Ecological Modelling 221 (2010) 2177–2187

Contents lists available at ScienceDirect

Ecological Modelling

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

Exploring the future of European crop production in a liberalised market, with specific consideration of climate change and the regional competitiveness

C.M.L. Hermans[a,*], I.R. Geijzendorffer[a], F. Ewert[b,c], M.J. Metzger[a,d], P.H. Vereijken[e], G.B. Woltjer[f], A. Verhagen[e]

[a] Alterra, Wageningen UR, PO Box 47, 6700 AA Wageningen, The Netherlands
[b] Institute of Crop Science and Resource Conservation, University of Bonn, Katzenburgweg 5, D-53115 Bonn, Germany
[c] Department of Plant Sciences, Plant Production Systems Group, Wageningen University, PO Box 430, 6700 AK Wageningen, The Netherlands
[d] Centre for the study of Environmental Change and Sustainability (CECS), School of Geosciences, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, UK
[e] Plant Research International, Wageningen UR, PO Box 16, 6700 AA Wageningen, The Netherlands
[f] LEI, Wageningen UR, PO Box 29703, 2502 LS Den Haag, The Netherlands

ARTICLE INFO

Article history:
Received 22 November 2008
Accepted 23 March 2010
Available online 21 April 2010

Keywords:
Impact assessment
Crop productivity
Competitiveness
Climate change
Land use change

ABSTRACT

Long-term future development of European agriculture within the global market is highly uncertain, but can potentially have large impacts on the future of agricultural businesses, rural communities and amenities such as traditional landscapes and biodiversity. Despite great uncertainties it is of interest to explore the extent of these potential changes. This paper provides an explorative scenario of the European crop production in a liberalised world without European Union (EU) market interventions. The results do not form a prediction or a business as usual scenario, but rather a plausible and salient thought-experiment of a possible future based on the consistent integration of current conceptual and quantitative models.

Future scenarios for climate, demography, technology and global demand for agricultural commodities are used to assess the competitiveness of European agriculture. Regional economic competitiveness is determined by combining indicators for the economic strength of farms in a region and population pressure on agricultural land, and subsequently used to determine where agricultural production is likely to sustain under the market liberalisation scenario. The method is illustrated for the 27 EU member state countries for three commodities: wheat, potato and milk (relying on grass).

Results include maps of the dominant wheat, potato and milk producing regions across Europe as projected for 2050. They show that due to increased agricultural productivity, less agricultural land will be needed to supply the European demand for food and feed. In addition, production will concentrate in those regions which have a comparative advantage. This potentially leads to a strong polarisation between north-western Europe and southern Europe, which faces negative impacts of climate change and central and northern Europe where agricultural businesses lag in economic strength and farm size. A contrasting policy intervention scenario illustrates how differences in demand and productivity result in an expansion of the agricultural area, especially for the production of wheat.

Although the complete liberalisation scenario may seem unlikely, and the underlying assumptions have great uncertainty, the results help identify and map market pressures on agricultural land use across regions in Europe. As such, it stimulates policy debate on the desired future for the European agricultural sector and the trade-offs between economic competitiveness under global market conditions and policy intervention. In addition, it provides a basis for the planning of alternative economic strategies for agriculturally less competitive regions.

1. Introduction

Over the coming decades European agriculture is facing many challenges, including climate change impacts (Olesen and Bindi, 2002; EEA, 2008) and a substantial overhaul of the European Union (EU) agricultural policy (Fischer Boel, 2005; Bensted-Smith, 2007). Anticipating how European agriculture responds to these pressures is of great interest to the agricultural sector and policymakers, as well as to the wider society, which relies on agriculture for a wide range of ecosystem services (Metzger et al., 2006). Integrated assessment studies can provide insight in the complexity of interactions affecting agriculture and support planning and policy making

* Corresponding author. Tel.: +31 317481681.
E-mail address: tia.hermans@wur.nl (C.M.L. Hermans).

0304-3800/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolmodel.2010.03.021

(Van Ittersum et al., 2008; Ewert et al., 2009). By using explorative scenarios (e.g. Scenar, 2020 (EC, 2007), Eururalis (Klijn and Vullings, 2005), FFRAF (FFRAF, 2007)), complex and uncertain plausible future developments can be assessed, providing guidance for policy development and strategic planning (Peterson et al., 2003).

Since the 1960s the common agricultural policy (CAP) has protected European farmers from the pressures of the global market. However, CAP reform and subsequent redirections of policy measures (Fischer Boel, 2005; Bensted-Smith, 2007; DEFRA, 2007) could lead to reduced protection and may eventually result in a complete abolition of subsidies and tariffs. Furthermore, expansion of the EU means that competition from within Europe is also likely to increase. At the same time, the agricultural commodity market is changing as the productivity of labour and land is projected to grow faster than the number of consumers (OECD and FAO, 2005; Rosegrant et al., 2009), leading to increased competition in both the European and world food markets (Burrell and Oskam, 2005) for EU agricultural holdings. Combined with a continued rise in production capacity, spurred by the adoption of new technologies (Reidsma, 2007), unprofitable businesses are likely to disappear from the market.

