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Regionalised life cycle assessment of pasta production in Iran: Damage to terrestrial ecosystems

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ABSTRACT

The field of life cycle assessment (LCA) is moving towards the implementation of advanced damage models to assess specific areas of protection. The goal of this study was to quantify the main sources of terrestrial ecosystem damage from pasta production, based on a regionalised life cycle inventory and impact assessment. The impacts on terrestrial biodiversity caused by climate change, ecotoxicity, acidification, land use, photochemical ozone formation and water use were assessed for pasta production from durum wheat on 90 farms in Iran. The results showed that the agricultural stage was the main source of environmental damage in the life cycle of pasta production. Most variability between farms is caused by variation in the wheat yields. Climate change contribution, water use (for irrigation), and photochemical ozone formation were the main contributors to the impacts on terrestrial biodiversity. Climate change contribution was mainly due to carbon dioxide emissions from diesel fuel burning during agricultural operations. Nitrogen oxide emissions from nitrogen fertiliser production were the main contributor to photochemical ozone formation. Farmers can reduce their diesel use in field operations by combining tillage operations so that only one pass across the soil is required. Various innovative practices in irrigation, such as sprinkler irrigation, can result in higher yields which will lead to reduced environmental damage relating to water use.

1. Introduction

The environmental impacts of food production and distribution vary considerably, depending on the life cycle of the food product itself, the geographical location of production and consumption, and the degree of post-harvest processing (Hess et al., 2016).

Life cycle assessment (LCA) is a technique for the assessment of environmental impacts of product systems over their entire life cycle. It is commonly used to guide environmental policies and programs, to inform consumer's choices through environmental labelling and declarations (ISO 14044, 2006).

Regionalisation of inventories (Yang, 2016) and impact assessment methods is increasingly being implemented in LCA studies (e.g. electricity generation (Mutel et al., 2012) and agricultural activities (Nitschelm et al., 2016)). LCA studies require the collection of both activity data and increasingly region-specific background data to accurately depict supply chain processes and enable the application of an increasing number of geographically explicit impact assessment models (Morais et al., 2016).

Some environmental impacts can vary depending on the characteristics of their surroundings, and therefore on the location of the activity. This variability can be taken into account in environmental assessment using regionalised LCA (Nitschelm et al., 2016). Recent developments in LCA have focused, amongst other things, on the regionalisation of impacts (Hauschild and Huijbregts, 2015), and the further advancement of impact assessment (LCIA) methods. Examples include the implementation of impact assessment relating to water use (Verones et al., 2013) and land use (Elshout et al., 2014). These developments are especially important to agricultural LCA studies since the impacts analysed are clearly site-dependent. In agricultural LCA, land use and water use due to irrigation are the main drivers of impacts, and (terrestrial) biodiversity is directly and indirectly damaged due to crop cultivation

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(e.g., Mila i Canals, 2003).

Pasta is an important food product in Iran, not only because of its large production quantities, but also for its importance in the human diet. Iran's pasta industry is growing continuously, and based on the latest world pasta statistics, Iran is the sixth largest producer of pasta in the world at 560,000 t/y (IPO, 2014). Iranian pasta consumption is 8.5 kg/y, per capita, making Iran the seventh highest consumer of pasta in the world (IPO, 2014).

Previous LCAs of pasta production in southern Italy (Bevilacqua et al., 2007), Sicily (Giudice et al., 2011), Sweden (Roos et al., 2011) and Chile (Bengtsson et al., 2012) reported that wheat cultivation is the life cycle stage with the highest environmental impacts for many impact categories.

Most agricultural LCAs do not, however, consistently address land use and ecotoxicity impacts due to the expected high level of uncertainties in the impact assessment, and a lack of both specific characterisation factors (CFs) and inventory data (De Schryver et al., 2010). Most agricultural LCAs do not use site-specific inventory data coupled with regionalised CFs (Morais et al., 2016). Since the CFs in the majority of impact categories relevant to agricultural activities are dependent on site-specific characteristics, it is considered important to perform this type of analysis based on regionalised LCIA, and site-specific inventory data.

The goal was to quantify the damage of pasta production to terrestrial biodiversity in an Iranian context per functional unit (FU) of 1 kg of pasta produced. Inventory data was obtained from one pasta factory and 90 farms in Iran. Up to date CFs were used that allowed an Iran-specific analysis. Measures of terrestrial ecosystem damage due to climate change, acidification, photochemical ozone formation, ecotoxicity, land use and water use were included.

