O.D.D. description

of the LUCAS_GEMMES model

Projet: GEMMES
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We describe in this document the LUCAS_GEMMES model using the standard O.D.D. protocol[1]

Overview

Purpose

In (Truong et al., 2021), a first version of the model called LUCAS was introduced; farmers play the key role, basically driving all the dynamics of the model by individually selecting appropriate land-use types for their plot. This first version aimed to reproduce the distribution of land-use in the Mekong Delta, and to understand the impact of various climate scenarios (e.g. changes in temperature and rainfall) on this distribution. The provinces were represented as agents in the model, but their role was limited to providing, or restricting, funding for farmers' adaptation strategies.
The extension of LUCAS (named LUCAS-GEMMES) presented and explored in this chapter reinforces the economic dimension of the model, by allowing farmers to take out loans to invest in land-use changes beyond their initial financial capacity. More importantly, it strengthens the ability of provinces to influence individual adaptation strategies, according to the agro-ecological zone for which they are responsible and the level of subsidence measured: policies available to provinces can include prohibiting certain land-uses in order to limit or even prevent water pumping. The subsidence thresholds at which these policies are triggered, and the coordination between provinces

[1] Grimm V, Berger U, DeAngelis DL, Polhill JG, Giske J, Railsback SF. The ODD protocol: A review and first update. Ecological Modelling. 2010 Nov 24;221(23):2760–8.

in choosing these thresholds, are among the elements whose importance and relevance we wish to measure in order to provide concrete recommendations

Entities, state variables, and scales

Scales

The simulations are executed at the scale of the Vietnam Mekong Delta (VMD, ~ 40.577 km²). The smallest considered spatial units are 500mx500m cells.

The simulations are launched from 2015 to 2030. The simulation step is set to 1 year.

Entities

The model consists of 2 types of pro-active agent types that can make decisions at each simulation step: the *farming units* and the *provinces*. In addition, it contains two types of passive entities which are spatially located: the *agroecological zone* (AEZ) provides properties for different types of agriculture activities and the *land unit* provides detailed properties of soil texture, soil constraint water, and salinity. Finally, the model is completed with a non-spatial entity: the *land-use* provides information about the various land-use characteristics. In this model, we limit ourselves to the six dominant land-uses of the VMD: 3 rice and 2 rice (i.e. 3 or 2 rice crops per year respectively), Vegetables, Aquaculture (Shrimp), Fruit trees, Rice - shrimp.

The *farming unit* is the key entity of the model. It represents both the farmer (with its decision-making capabilities) and their agricultural parcel, which contains a land-use type. It is represented as a 500mx500m cell (the resolution depends on the input data). It is located in a province and a land unit. It is also characterized by individual annual income linked to cultivation activities and losses due to impact of climate change.

A *Province* entity is characterized by its name, location and spatial extent, its total budget for loan to farmers each year. The province is located in one or several agro-ecological zones. Thus, it will be able to choose an adaptation strategy for each of its farming units depending on the AEZ and a land subsidence threshold. Each strategy is defined as a list of permitted and prohibited land uses for a threshold in each AEZ.

All these agents are embedded in a global environment defining global variables and in particular providing data coming from exogenous submodels such as interest rate (*macroeconomic* submodel), map of temperature and precipitation (*climate* submodel), map of cumulated land subsidence (*subsidence* submodel), and dry-season surface water salinity map (*salinity* submodel).

