Persephone

Overview, Design concepts, Details (ODD)

## Purpose

The purpose of the Persephone model is to simulate the effects of CAP policies on the decisions of farmers in Europe, and consequently, on landscapes, biodiversity, and ecosystem services.

This model description follows the ODD format, as described by (Grimm et al. 2006; 2010; 2020).

## Entities, state variables, and scales

Persephone is comprised of a farm model and a nature model. It has two types of spatial entities and four types of biological entities:

**Patches** are grid cells in the landscape, characterised by location, habitat type, soil type, soil nutrients, soil water, soil organic matter, a plant and an insect community. This is the spatial level on which the nature model works.

**Plots** are contiguous aggregations of patches that form the management entities for farmers. They are characterised by location, size, owner and management regime (i.e. a crop and the associated husbandry practices). This is the spatial level on which the farmer model works.

**Plants** are modelled as superindividuals, with one superindividual representing all individuals of one species inhabiting one patch. The list of modelled species includes multiple crop species and a generic “wild herbaceous species”. Plants are characterised by their biomass, maximum dispersal distance, and growth parameters (dependent on soil type, nutrient and water availability, and temperature).

**Insects** are also modelled as superindividuals, analogously to plants. The modelled generic species each represent one functional group: pollinators, predators/parasitoids, and crop-specific pests. Insect superindividuals are characterised by their population size, target species (plants or other insects), feeding rate, and reproductive and dispersal parameters (rate, distance, and phenology).

**Animals** are modelled as individuals, with animals of different species exhibiting different behaviour. Indicator species modelled will include a butterfly, a bird, and a mammal. They are characterised by their location, age, current behavioural state, and energy level.

**Farmers** are the primary actors of the farm model, characterised by age, farm house location, plot properties, equipment, financial resources, attitude to farming, and a current management action.

The model has a spatial resolution of 5x5m for the patches and a maximum spatial extent of the landscape of approx. 10x10km. The overall temporal resolution is one day (hourly for animals), with a complete simulation running for 10 years.

## Process overview and scheduling

1. **Plant growth & dispersal.**
2. **Insect growth, feeding & dispersal.**
3. **Animal foraging, reproduction, resting, mortality.**
4. **Farmers’ actions.** Farmers’ actions are queued up for each plot based on its decided management regime and carried out upon their conditions being met (e.g. right time of year, right weather, high pest/weed densities, etc.). Once a management regime has been completed, a compatible regime is chosen by the farmer to succeed it.

## Design concepts

#### Basic principles

* Work with real species where possible and desirable (crops, target conservation species), use generic species to represent processes that are important but too complex for detailed modelling (wild plants, insect populations).

#### Emergence

* Farmer behaviour in a given socio-economic-environmental context
* Landscape structure (percentage of crops and semi-natural habitats)
* Animal behaviour & population dynamics

#### Adaptation

* Farmers react to market prices, weather, pest & weed densities
* Animals react to landscape structure and presence of plants and insects

#### Objectives

* Farmers: make a profit, satisfy internal motivation
* Animals: find enough food, reproduce

#### Learning

* Possibly in farmer decision making?

#### Prediction

* Possibly in farmer decision making?

#### Sensing

* Farmers know the conditions and management history of their fields, weather, and market prices
* Animals have a perceptory range within which they perceive the surrounding flora and fauna

#### Interaction

* Farmers’ management actions affect plants, insects, animals
* Plants attract certain insect species, insects feed on plants and each other
* Animals feed on plants and insects

#### Stochasticity

* Plant and insect dispersal

#### Collectives

* Superindividuals used to model plants and animals
* possibly social behaviour in animals (depending on target species)
* possibly collaborative actions of farmers

#### Observation

* Economic indicators:
  + farm income
  + overall production
* environmental indicators:
  + applied fertiliser & pesticides
  + soil characteristics
* ecological indicators:
  + habitat heterogeneity
  + population sizes & trends of target species
  + measures of pollination & pest control

## Initialisation

* read in map data & configuration files
* create patches with plant & insect populations
* create plots, assign owners & current management regime
* create animal populations

## Input data

* Spatial data: habitat types, soil types, plot boundaries
* weather data (temperature, precipitation) for the whole landscape
* plant species growth parameters
* farmer population & characteristics
* market prices for farm products

## Submodels

#### Policy context

This will consider CAP payments (direct payments and eco-schemes) as well as regulatory requirements on the EU (enhanced conditionality) and national (Düngeverordnung) levels.

#### Farmer decision making

This is the heart of the farm model and will integrate policy and economical considerations, personal motivations, and possibly farmer collaboration.

#### Management actions

These are based around the crops grown in the study areas and define which crops are grown in which rotation, when they are planted and harvested, and when which husbandry actions are carried out (e.g. plowing, fertilisation, pesticide application).

#### Soil

This is modelled for each individual patch and considers the changes in soil organic matter, nutrients, and water over time; depending on plant growth, management actions, and the weather.

#### Plants

This takes care of plant growth (based on soil type, nutrient and water availability, and temperature) and plant destruction (through animal foraging or farmer actions such as plowing or harvesting).

#### Insects

This is responsible for the population growth of superindividuals (depending on available plant resources and temperature), dispersal, and population decline (e.g. through pesticide application).

#### Animals

This simulates animal foraging, reproduction, resting, and mortality.

### Bibliography

Grimm, Volker, Uta Berger, Finn Bastiansen, Sigrunn Eliassen, Vincent Ginot, Jarl Giske, John Goss-Custard, et al. 2006. ‘A Standard Protocol for Describing Individual-Based and Agent-Based Models’. *Ecological Modelling* 198 (1–2): 115–26. https://doi.org/10.1016/j.ecolmodel.2006.04.023.

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