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Measuring and Marketing the Environmental Costs and Benefits of Agricultural Practice

Co-development of bioethanol, feed and food supply chains that meet European agricultural sustainability criteria

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Summary

The development of bioethanol refineries within the Yorkshire and Humber and neighbouring regions in the UK will impact on the Yorkshire and Humber agri-food system. The construction of refineries within and outside the Region has resulted in the need for an impact assessment to be used by food manufacturers utilising local wheat and those farmers who produce premium wheat for the food system (principally bread wheat). There are also priorities concerning regional food security that must be considered so that robust and sustainable biofuel-food policy is developed with food manufacturers, farmers and bioethanol producers. This research provides the basis for delivering these producer, manufacturer and processor driven (supply chain) frameworks.

Key words: Bioethanol, cereals, biorefinery, supply chain

Introduction

The bioethanol manufacturing and processing plants that are projected to become operational in 2009−2010 in the UK will require farmers and food manufacturers to have efficient forecasting methodologies for both land use planning and the determination of business risks associated with investing in biofuel and/or food crops.

The Vivergo fuels refinery near Kingston upon Hull will require 1.1 million tonnes of wheat each year. If we were to consider a conservative wheat yield for the Region (average for the UK) at 8.5 tonnes of grain per hectare, this will equate to a land-use requirement for almost 130 000 hectares of wheat within Yorkshire and Humber region. This is nearly 60% of the current Region's cultivated area of wheat (Defra, 2007). The impact of using wheat and other starch crops on food supply is not currently known. What is known is there is a demand for local wheat grain as a feedstock for bioethanol refineries because it will minimise transport costs and greenhouse gas (GHG) emissions associated with grain haulage.

There is now significant evidence that recycling carbon through agricultural production systems and biofuel supply chains can reduce GHG emissions and improve air quality (by replacing fuel oxygenates; see review by Martindale & Trewavas, 2008). Sensitivities regarding global land use change associated with biofuel production may stimulate the development of a completely UK-based biofuel industry. The research presented here aimed to determine how food and fuel chains could be developed sustainably within the Yorkshire and Humber Region of the UK. Most importantly, the results lead us to consider the impact of biofuel crops on other crops in the Region. This relationship is often misrepresented at global scales (as reported by Wassenaar & Kay, 2008) and it is important that similar misrepresentation is not developed regionally in the UK. The aim is to provide an impact assessment of the new bioethanol industries that will stimulate business

confidence across the wheat supply chain in the Yorkshire and Humber in order to facilitate the sustainable co-development of food and biofuel.

Methods

The research presented has developed a spatial analysis of crop production and bioethanol refineries. This study has used the Agcensus Database (http://www.edina.ac.uk) to plot 2004 agricultural land use datasets spatially using GIS analyses and cross referenced them with the Defra Agricultural and Horticultural Survey (AHS) 2007. Land use capacities were defined within 50 km radii of the Vivergo, Ensus and Cargill plants using MapInfo Professional 9.5 software tools and the Agcensus database published by EDINA.

Fig. 1 shows a GIS analysis for the three biorefineries including Cargill PLC (Trafford Park), Vivergo Biofuels Ltd (Saltend, Kingston upon Hull) and Ensus (Wilton) that will be of most importance in forecasting impacts on the Yorkshire and Humber grain chain. The concentric circles shown are 5 km wide circles with a total radius of 50 km from the biorefinery. The background grid (light grey) shows the Agcensus plots for each 2 km grid, the grey-scale grids show the intensity of land used for wheat production for 2 km radii (lightest grey shade at 510 hectares ; to darkest grey shade at 0). Black circles show the location of major bakeries from the Yorkshire Forward Food and Drink Cluster businesses database. A summary of the cereal, sugar beet and total cropping data for these 50 km radii is presented in Figs 2−4.

