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Indirect land use risk modelling with System Dynamics: the case of bioplastics

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Indirect Land Use Change (ILUC) is a land use process driven by increase in land demand and mediated by the global market: for example, the increase in demand for a certain crop in a specific country due to its use for the production of bio-materials drives up the global crop price, eventually resulting in land use change in some other country. Since land demand is already high for food/feed production, ILUC often defines if the production of a bio-material is sustainable or not. ILUC is very difficult to observe and therefore it is usually estimated through models rather measured; different models depends on which part of the complex problem is taken into account: economic equilibrium models (partial, general), causal-descriptive models, normative models. Most of these models are static, *i.e.* time is not directly factored in the model. A study of the JRC showed that ILUC models have high levels of uncertainty, both within and among models, due to uncertainty in input data, different assumptions and modelling frameworks. The (i) lack of model transparency, (ii) lack of dynamic effects and (iii) high model uncertainties make it difficult to include ILUC in sustainable policies.

Here, we present a dynamic causal-descriptive model to estimate changes in land demand as a proxy of the ILUC risk, and test it when increasing the production of bioplastic materials on a global scale. We used a system dynamic framework to (i) maintain the model easy to understand and (ii) account for dynamic effects like delays and feedback loops. We also addressed the (iii) uncertainty problem by: (a) considering ILUC on a global scale only, (b) use yearly time step to avoid short-term economic effects, (c) identifying control variables to use for model validation, (d) modelling only the projected change in land demand and translate it into global risk classes in line with the approach pursued in Europe by the Renewable Energy Directive. The model includes the relevant processes that literature identify as influential for ILUC: use of co-products, competition with the feed sector, price effect on agricultural production (intensive margin), expansion on less suitable land (extensive margin), use of agricultural residues, soil erosion, and increase in agricultural yields. The model was, then, calibrated and validated using the extensive FAOSTAT dataset and then studied using different sensitivity analysis techniques.

The validation shows that the model 10 years projections are reliable (~8% error). Both local and global sensitivity analysis show that that the most relevant factor influencing ILUC risk is the trend

of agricultural yields which, at the global level and contrary to what is usually assumed in other models, is insensitive to crop prices. Other relevant factors, interesting for policy makers, are the yields of bioplastics and the use of co-products. The analysis shows there are levels of production that have negligible risk in the next 30 years for specific biomasses and at specific growth and processing conditions. However, a full shift of use from fossil-based plastics to bio-based plastics would result in a 200-300 Mha land conversion globally.