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Why carbon footprinting (and carbon labelling) only tells half the story

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Summary

The UK is a world leader in the use of carbon footprints. The introduction of PAS2050 has legitimised carbon footprinting and manufacturers and retailers have responded by estimating carbon footprints for selected products. In industrial production, where the relationship between inputs and outputs is constant and the process is tightly controlled, carbon footprints tend to be reproducible. However, agricultural production is different, being influenced by biological, geological and climatic variation. Thus, although the use of a single value to represent the carbon burden of a food product is appealing, in practice it can be misleading. This paper discusses the variability associated with carbon footprints of agricultural products and considers the value of carbon labelling. We suggest that carbon footprinting is a useful approach that will assist in the transition to a low carbon society but that current approaches to carbon labelling may not help consumers understand the carbon burden of agricultural products.

Key words: greenhouse gas, agriculture, food, PAS2050

Introduction

A 'carbon footprint' is an estimate of all the greenhouse gases (GHGs) associated with a process or product. It converts emissions of individual GHGs into a single carbon dioxide equivalent (CO_2eq) value using the global warming potential (GWP) of the individual gases over a 100 year period. Although there are numerous GHGs, the footprint, especially in a farming and food context, represents the total emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The introduction of carbon footprinting has been driven by concerns regarding global warming and the need to understand and quantify the risks that CO_2 and the other GHGs pose to society. The UK is a world leader in the use of carbon footprints. The introduction of PAS2050 (BSi, 2008) has given the carbon footprint an official stamp of approval by the UK Government and its introduction, and use, is being watched throughout the world.

A carbon footprint is expressed in kg or tonnes of carbon dioxide equivalent (CO_2eq) per kg or tonne of output and can be calculated for any system or product. Carbon footprinting within industrial settings tends to focus on energy use, since all energy production emits CO_2. Reductions in the use of electricity, gas or diesel reduce the carbon footprint. In the majority of non-agricultural settings the relationship between energy consumption, GHG emissions and process/product is well understood and constant. Carbon footprinting within an industrial setting is normally a precise auditing process where variation is minimal and results can be presented with confidence.

In addition to carbon, agriculture is responsible for emissions of CH_4 and N_2O. CH_4 is produced by all ruminant livestock and N_2O by soils, especially where amended with manure or nitrogen fertilizers. Unlike industrial production, agricultural production is subject to the inherent variability of living systems. Auditing GHGs within an agricultural setting is not a precise process, variation can be considerable even within the same crop and region, but there is a tendency for the results to be presented with the same confidence as those from an industrial setting.

Over the last five years a number of studies have been undertaken to measure the carbon footprint of agricultural products, but few have measured or reported variation in their data. Exceptionally, Willams *et al*. (2006) suggested that emissions of N_2O could have a coefficient of variation (CV) of 70%. This level of variation is not unexpected. Consequently, all such calculations should be treated with caution and no statistical significance should be attached to the results (Defra, 2009*a*).

Carbon footprint of potato production

In a recent study (Defra, 2009*b*), carbon footprints were prepared for a range of crops from two different regions in the UK (Sussex and Lincolnshire). Data for potato are presented here to illustrate the level of variation within a single crop type. Eight crops were assessed. To aid understanding, the carbon footprint was sub-divided into five components: seed, field operations, fertilizer, pesticides and storage. Each component is discussed separately below and both the variability and the contribution that each makes to the total is described (Table 1).

Table 1. *Carbon footprint for potato in the production stage (to farm gate)*

Crop	Mean (g CO_2eq kg^{-1})	Range (g CO_2eq kg^{-1})	Coefficient of variation (%)
Seed	10.1	7.0−15.2	23.5
Field operations	27.9	18.9−45.7	30.8
Fertilizer	50.4	32.7−67.2	24.4
Pesticides	5.4	1.7−9.1	57.6
Storage	32.8	3.4−81.0	91.0
Overall carbon footprint	132.5	91.7 – 168.4	18.5

Seed

There are two distinct carbon burdens associated with ‘seed’: the inputs to grow the seed potato and the energy required to transport it to the farm. ‘Seed’ contributes little overall to the carbon footprint, just 7.6% on average, and although the variation within this category was the smallest of all five categories, it was still fairly high, with a CV of 23.5%.

Field operations

Field operations comprise seedbed preparation, planting, applications of fertilizers and pesticides, harvesting and any associated road and yard work. The carbon burden associated with field operations is due to CO_2 emissions from use of diesel in machinery. Field operations contributed 21% of the total carbon footprint. Variation was considerable with a CV of 30.8%, and was the result of differences in agronomy, field management, soil type and weather.

Fertilizer

The carbon footprint of fertilizers has two components: CO_2 emissions associated with the production process and N_2O emissions associated with its use. Fertilizer manufacture and use was the biggest contributor to the carbon footprint, accounting for 38% of the total. Although variation within this category only had a CV of 24%, its influence within the overall carbon footprint means that variation in this category can make a profound difference to the overall carbon footprint. Different application rates obviously contribute to the variation. However, variation is also due to the type of fertilizer applied, since each type emits different amounts of GHGs during production (Jenssen & Kongshaug, 2003) and use (Bouwman, 1996).

Pesticides

The manufacture and transport of pesticides contributed little to carbon footprints; just 4% on average. Pesticide use depends on disease, pest and weed pressure and will vary from season to season and region to region. As a result, variability can be very high; this study showed a CV of 57.6%.