On top of the increased competition, European agriculture will also be affected by climate change. Increasing temperatures, more frequent extreme weather events and decreasing water availability have been projected for Europe (EEA, 2006, 2008; IPCC, 2007) with region specific implications for agricultural production (Olesen and Bindi, 2002; Ewert et al., 2005; IPCC, 2007; Bondeau et al., 2007). Many studies have assessed potential impacts of climate change on agricultural production (e.g. Rosenzweig and Parry, 1994; Downing et al., 1999; Reilly et al., 2003), and several studies have explored the interaction between climate change, policy and market changes (e.g. ATEAM (Ewert et al., 2005; Rounsevell et al., 2005, 2006), Eururalis (Klijn and Vullings, 2005), FFRAF (FFRAF, 2007). However, the algorithms used to allocate projected land use change across regions have ignored differences in the competitiveness of regions and holdings, which will play a crucial role in a liberalised market economy.

This study aims to extend the methodology developed by Ewert et al. (2005) and Rounsevell et al. (2005) by explicitly taking into account the regional competitiveness of European agriculture in a plausible scenario of the future of European agriculture in an open market. The results do not form a prediction or a business as usual scenario, but rather a plausible and salient thought-experiment of a possible future based on the consistent integration of current conceptual and quantitative models.

2. Methods

The modelling approach presented in this paper consists of four steps. Future productivity is estimated by taking into account the potential effects of climate change, increasing atmospheric CO_2 concentration and technology development (1). Future demand estimates are derived from existing models (2). Subsequently, regions are ranked based on their competitiveness (3), which is then used to allocate market shares of the future demand, potentially pushing less competitive regions out of the market (4).

The analysis includes all regions of the EU27 and Norway. Results are calculated and presented at NUTS1 level [i.e. Nomenclature of Territorial Units for Statistics with 107 NUTS1 regions in EU27, (Eurostat, 2007)] for three important agricultural commodities: wheat (a cereal), potato (a root crop) and milk (relying on grassland). Cereals and root crops cover approximately 60% of the 100 million ha of arable land in EU27 (Eurostat, 2007). Permanent grassland and meadows as a representative for milk cover more than 50 million ha in EU27 (Smit et al., 2008). Data on crops and farms at NUTS1 level were obtained from Eurostat (2007). Future

Table 1
Scenario assumptions used to interpret the global storylines from the special report on emissions scenarios (SRES) (Nakicenovic et al., 2000) for Europe, based on the work by Ewert et al. (2005) and Rounsevell et al. (2006).

A1 – global economic scenario	B2 – regional environmental scenario
Rapid economic growth with convergence between regions	Low economic growth with very slow convergence between regions
A slight increase in population until 2050, then a decrease	Population remains stable
Very rapid development and uptake of new technologies	Uneven and relatively slow development and uptake of new technologies
Weak governments with commitment to market-based solutions	Weak central governments, but strong regional governments
Few restrictions in spatial planning	Differences in spatial planning between regions, but generally restrictive
A rapid enlargement of the EU	EU enlargement stops
A large increase in global food demand	There is little change in food demand
Rural development is not an important issue	Rural development increases due to self-reliance and demand for local products
There is little concern about environmental issues	There is great concern about environmental issues

projections refer to the A1 fossil fuel intensive (FI) scenario of the Intergovernmental Panel on Climate Change (IPCC) special report on emissions scenarios (SRES) (Nakicenovic et al., 2000), which is referred to as A1 throughout the manuscript.

The described method, using regional competitiveness to determine spatial allocation of future agriculture, is especially appropriate for the global economic assumptions underpinning the SRES A1 scenario. However, projections for the B2 regional environmental scenario have also been included to consider the range of uncertainty for the most important drivers, i.e. climate change, technology development and demand for agricultural commodities. Table 1 presents a summary of the scenario assumptions underpinning the European interpretation of the A1 and B2 scenarios by Rounsevell et al. (2006).

Step 1: estimating future productivity

Future change in agricultural productivity depends on biophysical changes in climate conditions and atmospheric CO_2 concentrations, as well as changes in technology and crop management (Ewert et al., 2005). Crop models have frequently been used to assess changes in potential crop productivity, based on changes in climate parameters and CO_2 concentration (Rosenzweig and Parry, 1994; Downing et al., 1999; Van Oijen and Ewert, 1999; Fischer et al., 2002; Tubiello and Ewert, 2002). Extensions of these models are available to also consider effects on growth and yield of water and nutrient (mainly nitrogen) limitation (e.g. Keating et al., 2003; Jones et al., 2003; Stockle et al., 2003; Van Ittersum et al., 2003). However, effects of yield reducing factors such as weeds, pests and diseases are not considered, but are important when evaluating simulations of actual yields (Jamieson et al., 1999). Also, models have been developed and are mainly calibrated for controlled experimental conditions at plot scale. Application to regions would require some way of considering the regional diversity of the yield determining, limiting and reducing factors as well as the genetic diversity of the varieties grown. Attempts have been made to apply crop models at regional scale using different methods of up scaling model inputs and/or simulations (e.g. Tan and Shibasaki, 2003; Parry et al., 2004; Bondeau et al., 2007; Challinor et al., 2009), but a fair comparison of up scaling approaches is still pending. Also, data availability of all