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Economic evaluation of agricultural land to assess land use changes

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ABSTRACT

Land-use models express the relationship between various driving forces of land-use changes and are increasingly employed in practical applications to predict possible future land uses. The relationship between the agricultural land market and land-use changes is often neglected in such models. The objective of this study is to assess the production values of agricultural land to be integrated in an operational land-use model with the aim to improve understanding of land-use changes in all 28 European Union countries. This economic evaluation of agricultural land is based on the Net Present Value (NPV) method, a method that aims at uncovering the operational production values of land rather than real estate market value. The scientific relevance of this work is the development of a comprehensive methodology for the economic evaluation of agricultural land uses in different EU countries, the integration of economic production values of land to the local suitability approach in the studied land-use model and the provision of a EU-wide database of the NPVs of agricultural land uses, including various energy crops.

1. Introduction

The European landscape is largely dominated by agricultural land uses; in fact, more than 35% of all land in the EU has an agricultural use. Thus agricultural land uses have a central role in terms of the potential impacts of land uses on the sustainability of the wider European environment. An understanding of the spatial dynamics of agricultural land cover is therefore crucial, even more so because these land-use changes are highly interrelated with many economic, social, political and environmental processes. These processes vary through time and space to include a complex range of interactions between human factors and the environment. Land-use models can be used to capture the interactions between many factors that drive land-use changes, and can be used to predict future changes in the land-use patterns. For a review of various land-use model types, we refer to Briassoulis (2000), Veldkamp and Lambin (2001), Parker et al. (2003), and Verburg et al. (2004). Land-use models are increasingly used in ex-ante policy evaluation. For example, the LUISA (Land-Use Integrated Sustainability Assessment) modelling platform is an operational model that is repeatedly used by the European Commission for ex-ante policy evaluation (see Baranzelli et al., 2014; Lavalle et al., 2011).

Physical and political factors are well captured in land-use models, as demonstrated by various studies in the literature (see Hoyman, 2010; Te Linde et al., 2011). However, there have been few efforts to model the economic processes underneath land-use change. This is unfortunate especially because modelling such economic processes allows a deductive approach to land-use modelling, which is found to yield more accurate results (Overmars et al., 2007) and enables the straightforward evaluation of financial and fiscal policy instruments. Koomen et al. (2015) present an example of an approach to integrate economic theories of the land market into a land-use modelling framework. The economic theories mentioned here derive from the theoretical work of Alonso (1964) and others, who assume that there is a competition for a parcel of land where economic agents express their willingness to pay through bid-prices. In Koomen et al. (2015), statistical and utility-based approaches are undertaken for the spatial distribution of bid land prices, which are subsequently used to define local suitability values for all modelled land-use types. This approach implies change of perspective in land-use models: where many land-use models induce land-use dynamics from observed behaviour, Koomen et al. (2015) model land-use changes by deducing model dynamics from agent behaviour. Among few other studies that used such a deductive approach, Overmars et al. (2007) linked land-use changes to single sector processes (e.g. agriculture) and Ettema

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et al. (2007) focused specifically on residential development (we refer to Koomen et al., 2015 for a detailed review).

The purpose of this article is to analyse, quantify and integrate agricultural land production values in order to deduce land-use changes for European member states. The results are primarily used for the LUISA model, but may serve many additional purposes. The Net Present Value (NPV) method, which provides a basis for the valuation of agricultural land in a wide variety of economic valuation studies, is used to represent the economic values regarding the agricultural land-use transitions in EU-28. This integrated land-use modelling framework aims at combining the economic processes with the physical and political factors, instead of focusing only on specific forces in determining the land-use changes in urban and rural areas. The agricultural land values provided in this study can be integrated to the low-scale spatially distributed suitability maps regarding the modelled land use. Following Koomen et al. (2015), the idea here is to integrate the bid-price theoretical work of Alonso (1964) and others as a measure of local suitability to express the societal sectors' willingness to buy or rent a piece of land in a particular location. Those bid prices are assumed to be the result of the net profits that a farmer may obtain from a piece of land with maximum yield and average costs. NPVs may vary spatially by local differences in the amount of crop yield that a land may provide.

The paper is structured as follows. The next section summarises the theoretical and empirical literature focusing on the used NPV approach. Section 3 discusses the inputs used for this article. It provides a review of the CAPRI model from which many inputs have been obtained and introduces the physical input costs, the labour costs, the revenues and the net cash flow processes. Section 4 summarises the main results of the NPV application and Section 5 offers the conclusions of the study. Finally, four annexes offer a more graphical and detailed information about the whole procedure.