2. Materials and methods

2.1. Goal and scope

Data were collected from a pasta factory near Karaj city, Iran, and data on durum wheat production were obtained during the growing period 2012–2013 by undertaking semi-structured interviews with durum wheat farmers from 90 Iranian farms. These farms account for 2% of the total durum wheat production of Iran and were randomly selected from farms around the cities of Dezful, Darab, and Orzueeyeh (30 farms per city). These cities are located in the provinces of Iran that produce the most durum wheat, i.e. Khuzestan (24% of national production), Fars (30%), and Kerman (16%). Damage to terrestrial biodiversity (as potentially disappeared fraction of species (PDF) integrated over space and time in m^2 y) was determined per FU of 1 kg of pasta produced. The following steps of the food product system were took into account during the analysis (Fig. 1):

2.2. Life cycle inventory

All data pertaining to emissions and resources extracted that are related to the FU are collected at the life cycle inventory (LCI) stage. In this study, inventory data for durum wheat production, transportation and pasta factory subsystems were collected by means of site visits and surveys of Iranian wheat farms, truck drivers, and the pasta factory. As illustrated in Fig. 1, the system is divided into two main sources of emission: material production and their consumption. The production phase of an input (e.g. diesel fuel) includes all the emissions relating to material extraction, production of the input and its transportation to the market. The consumption phase includes all the emissions relating to input use, e.g. emissions from diesel burning in the engine of tractors used in farm operations.

Pre-farm stage: Data from the manufacturing and transportation of inputs to farms, most importantly agricultural machinery, diesel fuel, durum seed, chemical fertilisers, herbicides and pesticides were taken from the Ecoinvent 3.2 database. The production chain of all inputs have been taken from the material subcategory of the process in the Simapro software (Pre-sustainability 2015), e.g. Iran-specific low voltage electricity from “electricity country mix” was selected as the electricity input, while diesel representative to the rest of the world (RoW) from the process of oil fuel was selected as diesel production for all stages of pasta production, because of a lack of Iranian-specific data. Herbicide, pesticide and fertiliser production were selected from the subcategory of materials-chemicals in the process branch.

On-farm stage (agricultural stage): Data on durum wheat production were obtained by undertaking semi-structured interviews with durum wheat farmers.

Transportation from temporary storage to the food processing

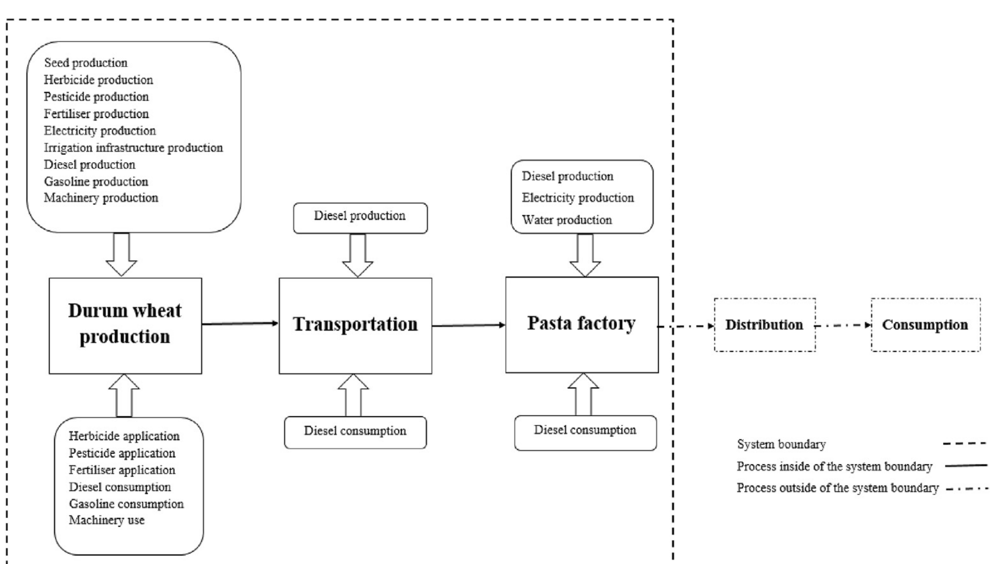

Fig. 1. Overview and system boundaries of the pasta production chain.