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How are the SSP storylines being implemented in the Integrated Assessment Models—with a focus on land-use changes

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Introduction

The Shared Socioeconomic Pathways (SSPs) articulate five different future socioeconomic development pathways (O'Neill et al., nd). These SSPs were designed to explore uncertainty in challenges to mitigation and challenges to adaptation. However, the resulting stories lead to large differences in population, income, diet, biomass, trade, and terrestrial climate mitigation potential, making these scenarios ideal for exploring uncertainty in the evolution of the terrestrial system.

Land use, land use change, and forestry (LULUCF) both influence and are influenced by climate change. LULUCF contributes approximately 25% of global greenhouse emissions today, mostly from deforestation CO_2, CH_4 from livestock and rice, and N_2O from fertilized soils (Tubiello et al., 2015). Conversely, climate-induced changes in ecosystem productivity alter LULUCF, resulting in changes in agricultural land and ecosystem carbon storage. The terrestrial system also has the potential to contribute to climate change mitigation, e.g., through biomass production or afforestation (Wise et al., 2009; Reilly et al., 2012; Popp et al., 2013). The future evolution of the terrestrial system is highly uncertain, depending on, among other sources of uncertainty, numerous factors that shape the five SSP storylines.

This paper will provide a deep dive into a single sector in the SSPs, focusing on the quantification of land use and land use change by six different Integrated Assessment Models. We will briefly describe the elements of the SSP storylines that are pertinent to the terrestrial system. Then, we will show land-related results from the SSP quantifications, including land use and land cover, food consumption, bioenergy production, emissions, and agricultural commodity prices. We will conclude with a brief discussion of how these results can be used by other communities, e.g., the Earth System Modeling and Impacts, Adaptation, and Vulnerability communities.

SSP Land-Related Storylines

The SSP storylines (O'Neill et al., nd) include qualitative information on the future evolution of the terrestrial system. For example, in SSP1, "[l]and use is strongly regulated to avoid environmental tradeoffs." In contrast, SSP3 is characterized by "continued deforestation due to competition over land and rapid expansion of agriculture." Table 1 summarizes these characteristics.

Table 1: SSP Land-Related Storylines

	SSP1	SSP2	SSP3	SSP4			SSP5
				Low Income	Medium Income	High Income	
Land Use Change Regulation	Strong	Medium	Weak	Weak	Medium	Strong	Medium
Agriculture Productivity Growth	Rapid	Medium	Slow	Slow	Medium	Rapid	Rapid
Environmental Impact of Food Consumption	Low	Medium	High	Medium			High
International Trade	Globalized	Regionalized	Regionalized	Limited Access	Globalized	Globalized	Globalized

Results of the IAM SSP Quantification

Differences in SSP storylines result in large differences in agriculture and land use. Figure 1 shows these differences for global cropland area, without any mitigation efforts. The SSP1 world, with its high productivity growth, low environmental impact of food, strong land use change regulation, and low population, results in the lowest cropland area. SSP3, in contrast, results in an expansion of cropland area in all IAMs. Forest area is a mirror image of cropland, where SSP3 has the lowest forest area and SSP1 has the highest forest area.

