Energy xxx (2016) 1–9

Contents lists available at ScienceDirect

Energy

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

A model calculation of the carbon footprint of agricultural products: The case of Slovenia

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ARTICLE INFO

Article history:
Received 20 November 2015
Received in revised form
21 October 2016
Accepted 24 October 2016
Available online xxx

Keywords:
Carbon footprint
Modelling
Life cycle assessment
Environmental impact assessment
Agricultural farming

ABSTRACT

The pursuit of sustainable development entails a strategic policy decision for all modern countries. Greenhouse gas abatement, the utilisation of renewable energy sources, and energy efficiency represent the main pillars of sustainable development. Agriculture contributes a significant share of greenhouse gas emissions and concurrently represents a carbon dioxide (CO_2) sink; it thus has twofold opposing impacts on climate change. The carbon footprint of agricultural products is one of main measures for monitoring the efficiency and sustainability of agricultural productivity processes. A model calculation of the carbon footprint in the agricultural sector was developed in order to calculate the carbon footprint of grains, fruit, and other agriculture products based on a calculation of total greenhouse gas emissions resulting from production, from the beginning of the production process to storage and delivery to the final consumer or the food industry. The first obstacles in such a calculation are the availability of input data on energy consumption by unit of land for all forms of agricultural land preparation and other work required for sowing, fertilisation, plant protection, harvesting, internal transportation, and other work. The mineral diesel fuel consumption of tractors with various connected machines and self-propelled work machines (e.g. harvesters or forage harvesters for maize) were measured. In addition, the energy consumption required for harvesting and the internal transport of crops on farms itself was included. The results of the model calculation of the carbon footprint of agricultural products consider the type of farming production for three different sizes of farms and for two scenarios regarding soil tillage and seeding.

1. Introduction

The pursuit of sustainable development entails a strategic policy decision of all modern countries. Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [1]. Research in recent years has been focused on different aspects of sustainable energy and environmental protection [2–5]. One of the environmental objectives of sustainability is the “reduction of negative impacts on the environment and health” [6]. The European Union is firmly committed to sustainable development and in 2001 adopted the first EU “Sustainable Development Strategy (EU SDS)” [7,8] and in 2005 adopted an ambitious and comprehensive renewed SDS for an enlarged EU [9]. The EU SDS identifies 7 key challenges and corresponding targets, operational objectives, and actions. The objective regarding climate change and clean energy is to limit climate change and its costs and the negative effects on society and the environment.

Greenhouse abatement, the utilisation of renewable energy sources, and energy efficiency represent the main pillars of sustainability development.

Agriculture contributes a significant share of greenhouse gas emissions and concurrently represents a carbon dioxide (CO_2) sink; it thus has twofold opposing impacts on climate change . Agriculture is the largest contributor to anthropogenic emissions of greenhouse gases [10]. Agriculture covers approximately 35% of the land area and accounts for nearly 13.5% of the total global anthropogenic GHG emissions, contributing about 25%, 50%, and 70% of CO_2, CH_4, and N_2O, respectively [11], and in the future it will be faced with significant requirements as regards reducing greenhouse gas emissions.

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http://dx.doi.org/10.1016/j.energy.2016.10.099
0360-5442/

Greenhouse gas emissions in the agricultural sector (direct emissions) arise from the use of fossil fuels (for machinery, space and process heating, and other uses), animal breeding (enteric fermentation of domestic animals, storage of livestock manure, etc.), and agricultural land use (fertilisation with mineral and/or organic fertilisers, the rinsing of nitrogen compounds in water, the decomposition of crop residues, processing histosols, etc.). Indirect GHG emissions arise due to the consumption of electricity and district heating in agriculture.

The carbon footprint of agricultural products is one of main indicators for monitoring the efficiency and sustainability of agricultural productivity processes.

The carbon footprint of a product is of great interest as a central measure of the environmental impact of supply chains [12]. A carbon footprint is a quantitative measurement describing the appropriation of natural resources by humans [13,14] and describes how human activities can impose different types of burdens and impacts on global sustainability [9]. A review of the literature indicates that the major categories of footprints developed to date are carbon, ecological, and water footprints, forming the so-called "footprint family" [15,16].

Determination of the carbon footprint of agricultural products requires a detailed analysis of energy consumption in the various processes used for crop production. Total input energy in agricultural production is the sum of all the components of the energy used in the different processes for the production of outputs (agricultural products – grain, fruit, etc.). Different studies and research have focused on an analysis of the direct energy inputs in grain production and their results are presented in [17–21]. Some studies have addressed individual agricultural processes in the production of one type of grain [22,23] or the energy inputs for the production of one important product (e.g. wheat) [24,25].