2. Modelling agricultural land-use changes in an economic framework

The concept of economic rent has its foundations in the classical economic theories first developed by Ricardo (1817) and Von Thunen (1826). These theories point to 'economic rent' regarded as a value in excess of real production. In other words, land rent at a specific location is equal to the annual net revenue the user receives at that location. The research on agricultural land values has expanded in the last century (Bean, 1938; Scofield, 1957; Johnson and Haigh, 1970; Pope and Goodwin, 1984). The works of Galton (1889) and Pearson (1894–1896), which focus on correlation analysis, have contributed to numerous studies that attempted to explain the significance of various attributes (such as existence of buildings, crop yields, distance to town centres) in explaining the value of land. By the 1920s, among the few econometric analyses to determine the contributions of buildings, land uses, crop productivity and distance to market on the land values are Haas (1922) and Wallace (1926). Significant contributions to this literature were made mainly after the 1960s. Advances in hedonic pricing approach, particularly pioneered by Rosen (1974), have resulted in additional progress. Such examples can be found in Chicoine (1981); King and Sinden (1988); Roka and Palmquist (1997); Tsoodle et al. (2006); Reed and Kleynhans (2011).

The basis of the analysis on the agricultural production values of land, as summarised above, is the NPV method. According to that method, agricultural farms can be considered as an investment option, which provides future revenues given the required investment. Therefore, rent value of agricultural land can be represented as the discounted value of the net expected future revenues over costs assigned to a land at a specific location. This is equivalent to the highest bid rent a farmer would be willing to pay for the use of the land at that location without making a loss. To represent the value of agricultural land, we apply a formulation similar to Feichtinger and Salhofer (2011):

$$NPV_{ji} = \sum_{j,i,t}^{m,k,n} a_{ti} E_{jt} (S_{j,i,t+1}) = \sum_{j,i,t}^{m,k,n} E_{jt} \left[\frac{(R_{j,i,t+1} - C_{j,i,t+1}}{(1+r_i)^n} \right] + \sum_{j,i,t}^{m,k,n} E_{jt} \left[\frac{G_{j,i,t+1}}{(1+r_i)^n} \right] \quad (1)$$

where NPV_{ji} is the Net Present Value of the revenues, costs and government support payments derived from land-use j for the region i in the base year 0; $S_{j,i,t+1}$ is balance of cash flows at time t comprising flow of revenues, $R_{j,i,t+1}$, flow of m different types of government support payments $G_{j,i,t+1}$ and flow of costs, $C_{j,i,t+1}$; E_{jt} is the expectations at time t on the future revenues (R_{t+1}), costs (C_{t+1}) and government subsidies (G_{t+1}) related to land-use j. The data sources for the used estimates of future revenues, support payments, and costs are elaborated upon in future sections. Lastly, a_{ti} is a discount factor defined as:

$$a_{ti} = 1/(1+r_i)^n \quad (2)$$

In which r_i is the discount rate, and n is the evaluation period. As is common when discounting investments, the discount rate r is the minimum interest rate set by the national bank for lending to other banks and used for the computations of present value. This interest rate differs across regions and countries as each area may have its own financial market characteristics; as a consequence, the used discount factor is region specific as well. For a discussion of discount rates, see Gittinger (1984), and Feichtinger and Salhofer (2011). Here, the costs comprise all the factors or inputs required for a particular agricultural production; the revenues are based on the market prices of the agricultural products and the yields that are obtained on a parcel of land. It has been recognised that other returns to land such as agricultural support programmes can also be capitalised into land values. Following Weersink et al. (1999), government support payments are also included into the NPV model as given in Eq. (1).

The empirical literature on the relationship between agricultural land prices and expected future returns on this asset has been extensively developed (Clark et al., 1993; Engsted, 1998; Lence and Miller, 1999). This literature has been extended with further improvements to the income approach model. The capital gain expectations were incorporated explicitly in the valuation models (Segura et al., 1984; Moss, 1997), and the behaviour of economic agents and the influence of transaction costs were considered in the land valuation models (De Fontnouvelle and Lence, 2002) (see Segura-Garcia del Rio et al., 2012 for the review of literature).

In the present study, the NPV method demonstrated in Eq. (1) is used to analyse the agricultural production values of land in the EU-28. 2010 is considered as the base year to which all future cash flows are discounted in order to compute the NPV. The NPV analysis is based on a 20-year evaluation period considering that this is a common evaluation period for the other cash flow studies concerning agricultural production systems (Stonehouse et al., 1988; Kuhlman et al., 2013; Anderson and Weersink, 2014). Interest rates for farmer loans (Table 1) in the EU are considered as discount rates specific to each EU country (see Van der Hilst et al., 2010).

Using the NPV approach, land production values per hectare of land are computed at the country level. To integrate them into a land-use model, those production values will be computed on a 100 × 100 m grid in which revenues may be subject to grid-cell specific yield reduction factors. In order to solve the land-use modelling task, all grid cells are assumed to have a generic agent without land-use preferences that decides on land-use transitions; thus,