Farm Explorer: A Tool for Calculating Transparent Greenhouse Gas Emissions

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Abstract

This demo provides an overview of *Farm Explorer*, a tool designed to calculate greenhouse emissions on farms in a transparent manner. *Farm Explorer* uses semantic descriptions of emission calculation formulas by leveraging knowledge graphs containing static and dynamic information about the farm operation and emission conversion factors. To enhance the transparency of emissions calculations, the tool records the provenance of the calculation process using standards like W3C PROV and W3C SOSA.

Demo: https://w3id.org/tec-toolkit/ISWC-2024-demo
Source: https://github.com/eats-project/farm-explorer

Keywords

provenance, carbon footprint, transparency, knowledge graph

1. Introduction

The agrifood systems, responsible for about a third of global anthropogenic greenhouse gas emissions [1], heavily rely on commercial carbon calculator tools [2]. Such tools aggregate results calculated using various emission methodologies, data sources (e.g., GFLI for feeds [3]) and carbon standards (e.g., GHG Protocol [4]) applied to specific aspects of agrifood activities (e.g., primary production on farms). Businesses provide data inputs that often need to be laboriously extracted from heterogeneous sources (e.g., sensors, manual records, machinery logs, etc.). For example, to estimate emissions on a farm, a calculator may consider the electricity required to operate heavy machinery, use of fertilisers, amount of manure produced, and other logistics. Here, a typical emission calculation would estimate the amount of emissions-

Posters, Demos, and Industry Tracks at ISWC 2024, November 13–15, 2024, Baltimore, USA
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generating resources (i.e., activity data) and multiply them by their corresponding emission conversion factor. We argue that semantic web technologies are ideally positioned to provide the technological backbone for a fine-grained "smart data" layer enabling such calculations by integrating heterogeneous data (e.g., manually extracted data, automated sensor measurements, etc.) into an integrated framework. Furthermore, data provenance models may support an understanding of the assumptions, parameters, and data interdependencies within the applied emissions calculation methods, which is crucial to ensure trustworthy estimates and enables their comparison at scale (e.g., across the food supply chain).

2. Demo: Transparent KG-driven Emissions Calculations Guided by Semantic Plans

We present *Farm Explorer*, a web-based application designed to capture and browse transparent emissions calculations based on semantic technologies. Our tool addresses the following aspects of the emissions calculation process:

a. **farm assets linked to emissions**, by describing farm assets generating carbon footprint such as agricultural land and crop area and machinery use; b. **farm operation logs**, by describing observations related to farm assets generated by sensors and humans; c. **emission calculation methods**, by creating semantic representations of carbon footprint executable formulas (leveraging farm assets and their associated observations); d. **transparent footprint calculation**, by capturing formula execution in a provenance trace with rich metadata to enhance the transparency of the calculation process.

Farm Explorer represents calculation formulas as semantic plans and uses `SPARQL CONSTRUCT` queries to generate a provenance trace recording the calculation process for increased trans-