Storage

Main crop potatoes are harvested in autumn but are supplied to the market year round, which means they could be stored for up to 11 months. This has large implications for energy use and consequently, the carbon footprint. Storage contributed 24.8% to the total budget on average, but variation was very large, with a CV of 91%. The influence of storage on the overall carbon footprint can be very great; potatoes straight from the ground could have a carbon footprint which is half that of potatoes that have been stored for 11 months.

Overall carbon footprint

The average carbon footprint for potato was 132.5 g CO_2eq kg^{-1}. Variation was considerable, with a range between 91.7 and 168.4 g CO_2eq kg^{-1}. The overall CV was 18.5% and the difference between the smallest and largest footprint was almost two-fold. There was considerable variation within all categories, although fertilizer and storage had the greatest influence on the overall footprint.

Discussion

This study has confirmed, what is intuitively obvious, that there can be considerable variation in the carbon burden associated with the production of a single crop type, in this case, potato. This is because inputs vary, largely as a result of biological, geological and climatic variation in the locations where individual crops are grown.

There is also considerable scope for variation in estimation of a carbon footprint by virtue of the methodology used. Fortunately, PAS2505 provides a framework for assessing GHGs and, in the majority of studies, should enable robust and repeatable assessments. This is especially true where only CO_2 emissions are assessed. However, agricultural products also require assessment of CH_4 and N_2O emissions and this is where variation can be introduced. Methodology used by the Intergovernmental Panel on Climate Change (IPCC) to calculate emissions of CH_4 and N_2O allows three options, or tiers, and suggests that the choice should be based on the availability of data within the national inventory and their robustness. The step from Tier 1 to Tier 2, and similarly from Tier 2 to Tier 3, is assumed to increase accuracy, although the datasets upon which the tier assumptions are based are relatively small for the size of the calculations performed. PAS2050 does not specify which tier should be used, but states that “the estimation of the non-CO_2 GHG emissions arising from livestock, their manure or soils shall use one of the following two approaches: a) the highest tier approach set out in the IPCC Guidelines for National Greenhouse Gas Inventories or the highest tier approach employed by the country in which the emissions were produced".

The IPCC's emission factor for N_2O from nitrogen (N) fertilizers is 0.01 kg N_2O-N per kg N but the uncertainty range is 0.003 to 0.03, a 10-fold difference. Emission factors for methane from dairy cows are between 99 and 128 kg CH_4 per head per year. This level of variation within emission factors is really too great to allow exact values for footprints to be presented with confidence, even though the variation will be reduced by aggregating the different GHGs. In our opinion, carbon footprints should always be qualified by providing details of the emission factors used and some discussion of the variation that can result.

A lack of primary data compounds the problem of variability within emission factors. The agriculture supply chain is long and diverse and collecting primary data can be time consuming and expensive. For this reason, secondary data are often used to estimate carbon footprints. Since the estimation of carbon footprints is a relatively new science, few practitioners exist and data auditing systems have not yet been established. Although the Carbon Trust has been involved in calculating footprints for selected products to date, it does not have the resources to oversee a large expansion, so self auditing is used by all practitioners. This is likely to lead to problems with implementation of the methodology and choice of emission factors.

A carbon footprint provides an estimate of all the greenhouse gases (GHGs) associated with a process or product and the values obtained are used in different and various ways. The aim of the Defra-funded project for which the data in Table 1 were collected, was to assess the environmental impact of horticultural and agricultural cropping and to improve the understanding of how the environmental burdens differ (Defra, 2009*b*). This information will be used to inform future policy decisions to help government address its targets in terms of reduction in GHG emissions. In addition, this type of information could be used as part of a benchmarking approach, to help farmers optimise their use of inputs and resources.

Carbon footprints are also being used to 'inform' consumers about the carbon burden of individual products. For example, several manufacturers and retailers have adopted carbon labels that state how many grams of carbon or equivalent GHGs were emitted as a result of growing, manufacturing, transporting and storing a product. The labels may also include information about the impact of preparing or using a product and of disposing of any waste. In this case, the value on a carbon label is presented as absolute. In addition, no other information is provided, for example, what the value means and how it compares with the carbon footprints of other similar products. For example, Tesco King Edward potatoes have a carbon footprint, in the production stage, of 211 g CO_2eq kg^{-1} (Tesco, 2008). This value appears high compared with the 70 to 168 g CO_2eq kg^{-1} presented in Table 1. However, the value calculated for the production stage, and indeed the range, is almost irrelevant since it is only one of five stages that Tesco have identified. The 'use' stage, which incorporates cooking, has the greatest impact, since the carbon footprint for this stage varies between 240 g CO_2eq kg^{-1} (boiling) to 1025 g CO_2eq kg^{-1} (baking) and introduces enormous variation. Thus by incorporating the 'use' stage in its carbon label, Tesco effectively provides little information about the other four stages involved. This type of approach may not be helpful in encouraging consumers to understand the carbon burden of agricultural products. We suggest that carbon labels should list the stages included in the assessment of the carbon footprint and their percentage contribution to the total burden.

Apart from the carbon burden, crops may also have an environmental impact through water use for irrigation and processing, the impacts of pesticides on non-target species and the potential for leaching, eutrophication and acidification through the process of crop production. These additional effects have to be taken into account when assessing the full environmental impact of a particular crop or production system. Whilst techniques analogous to the carbon footprint are being developed to estimate the impact of each of these effects, it is not entirely clear how the impact of one will be weighed against another.

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