ABMSim - A flexible framework for Agent Based Models to simulate spatially explicit structural change in agriculture, Version 1.0, ODD+D based general documentation

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Outline (→ template)		Guiding questions	Own ODD+D Model description
I) Overview	I.i Purpose	I.i.a What is the purpose of the study?	ABMSIM Understanding how spatial competition in land rental markets und spatial competition between dairies and farmers interact which each other and impact structural change in agriculture, and develop from there quantitative predictions
		I.ii.b For whom is the model designed?	Scientists
	I.ii Entities, state variables, and scales	I.ii.a What kinds of entities are in the model?	**Agents**: *farmers*, differentiation by dairy farmers and others, *dairies*; **Spatial units**: 100x100 m grid cells, partially combined to rectangular agricultural plots between 1 and 25 hectares; **System environment**: urbanization processes, general macro-economic environment in the region driving non-farm employment opportunities, prices for agricultural inputs and outputs (with the exemption of land rent and milk delivery prices which are endogenous); **Collectives**: none
		I.ii.b By what attributes (i.e. state variables and parameters) are these entities characterized?	**Farmers**: id, age, location, active/non-active, list of owned plots, list of rented plots, parameters of dual profit function and z-factors characterizing static endowments, bidding behavior with regard to plots and delivery contracts; for dairy farmers: list of milk delivery contracts **Dairies**: id, profit function, milk delivery contract policy **Spatial units**: grid cell id (which determines location), current land cover type (agriculture, industrial land cover, other urbanized land cover, forest), for agricultural plots (combination of one or several agricultural grid cells): id, center, size, width, height, differentiation between arable and grassland, owner, renter, end year of rental contract, rent paid per ha; further attributes (elevation, slope, climate and soil related parameters) are stored for each agricultural plot, but not yet used

		I.ii.c What are the exogenous factors / drivers of the model?	Urbanization, demographics of the farmers, GDP development in the non-agricultural sector, prices of agricultural inputs and outputs (with exemption of milk and land rental price); scenarios can also differ by behavioural assumptions and initial state
		I.ii.d If applicable, how is space included in the model?	**Georeferenced** raster, using CORINE land cover; alternatively, virtual landscapes can be constructed
		I.ii.e What are the temporal and spatial resolutions and extents of the model?	One time step represents one year, typical simulations cover several decades; grid cells represent 1 ha, landscapes are of varying sizes and represent rectangular cuts from a bounding rectangle of a NUTS2 region, typically >> 100 km²; alternatively, a virtual landscape of varying size can be constructed
	I.iii Process overview and scheduling	I.iii.a What entity does what, and in what order?	(1) **Land use cover change:** determines which grid cell switch from agricultural to urbanized land cover (2) **Farm exit module:** depicts farm exit decision of farmers depending on age of farmer, farm profits, off-farm job opportunities and a random term (3) **Plot rental auction:** assigns plots owned by non-active farmers where rental contract ends to active farmers (3) **Milk delivery contract auction module**
II) Design Concepts	**II.i Theoretical and Empirical Background**	II.i.a Which general concepts, theories or hypotheses are underlying the model's design at the system level or at the level(s) of the submodel**(s) (apart from the decision model)?** What is the link to complexity and the purpose of the model?	The basic concept describes farm structural change as a spatially-explicit dynamic process emerging from individual decisions about farm size, specialization and farm exits which interact via spatial explicit markets for agricultural plots and milk delivery contracts. The individual decisions depend further on exogenous drivers such as prices for input and outputs, shrinkage of agricultural area around urbanizations and off-farm work opportunities at regional scale, and are to a large extent depending on the initial state (age of farmer, farm endowments). Given the complex, spatial explicit feedback loops incorporated in that process, the agent based approach is chosen instead of e.g. trying to estimate a structural econometric model from past observation, in order to analyze in control computer experiment how changes in the initial state, in boundary conditions and assumptions about decision making impact structural change.
		II.i.b On what assumptions is/are the agents' decision model(s) based?	**Farmers:** The model is linked to micro-economic theory. While the backbone for the quantitative description of the farmers bidding behavior for land plot and milk delivery contracts as well as farm exit decisions is based on a dual profit function, the model allows to splits the farming population into different groups depending on their decision making: (1) Fully rational homo economicus (bidding according to marginal returns) (2) Bound rationality behavior (bidding according to average profits per ha of land or quantity of milk produced; modification of bids based on marginal or average profits by percentage add-on or deduction) (3) Ad-hoc rules such as bidding according to current average rental price in neighborhood

