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Development of a web application for estimating carbon footprints of organic farms

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ABSTRACT

Organic farmers often use complex management practices to foster a positive impact on the environment. Many tools exist to aid in estimating environmental services but few are able to properly handle the complexities of organic agriculture. We developed an online tool called OFoot to estimate the carbon footprint of organic farms located in the Pacific Northwest and to help evaluate the potential for environmental benefits. OFoot utilizes a cradle-to-gate carbon calculator and a biophysical, process-based, cropping and field management model. We present the software architecture of the tool, model descriptions, and a case study which simulates several scenarios of organic potato production. The scenario simulating potato production with organic fertilizers and a leguminous winter cover crop sequestered soil carbon. The other scenarios, either lacking fertilizer or cover crops, lost soil carbon. The usefulness of the tool as an aid to management decisions is demonstrated.

1. Introduction

Many farmers choose to follow organic farming practices because of the potential environmental benefits. Some agricultural systems degrade the land; agriculture contributes an estimated 14% of global GHG (IPCC, 2014), can lead to soil acidification (Ghimire et al., 2017), and soil loss (Feng et al., 2011). Organic agriculture, in comparison to conventional farming, has been shown to be more energy efficient (Smith et al., 2015) and produce less N_2O (Skinner et al., 2014) on a per-area basis. Furthermore, organic agriculture tends to reduce soil loss, increase soil organic matter, increase water holding capacity, and improve the soil microbial community (Gomiero et al., 2011). Many of the environmental benefits associated with organic agriculture can be attributed to farming practices that promote diversity (e.g., Kremen and Miles, 2012) and organic inputs such as complex crop rotations, green manures, intercropping, and natural pesticides (Gomiero et al., 2011). But there are tradeoffs. Organic agriculture is generally between 8% and 25% less productive than conventional (de Ponti et al., 2012; Reganold and Wachter, 2016). Results of lifecycle assessments, therefore, depend on the functional unit chosen (Adewale et al., 2016), i.e., whether results are expressed per unit area or per unit mass of farm product. Also, N_2O emissions from green manures can exceed those from inorganic sources, depending on the farming system and the time of year (Alluvione et al., 2010). In the context of these tradeoffs, growers who operate under the general assumption that organic agriculture provides a higher level of environmental services would be well-served by a mechanism whereby they could state beyond generalities that their operations are environmentally sound.

Numerous tools assist growers to understand the main sources of greenhouse gas (GHG) emissions and other environmental impacts of a farm (Denef et al., 2012; Colomb et al., 2013; Whittaker et al., 2013; Keller et al., 2014). However, few of these tools utilize process-based models that are needed to simulate accurately the complex management and crop rotations that are common to organic farms (Colomb et al., 2013). The MiLA tool (Peter et al., 2017) can account for the effects of crop rotation on soil dynamics at the farm level, but it is based on empirical models that limit its adaptability. Tools like MiLA, and its parent, the Cool Farm Tool (Hillier et al., 2011), that are based on empirical models have the benefit of often requiring less input data than those based on mechanistic models. However, with the recent movement of open access and open data (Lokers et al., 2016), obtaining detailed input data becomes an issue of computer scripts rather than human labor. Indeed, the COMET-Farm greenhouse gas accounting tool (COMET-Farm, 2017) leverages a series of online datasets to automatically provide input to the dynamic model DayCent

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(Parton et al., 1998). The development of COMET-Farm coincided with this project, but unlike COMET-Farm, this project had a focus on organic agriculture.

To better quantify the environmental impact of organic farms at the farm and field scale we developed a web-based tool called OFoot. Our purpose for developing OFoot was to create a tool that could account for the dynamic nature of organic farms by using mechanistic simulations models, to automate much of the complexities of providing site-specific input data for said models, and to focus on organic crops grown in the PNW.

The aim of this paper is to describe the development and structure of OFoot and to illustrate its use.

2. Software overview

OFoot uses a cradle-to-gate carbon calculator to quantify greenhouse gas emissions of the equipment, infrastructure, and consumables used on a farm; including the embodied energy and direct emissions associated with each item. In addition, OFoot includes a biophysical process-based model to simulate one or more fields on the farm. This field model is used to estimate soil and crop dynamics and associated GHG emissions based on user-specified management practices. The tool is accessible through any device that is able to run a modern Web browser such as desktop computers, laptops, cell phones, and tablets. The description of the farm and associated management practices are entered through a step-by-step navigation wizard and a series of interactive forms. The information persists through a database and is accessible and editable by the user at any time. After data entry is complete and the simulation models have run, a comprehensive report is dynamically generated providing a breakdown of the farm's carbon footprint and details of soil dynamics.

