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Straw use and availability for second generation biofuels in England

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ABSTRACT

Meeting EU targets for renewable transport fuels by 2020 will necessitate a large increase in bioenergy feedstocks. Although deployment of first generation biofuels has been the major response to meeting these targets they are subject to wide debate on their sustainability leading to the development of second generation technologies which use lignocellulosic feedstocks. Second generation biofuel can be subdivided into those from dedicated bioenergy crops (DESGB), e.g. miscanthus, or those from co-products (CPSGB) such as cereal straw. Potential supply of cereal straw as a feedstock for CPSGB's is uncertain in England due to the difficulty in obtaining data and the uncertainty in current estimates. An on-farm survey of 249 farms (Cereal, General Cropping and Mixed) in England was performed and linked with Farm Business Survey data to estimate current straw use and potential straw availability. No significant correlations between harvested grain and straw yields were found for wheat and oilseed rape and only a weak correlation was observed for barley. In England there is a potential cereal straw supply of 5.27 Mt from arable farm types; 3.82 Mt are currently used and 1.45 Mt currently chopped and incorporated. If currently chopped and incorporated cereal straw from arable farm types was converted into bioethanol, this could represent 1.5% of the UK petrol consumption by energy equivalence. The variations in regional straw yields (t ha^{-1}) have a great effect on the England supply of straw and the potential amount of bioethanol that can be produced.

1. Introduction

Concerns about energy security and the environmental impacts of energy production have led to the implementation of policies designed to encourage the production and use of renewable bioenergy [1–3]. By 2020 EU legislation requires that 20% of energy must be produced from renewable sources, with 10% of transport energy (final use) derived from a renewable source (EU, Directive 2009/28/EU) [4]. The USA has similar legislation in place that calls for 36 billion US gallons of renewable liquid fuel to be used by 2022 (USA, Public Law 110-140 (2007)). At present 'first generation' bioenergy has been the major technology deployed to meet these renewable targets [5,6], particularly in the transport fuel sector. However, first generation biofuels ferment starches and sugars from food crops (e.g. sugar beet/cane, corn and cereal grains) into liquid biofuels, leading to widespread concern over competition with food production; this aspect being further highlighted during times of increased food prices and food shortages [7–10]. In response, second generation technologies are being developed, often through public-private research initiatives (e.g. the UK's BBRSC Sustainable Bioenergy Centre [11]; the EBI [12] programme in the USA) which use lignocellulosic feedstocks (e.g. miscanthus, cereal straw). Glithero et al. (2012)

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[13], further sub divide second generation biofuel into dedicated energy crop second generation biofuel (DESGB) and co-product second generation biofuel (CPSGB), with the latter utilising co-products from ‘food’ crops (e.g. cereal straw; corn stover). Institutional and private interest in second generation technologies includes mandatory inclusion of lignocellulosic biofuel in the USA, and private sector investment in processing facilities by Inbicon in Denmark [14,15]. Within the UK, dedicated energy crop production remains an ‘infant industry’, with miscanthus and short rotation coppice currently only accounting for 0.044% of agricultural land use [16].

Dedicated energy crops offer the potential for efficient energy production per hectare – for example, some studies show that they are less demanding in their use of inputs than food crops [17] thus providing energy input savings per hectare; however, the overall energy efficiency of biofuel produced from wood or miscanthus (switchgrass) biomass sources is significantly lower than from biofuel produced directly from grains [18]. Moreover, farmer uptake of dedicated energy crops is anticipated to remain low in the foreseeable future [19,20]. By contrast, large areas of cereal crops are grown in the UK (3.013 million hectares of wheat, barley and oats [21] accounting for 16.5% of agricultural land use), with production being greatest in the eastern parts of the country. Production data on the area of cereal crops grown is known, together with industry estimates of quantities of grain produced. However, data on the quantities of straw produced, and the current utilisation of cereal straw (e.g. use in animal bedding/feed, in-field protection of high value crops, co-fired energy production, incorporation into the soil), is lacking. Estimates from a Defra-funded FBS (Farm Business Survey) survey of energy use on English farms in 2007 suggest that soil incorporation of straw occurs on 50% of cereal area (authors’ calculations). Based on crop data, grain to total biomass yields, harvestable straw yield data and requirements for straw by other agricultural sectors, Copeland and Turley (2008) [22], estimated there was a ’surplus‘ of 5.7 million tonnes of straw, from all crop types, in Great Britain. However, in practise, the availability of cereal straw for a bioenergy plant depends on numerous factors, including biomass produced within the field, harvesting height of the straw, cereal varieties grown and the relative proportions of straw to grain biomass. On arable farms in particular, direct straw incorporation into the soil is often practised, potentially providing soil organic carbon enhancement [23,24] and soil nutrients [13]; moreover, commercial farming practise is heavily influenced by policy incentives and directives, and soil health represents a key element of current Common Agricultural Policy (CAP) proposals [25]. In Denmark, growing interest in straw as an energy source has led to a more detailed assessment of the availability of straw for bioenergy production [15]; it was concluded that a significant change in Danish straw supply could arise from minor changes in the grain and straw yield relationship at production level.