A carbon footprint presents the total amount of CO_2 and other greenhouse gases (GHGs) emitted over the full life cycle of a process or product [26–28] and has become one of the most important environmental protection indicators [29,30].

A carbon footprint is quantified using such indicators as the GWP (Global Warming Potential) [17], which represents the quantity of GHGs that contribute to global warming and climate change.

The carbon footprint of agricultural food products can be compared to the energy labelling of appliances for households. There are different types of farming regarding the preparation of the soil, the use of fertilisers, and other chemical preparations (conventional, organic, integrated, etc.). The calculation of the carbon footprint is carried out for agricultural products using the Life Cycle Assessment (LCA) methodology [30–32].

LCA is one of the most widely recognised approaches to the environmental assessment of products and processes [33]. Several LCA methodologies have been developed thus far, and these have been somewhat improved over the last decades, namely: attributional and consequential LCA, hybrid LCA, process LCA, and input/output LCA [34]. Current activities regarding database improvement, quality assurance integration, consistency improvement, and the harmonisation of methods are contributing to this improvement process. Mainly, there are two main perspectives on LCA: retrospective and prospective. The selection of the elements of the physical system to be modelled depends on the definition of the goal and the scope of the study [33].

The model calculation of the carbon footprint of agricultural products using LCA requires a large database with data on the energy consumption for each activity in addition to data on the quantity of fertilisers used, annual product yield, plant protection products, etc.

This research is the first study on the carbon footprint of agricultural production in Slovenia. The carbon footprint of agricultural products is based on the input of energy for mechanised operations with farm machines and the input of fertilisers for different types of farming (conventional, organic, and integrated) and different farm sizes (small, medium, large).

This paper describes the structure of the model calculation of the carbon footprint of agricultural products and the establishment of a database for Slovenia. The results present an assessment of the carbon footprint of grains and fruit by different type and size of farming in Slovenia.

2. Greenhouse gas emissions from agriculture

The contribution of direct emissions from agriculture, excluding emissions resulting from fuel use, fertiliser production, and agriculturally-induced land use change, is estimated at 10–12% of global GHG emissions. Total GHG emissions (direct and indirect) rise to 30% of global GHG emissions when additional emissions from fuel use, fertiliser production, and land use change are included (land use change alone accounts for 6–17%) [10,35].

In the Slovenian case, electric irrigation pumps are not used in crop production and direct energy use in Slovenian crop producing farms only stems from diesel fuel (3%–7% biodiesel is mixed with mineral diesel fuel, in accordance with the Slovenian regulation on fuels) [36,37] and natural gas (used in some cases for drying grain).

The share of GHG emissions from the agriculture sector in Slovenia is about 10% of the total inventory of greenhouse gas (GHG) emissions (Fig. 1) in Slovenia (without emissions caused by energy consumption in agriculture) [38–40].

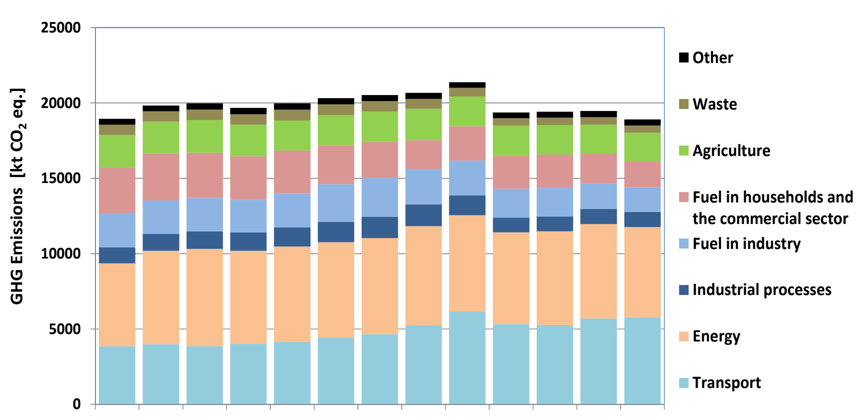

Fig. 1. Total GHG emissions in Slovenia for the period 2000–2012 by source.

Please cite this article in press as: Al-Mansour F, Jejcic V, A model calculation of the carbon footprint of agricultural products: The case of Slovenia, Energy (2016), http://dx.doi.org/10.1016/j.energy.2016.10.099