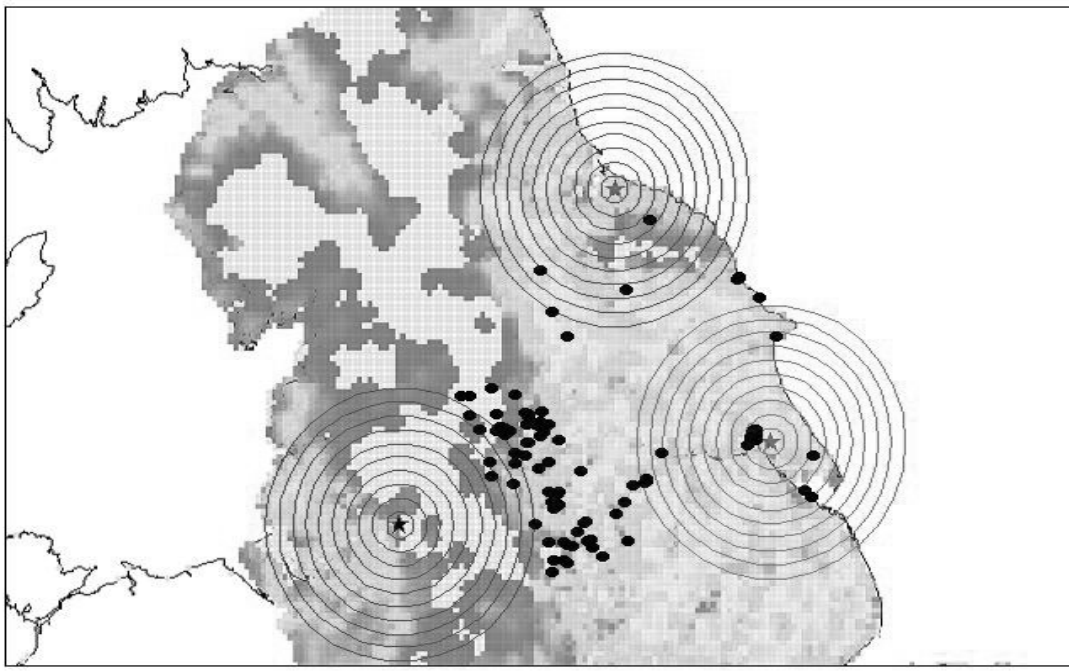

Fig. 1. The GIS analysis for the three biorefineries including Cargill PLC (Trafford Park), Vivergo Biofuels Ltd (Saltend, Kingston upon Hull) and Ensus (Wilton).

Using experimental data from field trials that have shown a hectare of wheat cultivation is associated with 1.5 tonnes of CO_2 emissions from agri-inputs and cultivation (Cowell & Clift, 1995); and, Life Cycle Assessment data that show 1 tonne of wheat is equivalent to 0.71 t CO_2eq (Nielsen *et al*., 2009) we can provide GHG emissions associated with this intensity of regional wheat production. A further environmental consideration is water use by feedstock crops. Using the equivalence measure of 750 g water transpired to produce 1 g C3 biomass provided by the review of Ehleringer & Monson (1993), we have calculated the water utilised by this intensity of regional wheat production.

Results

The amount of wheat produced within a 50km radius of the Vivergo plant is 1.386 million tonnes if 8.5 t ha^{-1} is considered a typical wheat grain yield for the 0.163 million ha producing wheat (Fig. 2) in this region. This area of wheat production results in 0.245 million tonnes of CO_2 and 0.984 million tonnes CO_2eq emissions. In this scenario for wheat, the wheat grown within a 50 km radius of the Vivergo plant requires 1.040 × 109 tonnes of water.