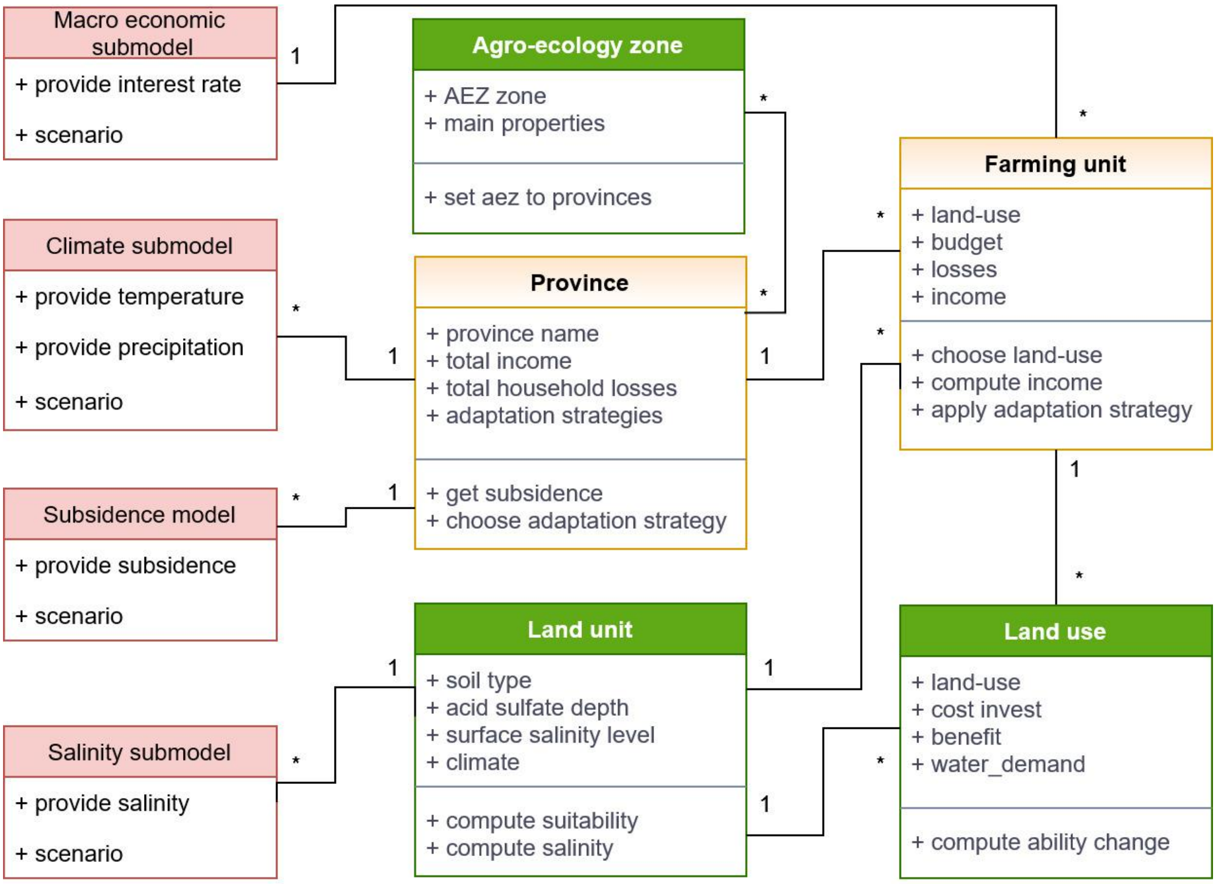

Figure: Main entities of the LUCAS-GEMMES model

Process overview and scheduling

The main processes of the LUCAS-GEMMES model are detailed in Figure 2. During a simulation the global data from exogenous models are updated with a frequency depending on the submodel: subsidence maps are updated every 10 years, macroeconomic and climate data are updated yearly, and the salinity map is updated every 20 years. From these updated data, exposed areas (i.e. areas where climate and salinity conditions overtake the tolerance of rice and shrimp (Truong et al., 2021)) are computed. Concerning the impact of subsidence, we assume that, beyond some threshold, cumulated subsidence will impact agricultural production by decreasing the income of farmers.

Provinces choose adaptation strategies for land-use change: depending on the AEZ and the situation of the land subsidence, they choose to allow or prohibit the land-use switch toward some other specific land-uses. Each province can have one or many strategies for the AEZ and the situation of land subsidence (e.g. living with floods, living with floods but saving groundwater): for each AEZ, the province chooses the land-uses allowed depending on a land subsidence threshold reached in the area. This choice corresponds roughly to allowing the pumping of groundwater for agricultural activities, or not. As the subsidence maps are updated every 10 years, the strategies are reevaluated with the same frequency, which corresponds to the plan period in Vietnamese land-use planning.

