ENVIRONMENTAL SCIENCE & POLICY 39 (2014) 13–24

Available online at www.sciencedirect.com

ScienceDirect

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

Emissions associated with meeting the future global wheat demand: A case study of UK production under climate change constraints

Mirjam Röder [a,*], *Patricia Thornley* [a], *Grant Campbell* [b], *Alice Bows-Larkin* [a]

[a] *Tyndall Centre for Climate Change Research, The University of Manchester, Manchester M13 9PL, United Kingdom*
[b] *Satake Centre for Grain Process Engineering, The University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom*

ARTICLE INFO

Article history:
Received 29 April 2013
Received in revised form
3 February 2014
Accepted 4 February 2014
Available online

Keywords:
Wheat production
Supply–demand trends
Climate change impacts
Adaptation
Mitigation
Life cycle assessment
Emissions

ABSTRACT

Climate change, population growth and socio-structural changes will make meeting future food demands extremely challenging. As wheat is a globally traded food commodity central to the food security of many nations, this paper uses it as an example to explore the impact of climate change on global food supply and quantify the resulting greenhouse gas emissions. Published data on projected wheat production is used to analyse how global production can be increased to match projected demand. The results show that the largest projected wheat demand increases are in areas most likely to suffer severe climate change impacts, but that global demand could be met if northern hemisphere producers exploit climate change benefits to increase production and narrow their yield gaps. Life cycle assessment of different climate change scenarios shows that in the case of one of the most important wheat producers (the UK) it may be possible to improve yields with an increase of only 0.6% in the emission intensity per unit of wheat produced in a 2 °C scenario. However, UK production would need to rise substantially, increasing total UK wheat production emissions by 26%. This demonstrates how national emission inventories and associated targets do not incentivise minimisation of global greenhouse gas emissions while meeting increased food demands, highlighting a triad of challenges: meeting the rising demand for food, adapting to climate change and reducing emissions.

1. Introduction

Wheat is one of the most important global food crops, accounting for 30% of global cereal production (FAO, 2013). Worldwide approximately 70% of wheat produced is for food and 30% for other uses including feed (FAO, 2011a), with rising demand driven by population growth, economic development, increasing wealth, urbanisation and changing lifestyles (Alexandratos and Bruinsma, 2012; Cohen, 2006; Gerbens-Leenes et al., 2010; Popp et al., 2010; Röder, 2008).

Wheat is grown worldwide in different climates but its optimal growing conditions are in temperate environments (Curtis et al., 2002; Gooding, 2009), where yields of over 10 t/ha

* Corresponding author. Tel.: +44 0 161 275 4344; fax: +44 0 161 306 3255.
E-mail addresses: Mirjam.roeder@manchester.ac.uk (M. Röder), P.Thornley@manchester.ac.uk (P. Thornley), Grant.campbell@manchester.ac.uk (G. Campbell), Alice.Bows-Larkin@manchester.ac.uk (A. Bows-Larkin).
http://dx.doi.org/10.1016/j.envsci.2014.02.002

can be achieved (Curtis et al., 2002). However, the agricultural sector is particularly sensitive to climate change impacts: temperature increases, higher atmospheric CO_2 concentration and longer growing periods are expected to favour agricultural production in higher latitudes over the next 40 years and impact negatively on production in lower latitudes (IPCC, 2007a). Other climate change factors, including pathogens, pests, weeds and extreme/unpredictable weather events will also affect production even in these favoured regions, resulting in increased volatility (Foresight, 2011; Olesen et al., 2010). As wheat is one of the global main crops, a sufficient wheat supply at a reasonable price is necessary to ensure food security.

At the same time agriculture is responsible for about 10–12% of the total global greenhouse gas emissions. About 38% of these emissions are nitrous oxide (N_2O) from soils, hence crop production and 62% methane (CH_4), mainly from livestock and rice production (UNEP, 2013). To meet the 2 °C climate change target, the agricultural sector has to contribute to reducing emissions, so it is important to consider the impact of adaptation and mitigation strategies on the net greenhouse gas emissions from the agricultural sector. This is particularly important, as the climate has a direct impact on agriculture and therefore food security, contributing significantly to the production of non-CO_2 emissions (Bows-Larkin et al., 2014).

