Food Policy 49 (2014) 378–388

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

From global economic modelling to household level analyses of food security and sustainability: How big is the gap and can we bridge it?

Mark T. van Wijk

International Livestock Research Institute (ILRI), Livestock Systems and the Environment, Nairobi, Kenya

ARTICLE INFO

Article history:
Available online 22 October 2014

Keywords:
Multi-scale
Integrated assessment
Models
Macro-economy
Food security
Sustainability

ABSTRACT

Policy and decision makers have to make difficult choices to improve the food security of local people against the background of drastic global and local changes. Ex-ante impact assessment using integrated models can help them with these decisions. This review analyses the state of affairs of the multi-scale modelling of policy interventions, with an emphasis on applications in developing countries and livestock systems. Existing models do not sufficiently capture the complexity of human–environment interactions across different scales, and especially the link between landscape and local market levels, and national and sub-national level policies and markets is missing. The paper suggests a step wise approach with increasing data needs to bridge this gap. Improvements need to be made at the description of effects of the distribution of local markets on price formation and the representation of farm diversity within a landscape. Analyses in contrasting agro-ecological systems are needed to derive generic summary functions that can be used as input for macro level model analyses. This is especially pertinent for macro level descriptions of crop and livestock production in relation to price developments and of the mosaic of different agricultural land use responses in regions with contrasting socio-economic conditions and developments.

Introduction

Achieving sustainable food security (i.e. achieving the basic right of people to produce and/or purchase the food they need, while not harming the social and biophysical environment) – in a world of a growing human population and large scale changes in economic development is a major challenge. The way land is used plays a significant role in the changing global food economy, and determines food availability at both macro and micro levels. Livestock plays an important role in achieving food security and is the largest land use sector on earth (Herrero and Thornton, 2013). Livestock and its related land use (e.g. grassland, forage production) bring both benefits and problems, and is a typical example of how agricultural land-use is determined by a multitude of environmental, economic and socio-cultural conditions (Lotze-Campen, 2008).

The policy environment has profound impacts on the opportunities and constraints that affect agricultural land users. Policy makers aiming to improve food security and rural livelihoods in the developing world in a sustainable manner face many uncertainties when exploring the future of food systems (Ericksen et al., 2009). Policy can play an important role to balance the multiple functions of agriculture and support sustainable development but needs adequate information on how different policy options affect the complex issues surrounding food security and sustainable development. Integrated Assessment Modelling (IAM; IA models are defined as models that combine knowledge from multiple disciplines, with the aim of shedding light on policy questions (Tol, 2006)) is increasingly seen as a way to explore different futures of land use and to support policy-making (Harris, 2002; Rotmans et al., 1990; Rotmans and van Asselt, 1996; Ewert et al., 2009). This paper reviews the application of the multi-scale modelling of policy interventions on livestock systems in developing countries. In the modelling, we emphasise the importance of taking into account the tribal relationship across food production, poverty reduction, and environmental sustainability.

Rapid development are taking place in model development (Parker et al., 2002), including applications to agriculture (Van Cauwenbergh et al., 2007; Van Ittersum et al., 2008). However, most models address specific issues, e.g. assessment of land use change (Verburg et al., 2008), nitrogen emissions and leaching (Velthof et al., 2007) or food production (Fischer et al., 2005). Many of these models are also developed to address questions at a specific scale or level, which can vary from a farming system to the globe (e.g. Ewert et al., 2009).

E-mail address: m.vanwijk@cgiar.org

http://dx.doi.org/10.1016/j.foodpol.2014.10.003
0306-9192/

However, for really integrated assessment of land use and food production multi-scale assessments are essential (Rounsevell et al., 2012). The viability of global food production, the maintenance of ecosystems services, and the reduction of poverty, involve increasingly complex interactions between land users and their socio-economic and biophysical environment. To decide where investment in and new policies for food producing systems are most efficient, ex-ante integrated assessment of the consequences of these investments at livelihood, community, landscape, and regional level needs to take place.

In recent years several reviews have been published on the state-of-the art in IAM and multi-scale assessment (i.e. assessments that run across different spatial and temporal extents (scales) and organisational levels (Ewert et al., 2011)). Examples are IAM in relation to Life Cycle Analyses (LCA) (Creutzig et al., 2012), land use and landscapes (Verburg et al., 2011, 2013a), land use modelling (Rounsevell et al., 2012; Berger and Troost, 2014) and one review that at least in the title claims to be a review of IAM and issues surrounding food security (Verburg et al., 2013b). Despite the latter's title, the focus on food security is still very much at landscape or regional scale, ignoring responses of crop and livestock based livelihoods. Despite all these reviews it is still not clear how multi-scale assessment can help to improve the description of geographical variations in the drivers of agricultural land use in macro-economic models. Capturing these variations is essential, because they result in a mosaic of different agricultural land use responses: continued expansion in regions with low population densities strongly affecting the functioning of (agro-) pastoralist communities, intensification in regions with good connections to urban markets, and decrease in agricultural land use near the rapidly expanding major cities. Furthermore, the reviews typically miss a description of how the implications of land use policies can be quantified at the level where many local land use decision are made, and where the consequences of a lack of food security are felt, i.e. the farm and household level. This review wants to fill this gap, and analyses how macro and micro level models are set up and analyse (livestock related) land use. Besides giving an overview of the state of affairs of multi-scale modelling of policy interventions, this paper also identifies key gaps in the current approaches to work truly across multiple integration levels, and suggests ways forward to deal with these gaps.

