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How can farmers' decisions and policy actions on novel bioenergy feedstocks affect the supply of ecosystem service bundles?

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Abstract: Meeting the world's growing energy demand through bioenergy production involves land-use change which could have severe environmental and social impacts. In this context, decision-making problems in agricultural management need to be informed by comprehensive impact assessments of novel bioenergy feedstocks that consider multiple ecosystem services (ESS). In this study, we assess the expansion of short rotation coppices (SRCs) in the Mulde watershed in Central Germany. We model cultivation decisions of profit-maximizing farmers under different economic scenarios based on a spatially explicit agent-based model. In addition, we assess two policy scenarios, in which SRCs are cultivated to fulfil the requirements of the EU Common Agricultural Policy. For all scenarios, we model ESS bundles for the modified landscape configuration. Only a substantial increase in SRC production beyond the regional demand of combined heat and power plants has a relevant effect, namely a negative impact on food production and a positive impact on biodiversity and regulating ESS. For example, an increase of SRCs in the landscape (14%) leads to an increase of carbon storage (5%) and a reduction of phosphorus export (-5%). However, the number of sites with balanced ESS bundles hardly increases due to larger shares of SRCs in the landscape. Their occurrence can be better explained by other biophysical and landscape factors. Challenges of our modelling approach, i.e., combining spatially-explicit agent-based modelling with environmental and ESS assessment models, are that it requires knowledge on farmers' behaviour as well as substantial biophysical and land-use data. Our approach can be extended to other novel land-use options within and beyond the context of bioenergy production systems. Thereby, it can inform policy actions for agricultural management (e.g., assessing consequences of the EU Common Agricultural Policy).

***Keywords**:* agent-based modelling; land-use change; ecosystem services; perennial energy crops; regional scale