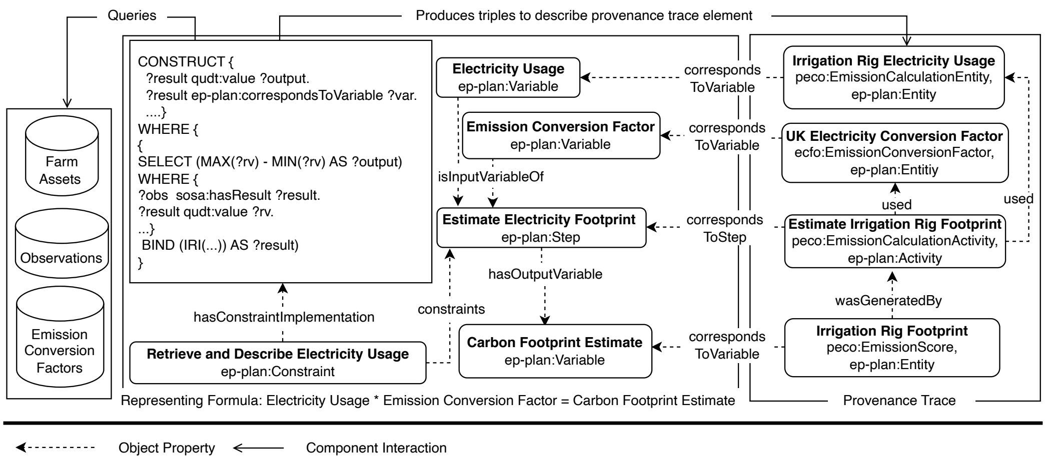

Figure 1: A high-level description of the calculation formula using EP-Plan and the corresponding provenance trace using PECO and ECFO (emission conversion factors). Prefixes in properties have been omitted for clarity. All prefixes are available at https://w3id.org/tec-toolkit/ISWC-2024-demo.

parency. Our approach thus aligns several existing ontology models (PROV [5], SOSA [6], EP-Plan [7], OpenMath [8], ECFO [9], PECO [9]) and aims to decouple the application code from the calculation logic for emissions calculations. The overall data model for describing farm data is based on the Agriculture Information Model (AIM) [10] and the W3C Semantic Sensor Network Ontology (SSN) [6].

3. System Overview

Let us consider a scenario where a series of daily smart meter readings capture fine-grained electricity usage of the irrigation rig for a particular season. Fig. 1 illustrates the main data elements of the *Farm Explorer* tool: a. description of the emissions calculation method (EP-Plan, OpenMath); b. Knowledge Graphs describing the farm operation (AIM, SOSA and SSN) and emission conversion factors (ECFO); c. emission calculation provenance trace (EP-Plan, ECFO, PECO). *Farm Explorer* captures a mixture of static and dynamic data. The static data describes the farm (`smart:AgriFarm`) and the farm assets such as a polytunnel (`smart:ArgiParcel`) and different pieces of machinery such as an electricity smart meter (`sosa:Sensor`) and an irrigation rig (`sosa:Actuator`). The dynamic part of the farm operation is represented as a series of observation results (`sosa:Observation`, `sosa:Result`). At its core, EP-Plan models provenance plans as acyclic graphs consisting of steps, input and output variables, and step constraints (see the calculation formula box in Fig. 1). We use EP-Plan to model emission calculation formulas, for example, inputs describing amount of kWh of electricity used by an irrigation rig (`ep-plan:Variable`) multiplied (`ep-plan:Step`, `openmath:Times`) by a specific electricity emission conversion factor (`ep-plan:Variable`) results in an output describing a CO2e emissions estimate (`ep-plan:Variable`). We use step constraints (`ep-plan:Constraint`) to define SPARQL CONSTRUCT queries to create an executable plan of the calculation method. The construct queries retrieve the corresponding variable values and create additional provenance descriptions in the execution trace (`ep-plan:ExecutionTraceBundle`) when the calculation method is executed on the farm data. For example, Fig. 1 describes a query that retrieves fine-grained electricity usage sensor readings and generates relevant description in a provenance trace recording the total energy usage for the period of interest as an input of the emissions calculation. Additional queries are defined for the remaining input and output variables.[1] PECO and ECFO ontologies [9] are used to describe the individual parts of the provenance trace (i.e., `peco:EmissionCalculationEntitiy`, `ecfo:EmissionConversionFactor`, `peco:EmissionCalculationActivity`, `peco:EmissionScore`) corresponding to the emissions calculation plan. Figure 2 shows these concepts in the *Farm Explorer* demo, depicting the step and details of inputs and outputs involved in calculating the CO2e emissions from electricity consumption in an irrigation rig.

