierbaum, R. and Fay, M., eds. *World Development Report 2010: Development and Climate Change*. Washington, DC: The World Bank.

Gill, S.E., Handley, J.F., Ennos, A.R., and Pauleit, S. 2007. Adapting cities for climate change: The role of the green infrastructure. *Built Environment*, 33(1): 115-133.

Nov 27 – Adaptation in ecology and conservation; land sparing vs. land sharing

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., ... & Zaks, D. P. 2011. Solutions for a cultivated planet. *Nature*, *478*(7369): 337-342.

Pyke, C.R., and Andelman, S.J. 2007. Land use and land cover tools for climate adaptation. *Climatic Change*. 80(3-4): 239-251.

Newburn, D., Reed, S., Berck, P., & Merenlender, A. 2005. Economics and land-use change in prioritizing private land conservation. *Conservation Biology*, *19*(5), 1411-1420.

Dec 2 – Adaptation in livelihoods and development

Wang, J., Brown, D.G., Agrawal, A. In Press. Climate adaptation, local institutions, and rural livelihoods: A comparative study of herder communities in Mongolia and Inner Mongolia, China. *Global Environmental Change*.

Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M., and Meinke, H. 2007. Adapting agriculture to climate change. *Proc. Nat. Acad. Sci.*, 104(50): 19691-19696.

IV. Presentations (Dec 4, 9, 11)

V. Final (Dec 13, 4-6 pm)

Selected References

I. Land Change Science

a. Definitions and Background

Berger, T. 2001. Agent□based spatial models applied to agriculture: a simulation tool for technology diffusion, resource use changes and policy analysis. *Agricultural economics*, *25*(2□3), 245-260.

Brown, D.G., Robinson, D.T., An, L ., Nassauer, J.I., Zellner, M., Rand, W., Riolo, R., Page, S.E., and Low, B. 2008. Exurbia from the bottom-up: Confronting empirical challenges to characterizing complex systems. *GeoForum*, 39(2): 805-818.

Cihlar, J., & Jansen, L. J. 2001. From land cover to land use: a methodology for efficient land use mapping over large areas. *The Professional Geographer*,*53*(2), 275-289.

Defries, R.S., Foley, J.A., and Asner, G.P. 2004. Land-use choices: Balancing human needs and ecosystem function. *Frontiers in Ecology and Environment* 2(5): 249-257.

Ellis, E. C. and N. Ramankutty. 2008. Putting people in the map: anthropogenic biomes of the world. *Frontiers in Ecology and the Environment* 6(8): 439-447.

Fagerholm, N., & Käyhkö, N. 2009. Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. *Fennia-International Journal of Geography*, 187(1), 43-60.

Haberl, H. Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., and Fischer-Kowalski, M., 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *Proc. Nat. Acad. Sci.*, 104(31): 12942-12947.

Happe, K., Kellermann, K., & Balmann, A. (2006). Agent-based analysis of agricultural policies: an illustration of the agricultural policy simulator AgriPoliS, its adaptation and behavior. *Ecology and Society*, *11*(1), 49.

Rindfuss, R., S. Walsh, B. Turner, J. Fox and V. Mishra. 2004. Developing a science of land change: Challenges and methodological issues. *Proc. Nat. Acad. Sci.* 101 (39): 13976-13981.

Turner, B.L. 2009. Sustainability and forest transitions in the southern Yucatan: The land architecture approach. *Land Use Policy*, forthcoming.

Turner, B.L., E.F. Lambin, A. Reenberg. 2007. The emergence of land change science for global environmental change and sustainability. *Proc. Nat. Acad. Sci.* 104 (52): 20666-20671.

Rudel, T.K., O.T. Coomes, E. Moran, F. Achard, A. Angelsen, J. Xu, and E. Lambin. 2005. Forest transitions: towards a global understanding of the land use change. *Global Environmental Change*. 15: 23-31

Walsh, S.J., Evans, T.P. and Turner, B.L. 2004. Population-environment interactions with an emphasis on land-use/land-cover dynamics and role of technology. In: S.D. Brunn, S.L. Cutter, and J.W. Harrington (eds.), *Geography and Technology*. Dordrecht: Kluwer, pp. 491-519.

b. Land Use History

Brown, D.G. 2003. Land use and forest cover in private parcels in the Upper Midwest USA, 1970-1990. *Landscape Ecology*, 18(8): 777-790.

Goldewijk, K.K. 2004. Footprints from the past: Blueprint for the future? In: R.S. DeFries, G.P. Asner, R.A. Houghton (editors), *Ecosystems and Land Use Change*. American Geophysical Union, Washington, D.C., pp. 203-215.