Given recent research and industry investment, together with favourable regulatory frameworks, second generation biofuels look set to be an important component of the bioenergy mix that is required to meet EU Directive 2009/28/EU [4]. While lignocellulosic processing plants may look to generate both DESGB and CPSGB, the potential for cereal straw to provide large quantities of feedstock without substantially compromising food production currently exists, and offers immediate potential as a feedstock to the sector. However, dedicated energy crops and cereal straw are both low-value bulky products, with transportation costs accounting for a large proportion of the delivered value of feedstocks. This raises two immediate questions with respect to industry logistics; first what is the total quantity of feedstock potential to supply a second generation bioenergy plant? Second, given the financial and energy costs of feedstock transportation, where do large quantities of ‘surplus’ cereal straw exist that are currently being incorporated into the soil? In order to address these questions we undertook a large-scale on-farm survey of arable farmers throughout England who also participated in the FBS. Survey data was linked to crop production and farm business data available from the FBS. The objectives of this paper therefore are to: (i) describe the scope and methodology of the on-farm survey, (ii) present the survey findings in relation to straw use in England, (iii) aggregate survey data to provide estimates for regional and national (English) straw supplies and use, (iv) investigate potential linkages between straw and grain yields in England, and v) consider the geographical implications of these findings in relation to location of a bioenergy processing plant and arable soil health. The survey scope, structure and sampling strategies are given in Section 2, together with the data aggregation and analysis methodologies. Observed straw yields, grain/straw relationships and aggregated straw use and values are then presented in Section 3. The implications of these findings are discussed in detail in Section 4.

2. Methods

Previous approaches for quantifying crop residue availability include the use of Geographical Information System (GIS) assessment dependant upon regional crop yields, harvested areas and residue to seed/crop product ratios [26]. For example Monforti et al. [26] built upon and updated previous studies [27,28] to estimate total UK crop residues of 20.4 Mt dry matter production of which 8.37 Mt were collectable and 4.2 Mt were available. However, wide ranging estimates of residue to seed ratios are frequently observed in these approaches (e.g. 0.6-1.75 for wheat; 0.9-1.8 for barley), which are further confounded by estimates of recoverable residue to seed ratios (0.8-1.6 for wheat; 0.8-1.3 for barley) [27]. Other researchers have used statistical data obtained from agricultural surveys, accounting for supply of and demand (livestock and humus/soil incorporation requirements) for straw in their analyses; based on an analysis of survey data for the Baden-Württemburg state of Germany, approximately 30% of straw was calculated to be ‘surplus’ [29]. Survey information can be potentially revealing, particularly with respect to regional variation. Within the UK, evidence suggests that 22% of cereal straw remains on the field following baling of cereal crops [30], while other estimates indicate that approximately 50% of stubble, chaff and uncollected straw are returned to the soil after baling [31]; again demonstrating the uncertainty surrounding harvested straw yields. On-farm anecdotal evidence also indicates that grain-straw relationships are not robust with respect to harvestable grain and straw yields. This is due to variation in on-farm practices e.g. cereal varietal choice, use of plant growth regulators to shorten straw height, crop harvesting techniques, cutting height, climate and soil conditions [26].