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Sustainability impact assessment using integrated meta-modelling: Simulating the reduction of direct support under the EU common agricultural policy (CAP)

S. Sieber[a,*], T.S. Amjath-Babu[a], T. Jansson[b], K. Müller[a], K. Tscherning[c], F. Graef[a], D. Pohle[a], K. Helming[a], B. Rudloff[d], B.S. Saravia-Matus[e], S. Gomez y Paloma[e]

[a] Institute of Socio-Economics, Leibniz-Centre for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, 15374 Muencheberg, Germany
[b] Swedish University of Agricultural Sciences (SLU), Arrheniusplan 4, 750 07 Uppsala, Sweden
[c] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Dag-Hammarskjöld-Weg 1-5, Eschborn, Germany
[d] German Institute for International and Security Affairs, Ludwigkirchplatz 3-4, 10719 Berlin, Germany
[e] European Commission, Joint Research Centre (JRC), Institute for Prospective Technological Studies (IPTS), c. Inca Garcilaso 3, E-41092 Seville, Spain

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A B S T R A C T

Assessing the impact of macro-level policy driven land use changes on regional sustainability is an important task that can facilitate complex decision making processes of introducing reforms. The research work demonstrates the ability of Sustainability Impact Assessment Tool (SIAT), a meta-model, in conducting ex ante spatially explicit cross sectoral impact assessments of changes in common agricultural policy (CAP). The meta-model is able to appraise impacts of CAP amendments on land use and their repercussions on multiple indicators of sustainability. The presented study comprehensively analyses the possible impacts of discontinuing direct financial support to farmers under CAP. The simulations of the meta-model are able to reveal the land use changes both at EU and regional levels as well as to bring forth the subsequent changes in a number of indicators representing the regional sustainability (for five case study regions). In a nutshell, the simulations indicate that a reduction in direct support brings in general, a decrease in farmed area, an increase in forested land, less fluctuation in natural vegetation coverage, increase in abandoned arable land area and negligible changes in built-up area despite regionally diverging land use trends. The simulated changes in sustainability indicators for the study regions in consequence to these land use changes show that the discontinuation of subsidies evokes responses that are in general climate friendly (reduction in methane and N_2O emissions, diminishing energy use and reduction in global warming potential), economically beneficial (increase in gross value of agriculture) and socially desired (decrease in unemployment rate) as well as environmentally harmful (increase in pesticide use). Even though the appraisals of diversity indicators such as forest deadwood and farmland birds are not conclusive for all regions, the changes are positive for the former indicator and slightly negative for the latter in general. The trade-offs among these regional sustainability indicators using their directional associations are also presented for a comprehensive assessment of the impacts.

Introduction

Over the last decades, a wide range of land use simulation model systems for Europe is developed to assess the impacts of policy changes (Renda, 2006). They often simulate impacts portfolio of alternate policies and hence are valuable supporting tools in decision making processes (Harris, 2002; Parker et al., 2002; Boulanger and Bréchet, 2005; Van Ittersum et al., 2008). Many of these model systems have been identified as appropriate ones for providing support to long term and complex decision making processes. The possibility of using multitude of criteria in the impact assessment makes these models important to the field of sustainable development policy formulation (Brouwer and van Ek, 2004; Wilkinson et al., 2004).

Sustainability impact assessment is taken as a special case of integrated assessment which evaluates prospective environmental, economic and social impacts of a particular policy, proposal or initiative (Pope et al., 2004). Integrated modelling of land use provides such a holistic assessment of alternate policy options (Wei et al., 2009; Houet et al., 2010; Verburg et al., 2010) and hence makes it especially appealing in the context of complex decision making processes of sustainability impact assessment. (Van Ittersum et al., 2008; Sieber et al., 2010; Sieber and Perez-Dominguez, 2011). This genre of modelling addresses multiple

* Corresponding author. Tel.: +49 33432 82 125; fax: +49 33432 82 308.
E-mail address: Stefan.Sieber@zalf.de (S. Sieber).

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scales, disciplines and functions of different land use types in an integrative way, taking their interactions into account (Zander et al., 2008; Verburg et al., 2009). Recent approaches also model interactions through generic frameworks that allow flexible (re-)uses and linkages of their components (Van Ittersum et al., 2008; Blind and Gregersen, 2005; Hinkel, 2009). Nevertheless, impact assessment methodologies and techniques could differ depending on analytical objectives, user requirements and the data availability. New policy questions require new approaches, models or new model combinations (in case of meta-models) addressing the appropriate levels of scale, disciplines and detail.

A recent, state of the art, integrated (meta) land use modelling approach is the Sustainability Impact Assessment Tool (SIAT), developed under the framework of European Union funded SENSOR (Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions) project (Helming et al., 2011a,b). SIAT supports integrated ex ante impact assessments in the context of multifunctional agriculture and sustainable development (Helming et al., 2008). It is designed to simulate spatially disaggregated (570 European NUTS regions) impacts of European land use policies over a longer time horizon (until 2025). The model accommodates a multitude of sustainability indicators (around 80 in number) and allows their regionalized trade-off analysis (trade-offs among various indices for any particular region) and conducts evaluations of sustainability decision choice spaces (Helming et al., 2008). It implicitly synthesizes the agriculture sector and the related sectors of forestry, tourism, nature conservation, energy and transport (Sieber et al., 2008).