Lepers, E., E. F. Lambin, A. C. Janetos, R. DeFries, F. Achard, N. Ramankutty and R. J. Scholes. 2005. A synthesis of rapid land-cover change information for the 1981-2000 period. *Bioscience,* 55 (2):115-124.

Ramankutty, N., and J.A. Foley. 1999. Estimating historical changes in global land cover: croplands from 1700 to 1992, *Global Biogeochemical Cycles* 13(4), 997-1027.

Ruddiman, W.F. and E.C. Ellis. 2009. Effect of per-capita land use changes on Holocene forest clearance and CO2 emissions. *Quaternary Science Reviews*, 28(27-28): 3011-3015.

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. 2011. A meta-analysis of global urban land expansion. *PloS one*, *6*(8), e23777.

c. Drivers

Geist, H.J. & Lambin, E.F. 2002. Proximate causes and underlying driving forces of tropical deforestation. *BioScience*, 52(2), 143-50.

Geist, H.J. & Lambin, E.F. 2004. Dynamic causal patterns of desertification. *BioScience*, 54(9), 817-29.

Lambin E.F., Turner II B.L., Geist H.J., Agbola S.B., Angelsen A., Bruce J.W., Coomes O.T., Dirzo R., Fischer G., Folke C., George P.S., Homewood K., Imbernon J., Leemans R., Li X., Moran E.F., Mortimore M.,

Ramakrishnan P.S., Richards J.F., Skånes H., Steffen W., Stone G.D., Svedin U., Veldkamp A., Vogel C. and Xu J. 2001. The causes of land-use and land-cover change: Moving beyond myths. *Global Environmental Change* 11:261–269.

Lubowski, R.N., Plantinga, A.J. and Stavins, R.N. 2008. What drives land-use change in the United States? A national analysis of landowner decisions. *Land Economics*, 84(4):529-550.

Walker R. and Solecki W.D. 2004. Theorizing land-cover and land-use change: The case of the Florida Everglades and its degradation. *Annals of the Association of American Geographers* 94(2):311–238.

II. Land Use Effects on Carbon Cycle

a. Land Use and Carbon

Birdsey, R., Pregitzer, K., and Lucier, A. 2006. Forest carbon management in the United States: 1600-2100. *Journal of Environmental Quality*, 35: 1461-1469.

Casperson, J.P., Pacala, S.W., Jenkins, J.C., Hurtt, G.C., Moorcroft, P.R., and Birdsey, R.A. 2000. Contributions of land-use history to carbon accumulation in U.S. forests. *Science*, 290: 5494: 1148-1151.

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, J. Kucharik, C. Monfreda, J.A. Patz, C. Prentice, N. Ramankutty and P.K. Snyder, Global consequences of land use, *Science* 309 (2005), pp. 570–574.

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

Haberl, H., K.-H. Erb, F. Krausmann, V. Gaube, A. Bondeau, C. Plutzar, S. Gingrich, W. Lucht, and M. Fischer-Kowalski, Quantifying and mapping the human appropriation of net primary production in the Earth's terrestrial ecosystems, *Proc. Nat. Acad. Sci.*, 104, 12942-12947, 2007.

Henebry, G.M. 2009. Carbon in idle croplands. *Nature*, 457(7233): 1089-1090.

Hurtt, G.C., Pacala, S.W., Moorcroft, P.R., Caspersen, J., Shevliakova, E., Houghton, R.A., and Moore, B., 2002. Projecting the future of the U.S. carbon sink. *Proc. Nat. Acad. Sci.*, 99(3): 1389-1394.

Pielke, R.A. Sr. 2005. Land use and climate change. *Science*, 310: 1625-1626.

Post, W.M. and Kwon, K.C. 2000. Soil carbon sequestration and land-use change: Processes and potential. *Global Change Biology*, 6: 317-328.

Ramankutty, N., H. K. Gibbs, F. Achard, R. DeFries, J. A. Foley, and R. A. Houghton, 2007. Challenges to estimating carbon emissions from tropical deforestation. *Global Change Biology*, 13, 51-66.

b. Managing Global Land Carbon

Anderson-Teixeira, K. J., Duval, B. D., Long, S. P., & DeLucia, E. H. 2012. Biofuels on the landscape: Is "land sharing" preferable to "land sparing"? *Ecological Applications*, *22*(8): 2035-2048.

Brown, S., M. Hall, K. Andrasko, F. Ruiz, W. Marzoli, G. Guerrero, O. Masera, A. Dushku, B. DeJong, J. Cornell. 2007. Baselines for land-use change in the tropics: Application to avoided deforestation projects. *Mitigation and Adaptation Strategies for Global Change*, 12: 1001-1026.