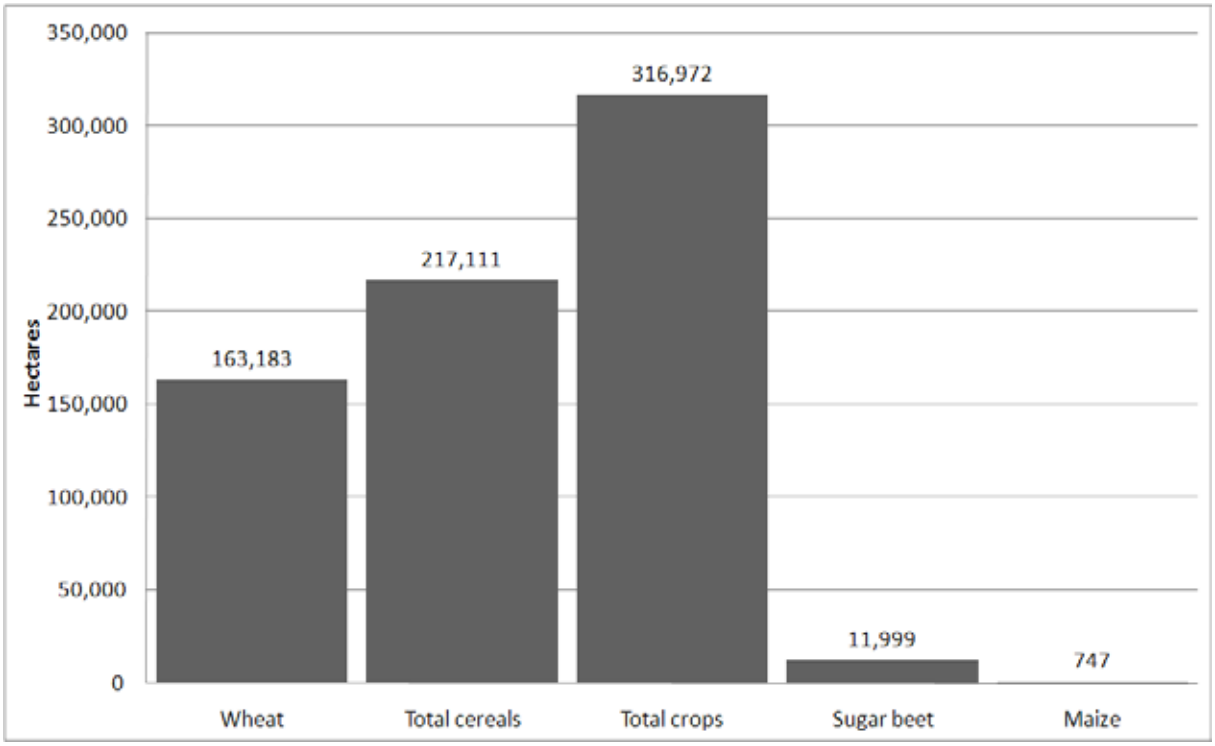

Fig. 2. Selected crops within the 50 km radius of the Vivergo plant using 2004 Agcensus data.

The amount of wheat produced within a 50 km radius of the Ensus plant is 0.621 million tonnes if 8.5 t ha^{-1} is considered a typical wheat grain yield for the 0.073 million ha producing wheat (Fig. 3) in this region. This area of wheat production results in 0.120 million tonnes of CO_2 and 0.441 million tonnes CO_2eq emissions. In this scenario for wheat, the wheat grown within a 50 km radius of the Ensus plant requires 0.466 × 109 tonnes of water.

The amount of wheat produced within a 50 km radius of the Cargill plant is 0.204 million tonnes if 8.5 t ha^{-1} is considered a typical wheat grain yield for the 0.024 million ha producing wheat (Fig. 4) in this region. This area of wheat production results in GHG emissions of 0.036 million tonnes of CO_2 and 0.145 million tonnes CO_2eq emissions. In this scenario for wheat, the wheat grown within a 50 km radius of the Cargill plant requires 0.153 × 109 tonnes of water.