2.1. Workflow

OFoot is broken down into six sequential steps, four of which gather user input and two of which provide feedback to the user

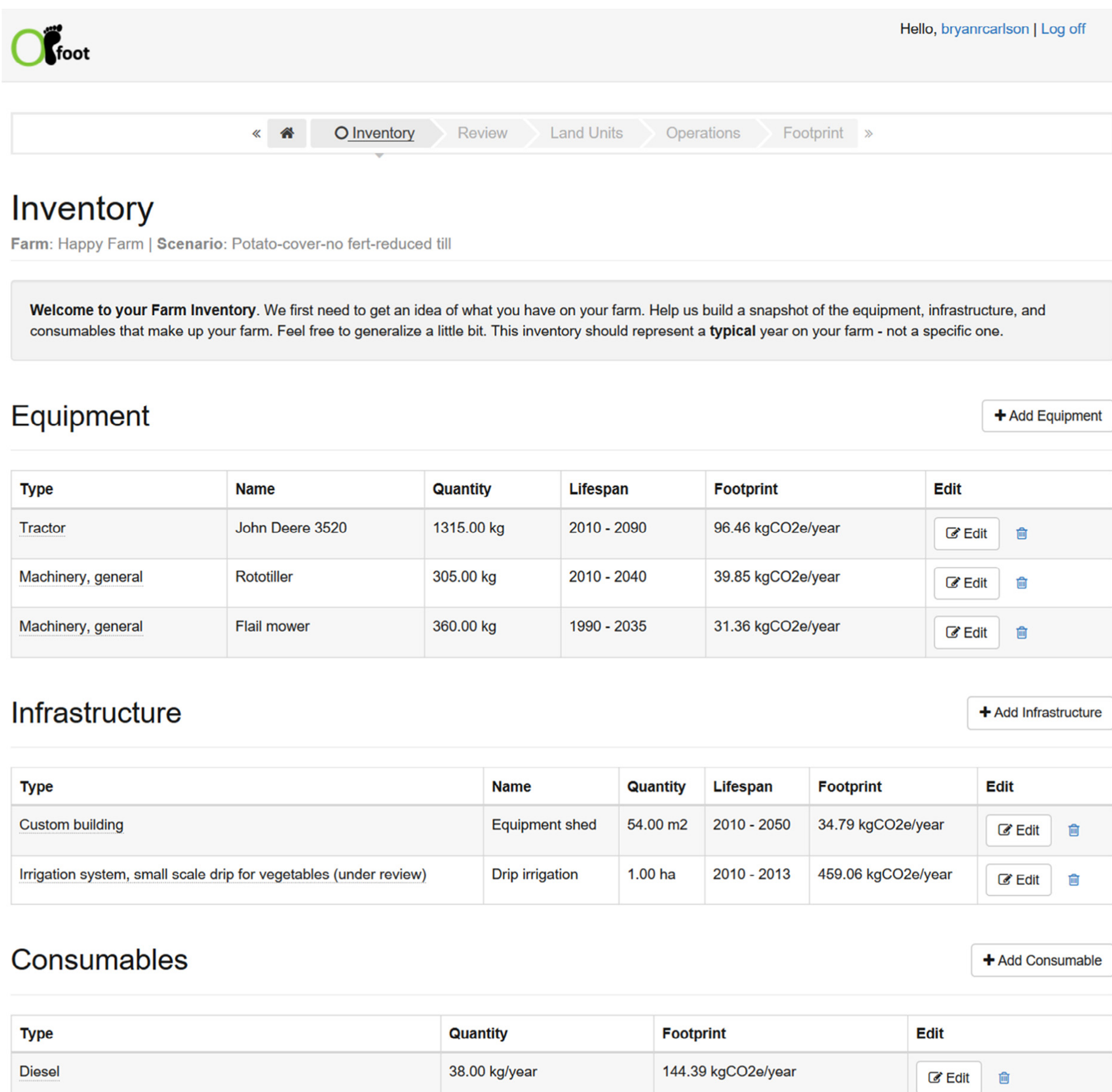

Fig. 1. Screenshot of the OFoot tool displaying the farm inventory screen. In this section of the tool, users choose equipment, infrastructure, and consumables from prepopulated lists and describe the quantity and lifespan of the item. OFoot calculates the carbon footprint of the items as they are added. A navigation wizard is located at the top of the screen to allow movement between parts of the tool and to emphasize the flow of data entry.