Current state of affair of multi-scale IAM

In the scientific literature modelling efforts have focused on specific aspects of policy, market and land systems (e.g., Dalgaard et al., 2003; Volk and Ewert, 2011) and there is a clear methodological divide in describing food production and land use: current approaches either use top-down global and continental approaches (e.g. macro-economics and large scale land use modelling (e.g. Zhang et al., 2013; Creutzig et al., 2012) or bottom-up approaches, from farm level upwards (farm household modelling, micro-economics, agent based models and landscape level land use modelling) (e.g. Rufino et al., 2011; Parker et al., 2003; Valdivia et al., 2012). This section describes the current state of affairs of both approaches, the gap between the approaches, and existing approaches to bridge the gap.

Top down macro-economic modelling of agricultural land use

Elaborate reviews of macro-economic models can be found in recent work by Dumollard et al. (2013) and Zhang et al. (2013), so here I will limit myself to a short description of contrasting approaches. All global and continental models describing land use and food production have a similar setup (for a schematic overview see Fig. 1). The globe is divided in a number of regions (currently in most applications this values ranges been 6 and 32 regions) and a macro-economic model solves the price equilibrium based on calculations quantifying regional supply and demand. The price formation calculated and the regional estimates for supply and demand are input to a finer scale land use model that calculates how this supply can be generated (Fig. 1). Existing macro-economic models can be grouped according to several characteristics. At the level of the macro-economic description, two types of models can be distinguished: Computable General Equilibrium (CGE) models, which perform economy-wide analyses (multi-sector analyses) and Partial Equilibrium (PE) models, which describe specific segments of the economy (i.e. only one or a few sectors). Examples of CGE models are ENVISAGE, FARM, GTAP, GTEM and IMAGE (see Dumollard et al., 2013 for an overview). GLOBIOM (Havlik et al., 2011), IMPACT (Rosegrant et al., 2012; and also Msangi et al., 2014)) and MAgPIE (Lotze-Campen et al., 2008, 2010) are examples of PE models.

Another way to group models is based on the way they describe land use allocation. Three ways can be distinguished. The first approach is used by the rule based models (i.e. CGE models and the IMPACT model) and represents land use at an aggregated spatial level (different macro-regions, countries or groups of countries). In CGE models, land is considered as a production factor and the different economic sectors that require land (crop sectors, livestock, forestry) compete on a regional land market. The IMPACT model follows a different approach: harvested area for each sector and each region is expressed as a function of output prices of the sector's commodity itself but also of competing commodities, which enable the representation of substitution effects. These then form input to the set of equations IMPACT solves (Rosegrant et al., 2012).

The second approach is used by optimisation models as GLOBIOM and MAgPIE, in which land use is represented on a spatially disaggregated level (Havlik et al., 2011; Lotze-Campen et al., 2008). GLOBIOM and MAgPIE use exogenous agricultural yields and production prices that are location specific. As a consequence land allocation is the only endogenous variable left to reach optimality. As yields and production costs are grid-cell specific, these models are able to establish a link between land productivity and land allocation at the local level, although the drivers of the allocation process are the regional food markets (Dumollard et al., 2013).

The third approach is the so-called 'geographical' or 'geostatistical' approach (e.g. Rounsevell et al., 2012). In the past this approach was especially applied to regional land use analyses and studies of rural–urban land use connections, but it is now increasingly applied in continental or even global land use studies. In models like CLUE (Verburg et al., 1999) and LandSHIFT (Schaldach et al., 2011) spatially explicit land-use patterns are calculated using data on land suitability and assumptions on agricultural demand. Future land-use change in these models is determined by statistical relationships of past trends in land use. The macro-economic models simulate outputs (prices, supply and demand) that serve as input for the spatially explicit land use models (e.g. IMAGE, LandSHIFT) and the overall model framework can thereby simulate scenarios of developments in land use.

The lowest spatial scale at which the large scale economic land use models make predictions differs strongly between the models. Many global studies now aim at a 5 arcminute ($\sim 10 \times 10$ km) spatial resolution (Verburg et al., 2013b). Models like GLOBIOM, CLUE and LandSHIFT now in general have a resolution of 0.5°, whereas CGE models, because of the more comprehensive economic model that drives the simulations, land use shifts are calculated at a much larger integration level, normally at regional or country level (Zhang et al., 2013). The increasing resolution of the land use models causes problems in the description of land use systems that are