Fig. 2 shows that the 1.1 million tonnes of wheat capacity of the Vivergo refinery can be met within 50 km of the refinery if optimal agronomic yields are achieved. Over 0.163 million hectares of wheat are grown within this radius. If optimal yields approach those of the national average the refinery capacity will be reached with a near 40% reserve on the 1.1 Mt of grain required. The Ensus Refinery has 40% of the wheat area capacity of the Vivergo refinery (Fig. 3) and the Cargill starch refinery has 14% of the wheat area capacity of the Vivergo refinery (Fig. 4).

The Vivergo Fuel refinery will also produce 0.5 million tonnes of animal feed each year. The value of these co-products in new and existing feed and fine/speciality chemical chains is currently untested and the impact of wheat grown for bioethanol on current feed chains might be minimal. The relationship between feedstock, fuel, feed and impact on crop management is unknown and future research will define these relationships.

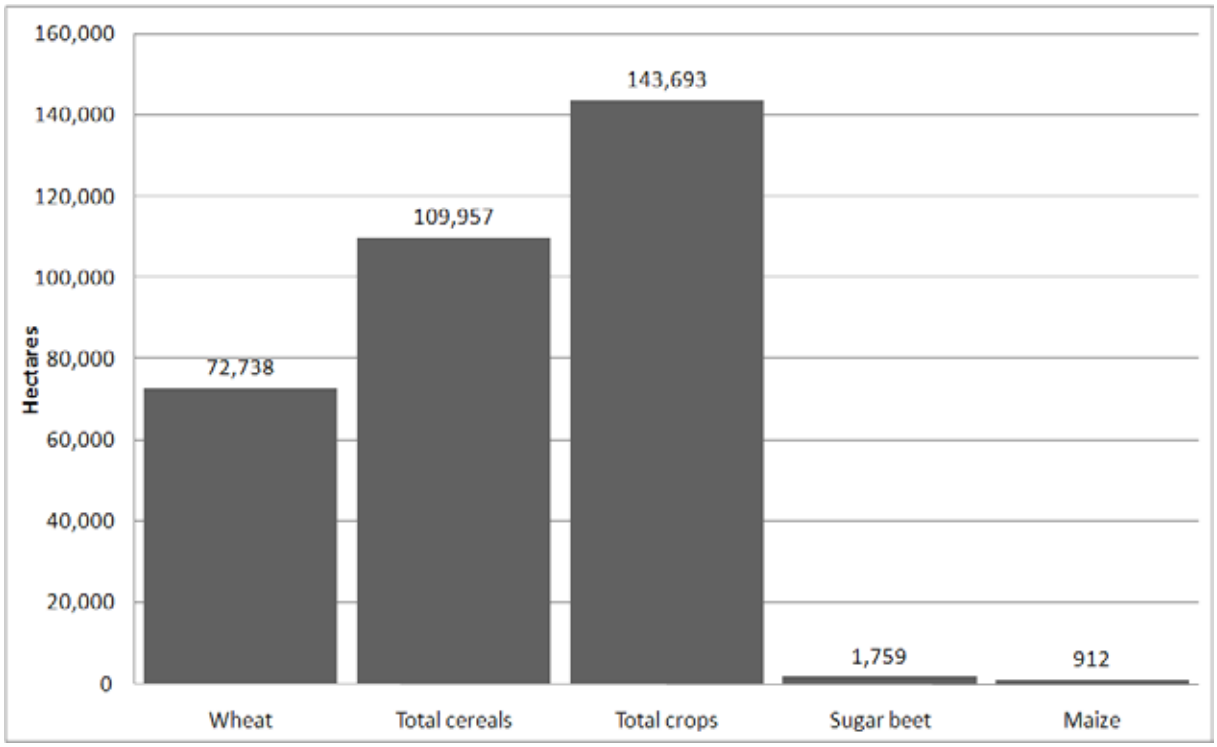

Fig. 3. Selected crops within the 50 km radius of the Ensus plant using 2004 Agcensus data.