Finally farming units select land-use candidates from the ones allowed by the strategy of the province (policy), then choose the land-use based on multicriteria decisions that match land unit, income, ability to change (technically), and impact of neighbors (land-use of neighbors) (detailed in Session 3.3.3.2). Farming units have a budget to switch or maintain the current land-use. They may need an additional budget in the event of a change in land-use; if so, they ask for a new loan (depending on the interest rate). At the end of each year, farming units update their budget and income. In the event that a farming unit was impacted by climate conditions, they will lose the income of the year and individual losses increase in line with cost of implementation. The province updates total household losses at the end of each year.

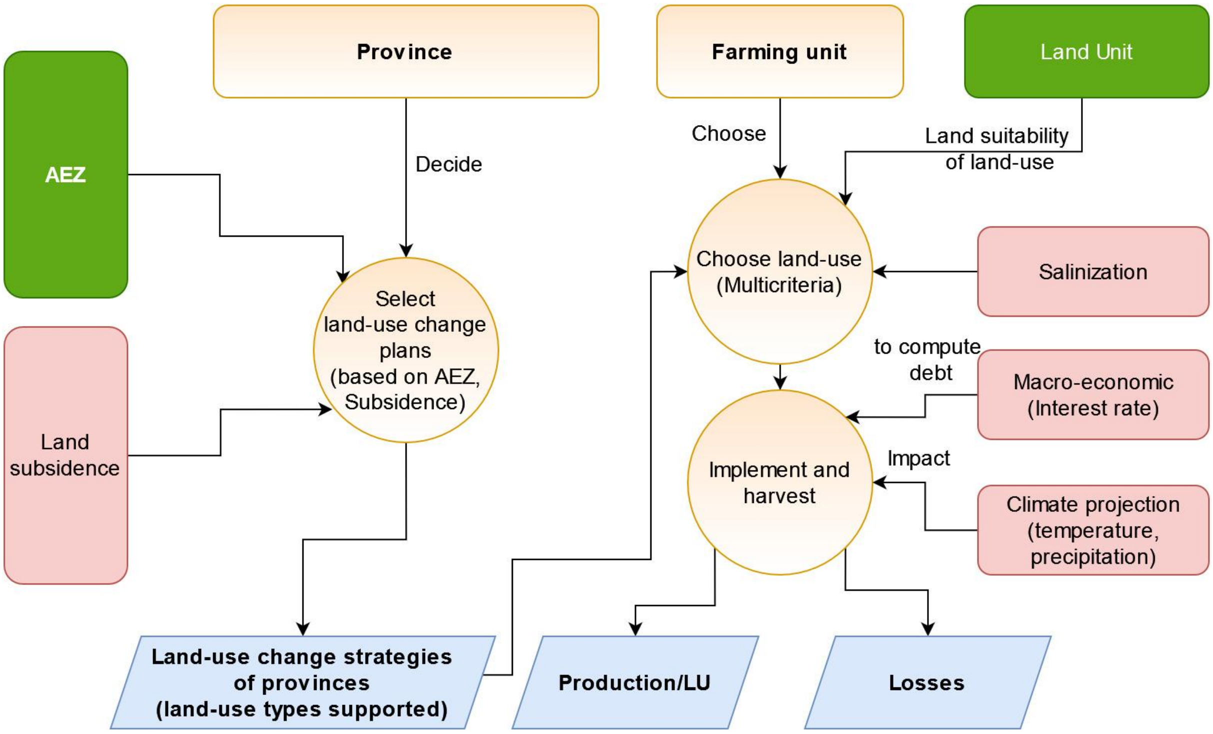

Figure 2. Conceptual model of LUCAS-GEMMES

At the end of each year, the model provides a land-use map, total area for each land-use type, total income from agriculture activities, water demand, and losses caused by climate change and subsidence by province (for each of their AEZ), and for the whole VMD.