Previous investigations have examined climate change impacts and food security (Alexandratos and Bruinsma, 2012; Bruinsma, 2009; Foresight, 2011; Glantz et al., 2009; IPCC, 2007a; Parry et al., 2004; Peltonen-Sainio et al., 2010; Popp et al., 2010), but this work considers adaptation and mitigation together, evaluating the consequences of adaptation strategies for emissions mitigation and the implications of national mitigation targets for globally efficient adaptation strategies. It synthesises published data on wheat production, adaptation and projected demands to identify food security risks and evaluates the life cycle greenhouse gas impact of adapting existing wheat production to supply future demand.

After giving an overview over global wheat demand trends and climate change impacts, the analysis of UK wheat production emissions will demonstrate a specific case of how production regimes will change due to climate change impacts and how this will affect future emissions. The UK, the third biggest wheat producer in the EU after France and Germany and one of the top 10 global producers, is chosen as it is a nation with high agricultural productivity and production efficiency. Even though the UK wheat production and resulting emissions appear small compared to overall UK and global agricultural emissions, it is a case to help understanding possible mitigation and adaptation challenges for one of the main food crops in a typical high yielding production system.

2. Challenges for the global wheat supply

2.1. *Global wheat production and demand trends*

In 2009 approximately 685 Mt of wheat was produced worldwide (FAO, 2013) with an average global wheat yield of about 3 t/ha (FAO, 2013). The main producers, illustrated in Fig. 1, provided about 70% of the total global wheat (FAO, 2013) and the EU, with a total production of about 135 Mt, is the largest wheat producing region.

While the main European wheat producers and Canada achieve yields close to their agro-ecologic potential (Bruinsma, 2009), other wheat producers (USA, Australia, Russian Federation and Ukraine) could double their yields (Bruinsma, 2009). Yield increases are not incentivised where enough land is available and wheat is produced on larger areas with lower inputs, lower costs and lower yields (Sylvester-Bradley et al., 2008).

Global wheat demand will increase to about 900 Mt by 2050 and trade double to around 240 Mt (Alexandratos and

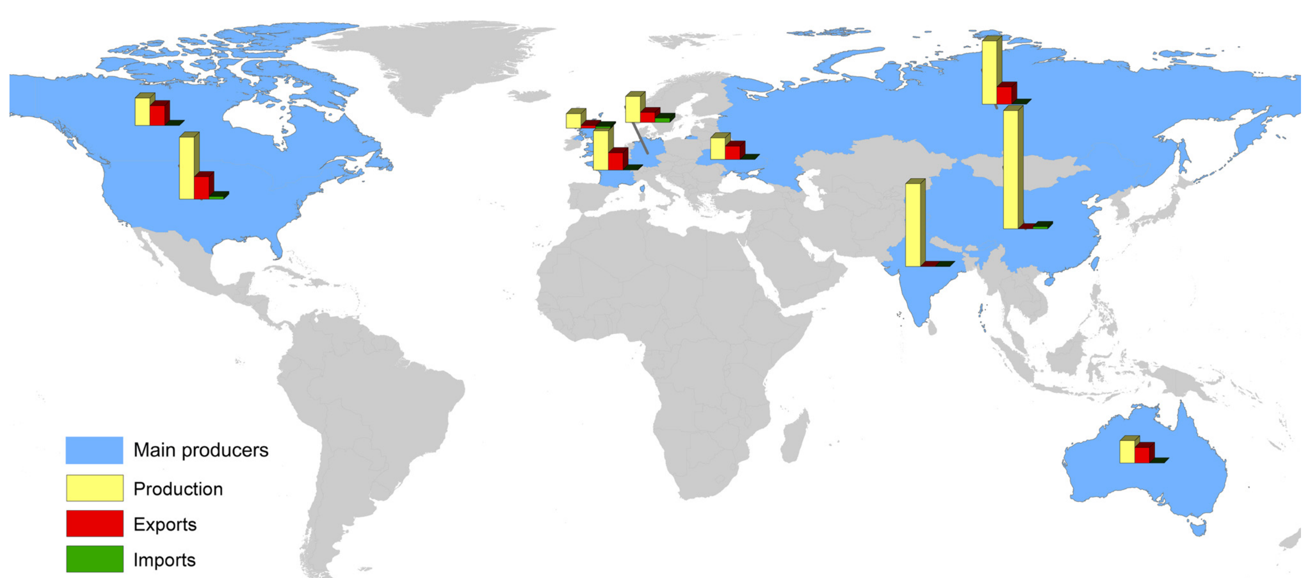

Fig. 1 – Major wheat producers including trade generated from FAO production and trade statistics.