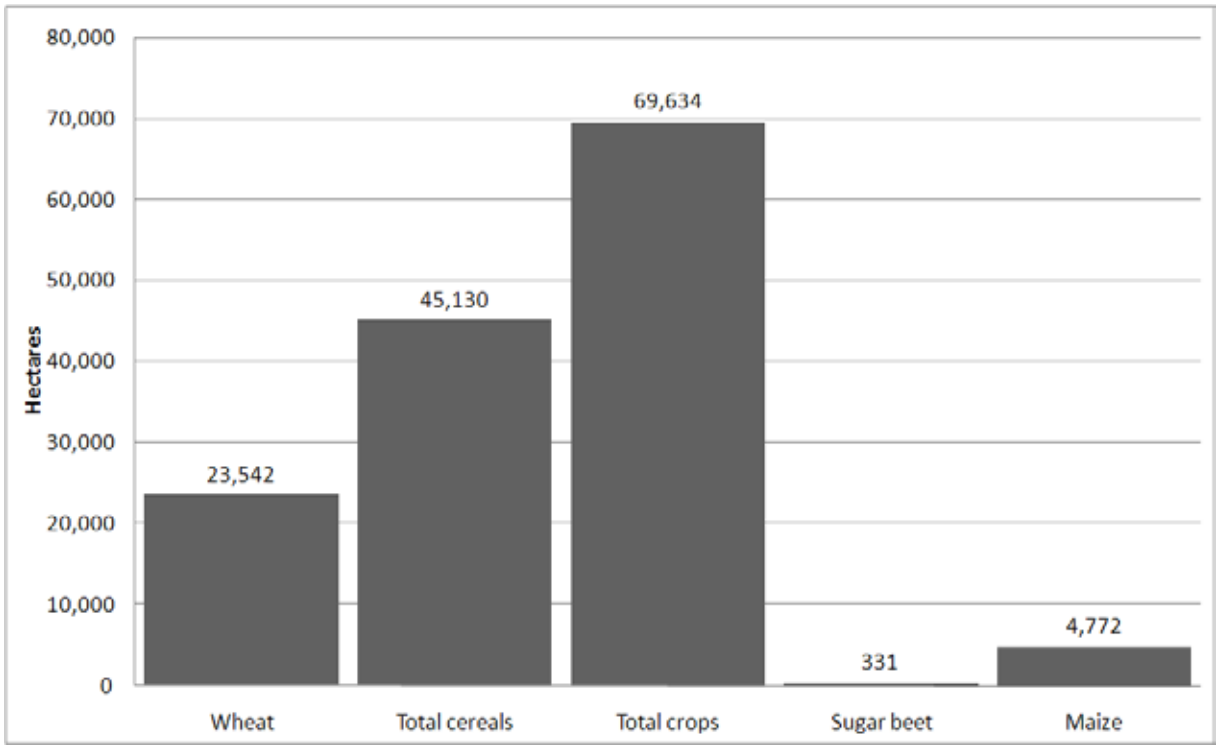

Fig. 4. Selected crops within the 50 km radius of the Cargill plant using 2004 Agcensus data.

This study has made an estimate of the regional bakery demand for local grain based of the local grain requirements of a specific bakery and extrapolated these findings to 36 other bakeries in the Region using companies reported annual financial turnovers. This estimate of local grain demand by regional bakeries has suggested a land requirement of 0.023 million hectares to produce 0.195 million tonnes of wheat for the 37 regional bakeries that have a total turnover of £214 million and 8 071 employees. This level of production is associated with nearly 0.035 million tonnes of CO_2 emissions and requires 146 million tonnes of water in agricultural wheat production. Using an equivalence measurement provided by the research of Hoekstra & Chapagain, (2007) who have

shown the water used in manufacture of bread is ten times the volume used in farm production we can suggest the water required to process and manufacture wheat is 1.46 billion tonnes for the 37 bakeries considered in this study.