		II.i.c Why is a/are certain decision model(s) chosen?	One aim of the model is to analyze to which extent assumptions about the bidding behavior in land rental and milk delivery contract markets impact structural change, i.e. if behavioral assumptions with regard to about decision behavior are important compared to other elements such as initial conditions and the macro-economic environment. Accordingly, several decision models can be used in different shares to analyze these relations. Using a dual profit function as the backbone gives a clear benchmark based on full rationality.
		II.i.d If the model / a submodel (e.g. the decision model) is based on empirical data, where does the data come from?	The structure of the farming population (e.g. hectares own, type of farming, initial herd size and milk yield) stems from farm structural statistics; the shares of farmers with regard to bidding behavior is currently assumed (part of the experiment design). The geo-referenced data (land cover, elevation, slope, climate, soil, detail on agricultural land cover) stem from different maps. Details are given in the detailed sub-module description.
		II.i.e At which level of aggregation were the data available?	Broader groups of farms (by specialization and size) at NUTS2 level, according to data availability at EUROSTAT
	II.ii Individual Decision Making	**II.ii.a What are the subjects and objects of decision-making? On which level of aggregation is decision-making modeled? Are multiple levels of decision making included?**	**Farmers** decide in each year if they exit farming. For farmers below the age of 65, the decision is made between on- and off-farm work. At age of 65, the probability is determined if the farmer finds a successor. If the farmer stays active, (s)he participates in auctions about plots to rent and milk delivery contracts. (S)he thus cannot directly decide about farm size (hectares, total milk quantity sold), but have to put bids / asks in auctions. After each successful contract, the involved seller and buyer can change outstanding bids and asks. **Dairies** put bids out for milk delivery contracts resp. accept asks by the farmers.
		II.ii.b What is the basic rationality behind agents' decision-making in the model? Do agents pursue an explicit objective or have other success criteria?	For the **dairies**, a classical optimization approach is used. It is later planned to develop a variant where dairies can also be owned cooperatively by farmers. For the farmers, as noted already above, several behavioral models can be used: classical optimization or routine based (bidding according to marginal profit or observed rents / milk prices in the neighborhood).
		II.ii.c How do agents make their decisions?	The bids are either derived from a dual profit function (marginal return or average profits) or from observing prices in the neighborhood.
		II.ii.d Do the agents adapt their behavior to changing endogenous and exogenous state variables? And if yes, how?	The behavioral model itself (e.g. full rationality versus rule based) is fixed. But clearly, how agents bids in markets depends e.g. on input/output price relations and how prices in local markets for plots to rent and milk delivery contracts change, according to the interaction between the agent specific dual profit function and the chosen behavioral model.
		II.ii.e Do social norms or cultural values play a role in the decision-making process?	No

		II.ii.f Do spatial aspects play a role in the decision process?	Those farmers who bid according to prices in the neighborhood are clearly influenced by space. Equally, bids to plots reflect distances between the farm stead and the plot. Delivery contacts made by the dairy reflect distance to farmers.
		II.ii.g Do temporal aspects play a role in the decision process?	Yes, the dual profit function is estimated from simulations with a fully dynamic farm model which is initial state dependent (memory).
		II.ii.h To which extent and how is uncertainty included in the agents' decision rules?	Farmers are currently assumed as risk neutral. However, the bidding behavior can include a stochastic element in order to reflect uncertainties in their behavior.
	II.iii Learning	II.iii.a Is individual learning included in the decision process? How do individuals change their decision rules over time as consequence of their experience?	No
		II.iii.b Is collective learning implemented in the model?	No
	II.iv Individual Sensing	II.iv.a What **endogenous** and **exogenous** state variables are individuals assumed to sense and consider in their decisions? **Is the sensing process erroneous?**	Currently, there is no focus on sensing and expectations in the prototype.
		II.iv.b What state variables of which other individuals can an individual perceive? **Is the sensing process erroneous?**	It is generally assumed that only the auctioneer has knowledge about the price part of the bids and asks, whereas the bidder and askers (depending on the auction) can observe other attributes of the good acutioned such as the location of the plot or the bidder/asker, the amount of milk in a delivery contract or the delivery point.
		II.iv.c What is the spatial scale of sensing?	Local neighborhood
		II.iv.d Are the mechanisms by which agents obtain information modeled explicitly, or are individuals simply assumed to know these variables?	Individuals are assumed to know the variables in the current prototype version.
		II.iv.e Are costs for cognition and costs for gathering information included in the model?	No
	II.v Individual	**II.v.a Which data uses the agent to predict future conditions?**	

