Jul 13th, 8:50 AM - 9:10 AM

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International Environmental Modelling and Software Society (iEMSs)
8th International Congress on Environmental Modelling and Software
Toulouse, France, Sabine Sauvage, José-Miguel Sánchez-Pérez, Andrea Rizzoli (Eds.)
http://www.iemss.org/society/index.php/iemss-2016-proceedings

Trade-offs between carbon storage, crop yield production and water supply at the global scale

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Abstract: Through land-use, humans affect natural ecosystem functioning and ecosystem services (ES). The present pattern of land-use types developed over the last millennia in response to a complex interplay of natural-system constraints and socio-economic pressures. However, the current land-use pattern might not be considered optimal in terms of its provision of a variety of ES. At the global scale food security, water availability and carbon storage are three objectives of highest importance. Knowledge about the trade-offs between these objectives is of concern if global pathways for future developments are discussed. To provide information on these trade-offs we evaluate the global configuration of different land uses under the sole premise of optimizing for carbon storage, crop yield production and water supply. The LPJ-GUESS dynamic vegetation model is used to simulate the ES provision of global land under different allocation of land use (potential natural vegetation and 5 major crop types) considering today's conditions of climate, atmospheric CO_2 levels, irrigation water availability, and the distribution of protected areas. Land use is optimized globally by varying the configuration at the level of 762 units (food producing units intersected with major watersheds and biomes) using a multi-objective genetic algorithm. Optimality is thereby defined as Pareto optimality, i.e. the configurations that do not allow an increase in the provisioning of one ES without losing provisioning of the other services. Determined optimal land-use configurations that appear possible considering the global demand for these services are contrasted with the ES provision for the current land use. We highlight opportunities in land management and possible pathways to adapt current land use to increase ES provision towards higher performing allocations. We identify several major regions where significant changes in current land-use practices would be required to approach optimal ES provision.

***Keywords**:* ecosystem services, carbon sequestration, land use, scenario analysis, trade-off analysis