Canadell, J.G., and M.R. Raupach. 2008. Managing forests for climate change mitigation. *Science*, 320: 1456-1457.

Fargione, J., Hill, J., Tilman, D., Polasky, S., Hawthorne, P. 2008. Land clearing and the biofuel carbon debt. *Science*, 319(5867): 1235-1238.

Gibbs, H.K., Brown, S., Niles, J.O. and Foley, J.A. 2007. Monitoring and estimating tropical forest carbon stocks: Making REDD a reality. *Environmental Research Letters*, 2: 045023 (13 pp).

Lubowski, R.N., Plantinga, A.J., Stavins, R.N. 2006. Land-use change and carbon sinks: Econometric estimation of the carbon sequestration supply function. *Journal of Environmental Economics and Management*, 51: 135-152.

Miles, L. and V. Kapos. 2008. Reducing greenhouse gas emissions from deforestation and forest degradation: Global land-use implications. *Science*, 320: 1454-1455.

Sathaye, J.A. and Andrasko, K. 2007. Land use change and forestry climate project baselines: A review. *Mitigation and Adaptation Strategies for Global Change*, 12: 971-1000.

Searchinger, T. R. Heimlich, R. A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T.-H. Yu. 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science* 319, 1238-1240

Thomson, A.M., Izaurralde, R.C., Smith,S.J. and Clark, L.E., 2008. Integrated estimates of global terrestrial carbon sequestration *Global Environmental Change*, 18(1):192-203.

Wise, M., Calvin, K., Thomson, A., Clarke, L., Bond-Lamberty, B., Sands, R., Smith, S.J., Janetos, A., and Edmonds, J. 2009. Implications of limiting CO_2 concentrations for land use and energy. *Science*, 324(5931): 1183-1186.

III. Climate, Land Use, and Human Well-Being

a. Land Use, Livelihoods, and Vulnerability

Acosta-Michlik, L. and V. Espaldon. 2008. Assessing vulnerability of selected farming communities in the Philippines based on a behavioural model of agent's adaptation to global environmental change. *Global Environmental Change*, 18: 554-563.

Berry, P.M., Rounsevell, M.D.A., Harrison, P.A., Audsley, E. 2005. Assessing the vulnerability of agricultural land use and species to climate change and the role of policy in facilitating adaptation. *Environmental Science and Policy*, 9(2): 189-204.

McGranahan, G., Balk, D., and Anderson, B. 2007. The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, 19(1): 17-37.

Metzger, M.J., Rounsevell, M.D.A., Acosta-Michlik, L., Leemans, R., and Schroeter, D. 2006. The vulnerability of ecosystem services to land use change. *Agriculture Ecosystems and Environment*, 114: 69-85.

de Sherbinin, A., VanWey, L.K., McSweeney, K., Aggarwal, R., Barbieri, A., Henry, S., Hunter, L.M., Twine, W., and Walker, R. 2008. Rural household demographics, livelihoods and the environment. *Global Environmental Change*, 18: 38-53.

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., and Wunder, S. 2005. Livelihoods, forests, and conservation in developing countries: An overview. *World Development*, 33(9): 1383-1402.

Turner B.L., Kasperson R.E., Matson P.A., McCarthy J.J., Corell R.W., Christensen L., Eckley N., Kasperson J.X., Luers A., Martello M.L., Polsky C., Pulsipher A., Schiller A. 2003. A framework for vulnerability analysis in sustainability science. *Proc. Nat. Acad. Sci.*, 100(14): 8074-79.

b. Adaptation

Berrang-Ford, L., Ford, J. D., & Paterson, J. 2011. Are we adapting to climate change?. *Global environmental change*, *21*(1), 25-33.

Brännlund, I. and Axelsson, P. 2011 Reindeer management during the colonization of Sami lands: A long-term perspective of vulnerability and adaptation strategies. *Global Environmental Change*, 21(3): 1095-1105

Lambin, E. F., & Meyfroidt, P. 2011. Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, *108*(9), 3465-3472.

Phalan, B., Onial, M., Balmford, A., & Green, R. E. 2011. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science*, *333*(6047), 1289-1291.

Hisali, E., Birungi, P., Buyinza, F. In Press. Adaptation to climate change in Uganda: Evidence from micro level data. *Global Environmental Change*.

Polsky, C., and Easterling, W.E. 2001. Adaptation to climate variability and change in the US Great Plains: A multi-scale analysis of Ricardian climate sensitivities. *Agriculture, Ecosystems and Environment*, 85(1-3): 133-144.

Verchot, L.V., van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, K.V., Palm, C. 2007. Climate change: Linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change*, 12: 901-918.

Land Use Land Cover Datasets

HYDE
GLOBCOVER

(un:danbrown; pw:lugcsnre2013)