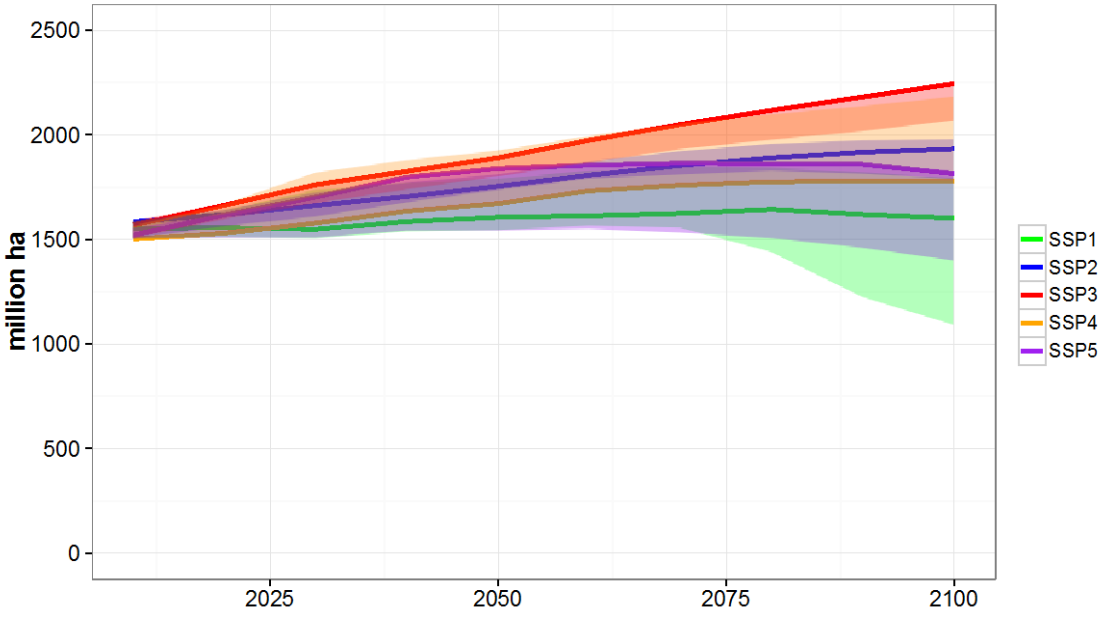

Figure 1: Global Cropland Area, across SSPs, without climate change mitigation. Lines indicate marker model scenarios and shading indicates ranges across IAMs.

In addition to differences in land use and land cover, the SSPs result in differences greenhouse gas emissions (GHG). In this context, SSP3 has the highest GHG emissions as a result of continued deforestation, leading to land-use change CO_2 emissions, and high agricultural production, leading to high CH_4 and N_2O emissions.

Discussion

The SSPs are designed to facilitate future climate-related research. There are many different avenues that this research could take. For example, the SSPs exclude climate change mitigation or impacts and adaptation. Research exploring the effects of mitigation in different SSPs is already underway, and initial results are documented in Riahi et al. (nd). The implications of these scenarios for future climate are also being quantified through the next Coupled Model Intercomparison Project (see O'Neill et al, 2016). Other areas of potential future research include (1) understanding the effect of climate change impacts and the potential for adaptation under different socioeconomic pathways, (2) quantifying the effect of resource limitations (e.g, water availability) on the SSPs or mitigation under the SSPs, and (3) downscaling the SSPs at national and local scales.

References

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok, K., Levy, M., Solecki, W., n.d. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Glob. Environ. Change. doi:10.1016/j.gloenvcha.2015.01.004

O'Neill B O 2016 ScenarioMIP documentation paper in prep for CMIP special issue of GMD

Popp, A., Rose, S.K., Calvin, K., Vuuren, D.P.V., Dietrich, J.P., Wise, M., Stehfest, E., Humpenöder, F., Kyle, P., Vliet, J.V., Bauer, N., Lotze-Campen, H., Klein, D., Kriegler, E., 2013. Land-use transition for bioenergy and climate stabilization: model comparison of drivers, impacts and interactions with other land use based mitigation options. Clim. Change 123, 495–509. doi:10.1007/s10584-013-0926-x

Reilly J, Mellilo J, Cai Y, Kicklighter D, Gurgel A, Paltsev S, Cronin T, Sokolov A, Schlosser A (2012) Using land to mitigate climate change: Hitting the target, recognizing the trade-offs. Environmental Science & Technology 46:5672-5679.

Tubiello, F.N., Salvatore, M., Ferrara, A.F., House, J., Federici, S., Rossi, S., Biancalani, R., Condor Golec, R.D., Jacobs, H., Flammini, A., Prosperi, P., Cardenas-Galindo, P., Schmidhuber, J., Sanz Sanchez, M.J., Srivastava, N., Smith, P., 2015. The Contribution of Agriculture, Forestry and other Land Use activities to Global Warming, 1990–2012. Glob. Change Biol. n/a–n/a. doi:10.1111/gcb.12865

Wise M, Calvin K, Thomson A, Clarke L, Bond-Lamberty B, Sands R, Smith SJ, Janetos A, Edmonds J (2009) Implications of Limiting CO2 Concentrations for Land Use and Energy. Science 324:1183-1186.