Design Concepts

Basic principles

We rely on the land-use change behavior of farmers for each year. The decision is made by a multi-criteria condition. These factors are computed by several sub-models, such as macro-economy, salt intrusion and land subsidence. It also coupled with the government policy model with the AEZ.

Emergence

The main emergence (which is complex to happen in reality) is the evolution of land use planning for agriculture under two contrary factor of vary scale profit (farmer, province) and sustainability development under climate change

Adaptation

There are several adaptation strategies declared by the government (the 4 AEZs).

Sensing

The farmer

Interaction

Table: Agent actions in land-use adaptation.

Action	**Input**	**Output**	**Function**
Agro-ecology zone (AEZ)			
Set AEZ to provinces	List of provinces.	List of AEZ that province is located.	Each AEZ asks the provinces that intersect with the AEZ to set the list of AEZ.
Province			
choose adaptation strategy	- Salinity level. - Subsidence cumulative threshold to react. - AEZ regions where the province is located.	- Provincial adaptation profiles. Set of land-use types allowed for each selected profile.	Select a list of adaptation profiles. Each province can have many adaptation profiles based on the AEZ and the threshold of land subsidence that provinces react with.
Get subsidence	- AEZ regions of the province. - the list subsidence maps.	Land subsidence regions each 10 years (this period of time depends on the subsidence dataset).	Update the list of subsidence regions in the province.
Farming unit (F.U)			
choose land-use	- List of provincial adaptation profiles. - macroeconomic cut-off, F.U budget. - land suitability - Benefit and cost of land-use candidates.	A selected land-use type for the current farming unit.	Select the land-use for the year with the multicriteria selection based on factors: land suitability, profit, ability to convert land use type, influence of the other farmers (neighboring).

Compute income	- Benefit of LUTs per hectare - Land suitability of land-use.. - Macro variable: interest rate.	- Benefit of the year. - Losses by impact of climate change.	Calculate the benefit of the current land-use. Update the loose if this cell is damaged by climate constraints.
Apply adaptation strategy	Provincial adaptation profile in the AEZ and subsidence region.	Land-use type for current farming unit.	Apply multicriteria selection only on the supported LUT of adaptation strategy (to avoid risk).
Land unit			
Compute suitability	- Properties of land unit - List of land-use candidates. - Salinity levels.	Suitability level of the land-use candidates.	Evaluate for suitability levels.
Compute salinity	Salinity maps.	Salinity levels impact land suitability of land-use type.	Classify the salinity level for the cells.
World - global entity			
Providing climate data	- Climate dataset. - Climate station at district level.	Climate data (temperature and precipitation) of the stations, assigned to the districts within the province	Update the list of climate data per year for the stations in the provinces.
Providing salinity	- Salinity maps - Scenarios (4.5RCP; 8.5RCP)	Salinity maps for 2030 and 2050	Provide salinity map, updated for 2030 and 2050 (The period depends on available salinity data)
Providing macro-economic	Macro economic dataset from GEMMES model	Interest rate each year	Provide an interest rate each year for calculating the investment and losses.

Vulnerability analysis	- List of farming unit cells at risk.	- Vulnerable cells for 3-rice crops and shrimp - Vulnerable area for rice and shrimp per year.	Estimate vulnerable maps for rice and shrimp based on the tolerance of rice and shrimp under impact of temperature and precipitation, salinity by climate change.
Estimating water use	- List of farming units. - List of water demand of land-use type.	Amount of fresh water demand for each year.	Estimate the amount of fresh water demand, corresponding with the land-use type every year.
Estimating benefit and losses	- List of farming units. - List of farming units that were impacted by climate and salinity.	- The total benefit per year. - The total accumulated losses by risk.	- Calculate the total benefit of agricultural activities per year. - Calculate the accumulated losses for rice and shrimp cultivation by climate constraints.

Stochasticity

Collectives

Observation

Details

Initialization

Submodels