The current research work applies SIAT framework to analyse the effects of abolishing the agricultural direct subsidies under common agricultural policy on land use at European Union (EU) level, and compute a set of economy, society, environment, energy, climate and diversity related indicators across five representative regions. The study shows how the SIAT framework contributes to generation of additional knowledge for sustainability impact evaluation and decision making, especially in the case of EU level agricultural policy decisions and their regional sustainability impacts. We also propose appropriate ways to improve this methodology and identify its limitations.

Materials and methods

The Sustainability Impact Assessment Tool (SIAT)

The SIAT is an interlinked meta-model framework (see Fig. 1), which simulates the effects of policy alternatives on sustainability issues in a European context (Helming et al., 2011a). This integrated model assesses driving forces (based on indicators) and land use policy scenarios in order to identify region-specific portfolios of impact indicators (Sieber et al., 2008). In contrast to previous region specific applications of the SIAT model (Helming et al., 2011b), the current study analyses the trade-offs of selected indicators among the selected regions. A set of five case study regions (respective Eurostat NUTS-code is given in brackets) viz. Brandenburg Nord-Ost (DE41) in Germany, Sevilla (ES618) in Spain, Heves (HU312) in Hungary, Harghita (RO074) in Romania and South western Scotland (UKM3) in United Kingdom are selected in a heuristic way to balance the diversity of regions types according to the OECD classification typology viz. predominantly urban regions; intermediate rural regions, close to a city; intermediate rural, remote regions; predominantly rural regions, close to a city and predominantly rural, remote regions (Dijkstra and Ruiz, 2010) while retaining a regional balance among eastern and western Europe and a focus to agricultural sector.

The SIAT relies on a system of interlinked models (Fig. 1, right hand side) combining a macroeconomic model, a land use model, and five sector models. Considering the scope of the study and the limitation on the length of the article, brief descriptions of the individual models can only be provided here. All models are extensively documented elsewhere, and the interested readers are directed to the references provided in the following text.

Let us now explain how policy simulations are carried out under the SIAT meta-model framework. In each policy simulation, a joint solution for all the models involved is iteratively computed by the following steps:

1. The first step is to solve the regionalized agricultural sector model CAPRI (Britz et al., 2008). CAPRI contains a mathematical programming model for each of 250 regions of the EU, where the producers choose a mix of 50 agricultural production activities so as to maximize profit. CAPRI also contains a multi-commodity market model, where behavioural equations allow the computation of demand, prices, primary processing and international trade flows. Solving CAPRI provides, among other variables, agricultural production, input use (such as fertilizers and plant protection), output prices, land rents (conditional on a given land endowment), input prices, technological efficiency, labour and capital costs, and consumer expenditure.
2. The second step is to use the results of CAPRI model simulation as inputs in the multi-sector (30 sectors) macro-econometric model NEMESIS for EU countries (Brécard et al., 2006) to compute (among many other variables) a market balance between land supply and land claims on a national level over all sectors, and in particular agriculture, forestry, tourism, transportation and urban sectors. Covering all sectors of the economy, NEMESIS also ensures equilibria on labour and capital markets.
3. The third step is to apply the land-use change model DYNA-CLUE (Verburg and Overmars, 2009) to disaggregate the national allocation of land to agriculture indicated by NEMESIS to appropriate sub-regions that can be used by CAPRI and other linked models. The regional disaggregation takes into consideration the existence of other (competing) land uses around any given location, the suitability of land for different uses (given climatic and other physical conditions) and local policy constraints such as protection of certain areas.
4. Then in the next stage, step 1 is repeated using the simulated regional agricultural land endowment (from DYNA-CLUE) together with other selected outputs of NEMESIS (input prices, technical progress, labour and capital costs, and consumer expenditure) as exogenous shocks for CAPRI model. The iterations are repeated until convergence, defined as no change in key variables between two consecutive iterations.
5. After convergence, the remaining models are solved, taking the results obtained as given, in order to provide in-depth analyses of specific sectors. The model, EFISCEN (Sallnäs, 1990; Schelhaas et al., 2007; Lindner et al., 2002) uses demand for forestry products together with land allocated to forestry to determine forestry management practices and resulting forest characteristics. Similarly, the sub-models SICK, TIM and B&B compute indicators related to urban growth, transport infrastructure and tourism respectively (see Helming et al., 2011a,b for details).

The detailed procedures for solving the models are provided in Helming et al. (2011a,b) while calibration methods and robustness checking routines can be found in Brécard et al. (2006), Schelhaas et al. (2007), Britz et al. (2008), Verburg and Overmars (2009) and Jansson et al. (2008).

Once the system of models has been solved for a wide range of policy settings, the results are used to estimate a set of (quadratic) *response functions* that accurately replicate the joint behaviour of