Discussion

An important consideration in utilising wheat for bioethanol is to consider benchmarking gross margins of wheat production against other biomass (cellulosic) crops that are utilised for fibre, heat and power. The National Non-Food Crops Centre (NNFCC) has developed a calculator for this purpose (NNFCC, 2009). The calculator shows that wheat produced at a yield of 8.25 t ha^{-1} needs to reach a price of £110−120 t^{-1} to compete with a tonne of hemp fibre, £100−110 t^{-1} for a tonne of Miscanthus and £90−100 t^{-1} for a tonne Short Rotation Coppice (SRC, willow). The price of feed wheat per tonne in the UK has varied between £90 and £110 per tonne in the 2008/2009 period (reported HGCA delivered prices).

The Region's food manufacturers and farmers who have invested in local procurement of wheat require a forecasting tool that will allow them to assess the impact of diverting wheat grain into fuel and associated feed chains. Wheat grown within the 50 km radius of the Vivergo plant represents 50% of the cropping land in this area. Thus, it will potentially have clear implications for sustainability criteria required for the direct Single Farm Payment. Although, these issues should not present conflict between wheat biofuel and food production methods, cross compliance sustainability criteria must be observed and responded to should fuel or food demand change in the future.

There is a requirement to know how wheat biofuel crop production systems in the Region will comply with the Renewable Fuels Agency Carbon Calculator that currently provides the mechanism to assess GHG emissions, qualify assurance and traceability issues associated with biofuel supply. This will require an understanding of potential land use impact and associated changes in the use of nitrogen fetiliser, diesel fuel and other farm management variables in response to the demand for biofuel wheat crop in the Region. While in-depth specific farm survey is not yet possible in the context of the Yorkshire and Humber Region our research has started to develop transportation and haulage scenarios and utilise existing LCAs for bioethanol production in order to provide regionally specific GHG emission balances.

The influence of imported wheat is currently untested in these scenarios and will need to be considered with associated environmental impacts and GHG emission balances. The potential utilisation of other crops such as sugar beet, potato, maize and triticale will also need to be assessed.

The impact of lower nitrogen wheat will also be assessed. There is the potential to develop food technology solutions (enzyme and protein addition) to enable the use of lower protein wheat in bread making. These are innovative and if proven, the techniques will be of international importance. Indeed competition between bread and fuel wheat needs to be determined because the conflict between food and fuel may be manageable using current land use scenarios presented in Figs 1−4. Evidence derived from existing biofuel crop systems show GHG emissions associated with less intensive agricultural production (lower nitrogen fertiliser inputs) are likely to be lower than those of high quality wheat production (bread making wheat). There is an immediate requirement for a study of the Vivergo Fuel refinery impact on the growing of higher nitrogen bread wheat in the region.

The demand for local wheat by millers and bakers in the Yorkshire and Humber Region is not accurately recorded and the food chain data in this study has been extrapolated using limited data. We are currently developing more robust GIS models and scenarios for the production and supply of feedstock into food, biofuel and co-product supply chains. The water, GHG and land use impacts of these production scenarios will be benchmarked and ranked with respect to agri-sustainability

criteria. A key element of agri-sustainability will be economic outcomes and the NNFCC biofuel crops calculator shows how the current relationship between food and fuel feedstock is only just providing economic support for the use wheat as a biofuel crop. This economic calculator demonstrates wheat will have to reach prices of over £100 per tonne to be competitive with the current prices obtained for Miscanthus and SRC. Currently, the price offered for delivered biomass feedstocks (for heat and power) might be considered stronger with the demand from power generators having been established on the basis of renewable energy obligation and carbon reduction targets. Liquid fuel (gasoline substitute and gasohols) security has been a significant driver in the development of biofuels and the volatility of wheat price will increasingly be a factor in determining how the liquid biofuels industry in the UK develops. Furthermore, farm management systems that can deliver increased gross margins for wheat destined for the biofuel, feed or food will be of increased importance in the emerging European biofuels industry.

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