[1] https://github.com/eats-project/farm-explorer/blob/main/src/main/resources/static/data/examples/exampleQueries.txt

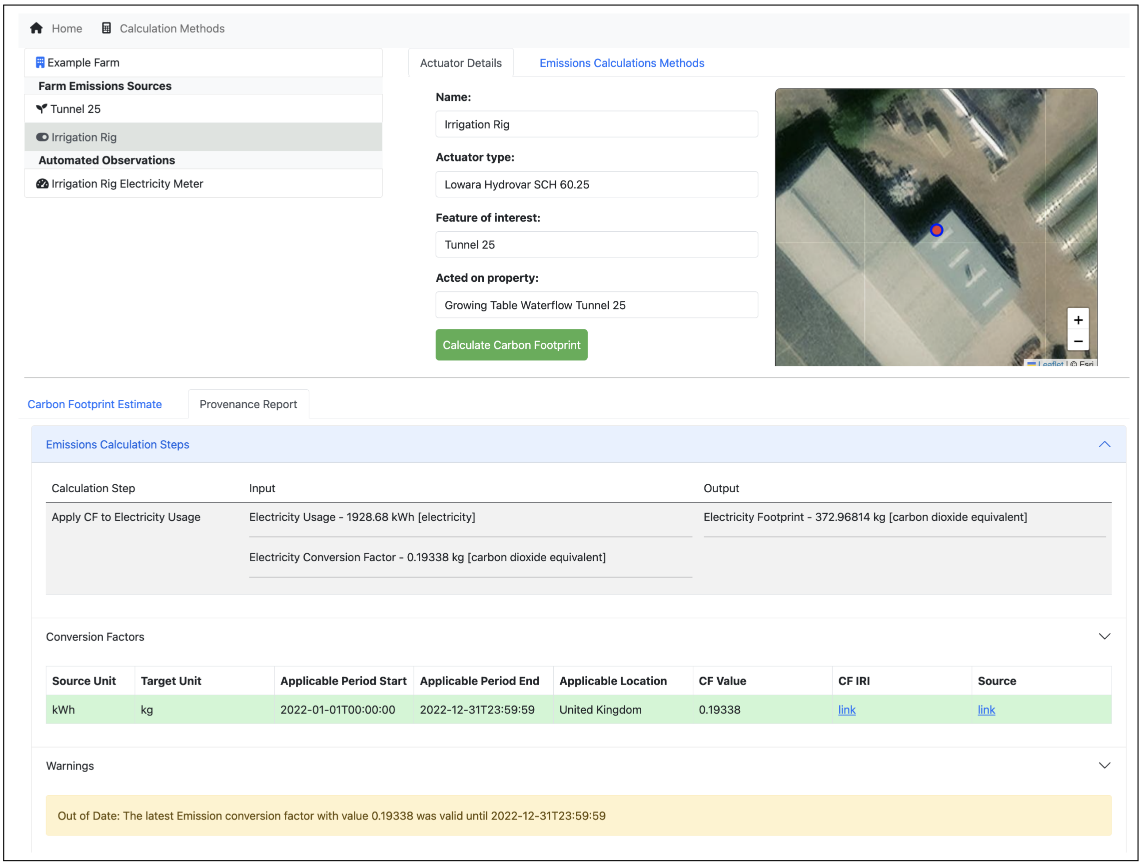

Figure 2: Overview of FarmExplorer showing the power consumption of an irrigation rig. The provenance report shows precisely the electricity consumed and the conversion factor used to calculate the output carbon dioxide equivalent emissions. Results of automated checks to inform, for example, about the presence of out-of-date conversion factors in the provenance trace are also included.

4. Conclusions & Future Work

We have briefly described *Farm Explorer*, our progress towards achieving transparent emissions calculation pipelines. Our ultimate future goal is to achieve full automation of emissions calculations and their comparisons across complex business networks. Further unresolved challenges include: automatic alignment of appropriate conversion factors to specific assets/activities, descriptions and the integration of process-based and machine learning components for emissions estimates within semantic pipelines, automatic generation of data processing queries and calculation explanation from provenance traces (e.g., using Large Language Models [11]).

5. Acknowledgments

This work was supported by the UK Engineering and Physical Sciences Research Council [grant numbers EP/V042270/1, EP/V050869/1, EP/S019111/1].

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