	Prediction	II.v.b What internal models are agents assumed to use to estimate future conditions or consequences of their decisions?	
		II.v.c Might agents be erroneous in the prediction process, and how is it implemented?	
	II.vi Interaction	II.vi.a Are interactions among agents and entities assumed as direct or indirect?	Indirect via auctions
		II.vi.b On what do the interactions depend?	Spatial distance
		II.vi.c If the interactions involve communication, how are such communications represented?	Not applicable
		II.vi.d If a coordination network exists, how does it affect the agent behaviour? Is the structure of the network imposed or emergent?	Not applicable
	II.vii Collectives	II.vii.a Do the individuals form or belong to aggregations that affect, and are affected by, the individuals? Are these aggregations imposed by the modeller or do they emerge during the simulation?	The interaction between the farmers' behavior in auctions for milk delivery and the dairies behavior in the auctions influence each other. The (not coordinated) decisions of the farmers could be seen as an aggregate milk supply function which clearly affects the dairies.
		II.vii.b How are collectives represented?	Not applicable
	II.viii Heterogeneity	**II.viii.a Are the agents heterogeneous? If yes, which state variables and/or processes differ between the agents?**	The farmers differ in attributes such as age, initial endowments (stables, machinery, land, family labor) which determine their dual profit function. Additionally, they are situated at certain location and land-ownership refers to set of (spatially explicit presented) plots.
		II.viii.b Are the agents heterogeneous in their decision-making? If yes, which decision models or decision objects differ between the agents?	The farmers differ in the way they bid in auction for land and milk delivery contracts. The difference is how the information available from the profit function (marginal, average and total profits) is used (or not used) by the famers to determine their bids.

	II.ix Stochasticity	II.ix.a What processes (including initialization) are modeled by assuming they are random or partly random?	The size distribution of plots, location of farmers and assignment of plots to farmers is randomly drawn. Equally, the attributes describing the farmers are drawn from a systematic random sample (Design of Experiments) to yield a population which mimics the distribution of attributes found in farm structural statistics.
	II.x Observation	II.x.a What data are collected from the ABM for testing, understanding, and analyzing it, and how and when are they collected?	It is planned to compare simulated attributes relating to structural change (e.g. percentage changes in number of farmers, distribution in size classes) with past development.
		II.x.b What key results, outputs or characteristics of the model are emerging from the individuals? (Emergence)	
III) Details	**II.i Implementation Details**	**III.i.a How has the model been implemented?**	Programming language Java 1.8, own implementation; Computer system: standard desktop under Windows 7; Graphical User Interface including result exploitation: GGIG (GAMS Graphical User Interface Generator, Britz 2013); Development since 10/2013
		III.i.b Is the model accessible and if so where?	No
	III.ii Initialization	III.ii.a What is the initial state of the model world, i.e. at time t=0 of a simulation run?	Existing land cover, plot size distribution (random), number of active/non-active farmers and their location and size (stratified random), ownership of plots (stratified random sampling)
		III.ii.b Is initialization always the same, or is it allowed to vary among simulations?	Distribution of plots, location of farmers and attributes of farmers are drawn stochastically from distribution characterizing the population according to census data. Thus, depending on how the random number generator is used (with constant or random seed), the model can be started with fixed initial conditions (to analyse how changes e.g. in the assumptions with regard to the bidding behaviour or price relations impact results) or with different initial conditions (to learn about how sensitive the model is to the randomly determined part of the initial state)
		III.ii.c Are the initial values chosen arbitrarily or based on data?	The initial variables related to farm structure are drawn from distribution mimicking population statistics, the geo-referenced data stem from different maps.
	III.iii Input Data	III.iii.a Does the model use input from external sources such as data files or other models to represent processes that change over time?	No, all external information either define the intital stage or are used to parameterize the model.
	III.iv Submodels	III.iv.a What, in detail, are the submodels that represent the processes listed in 'Process overview and scheduling'?	see model documentation: Britz W. (2013): ABMSim - A flexible framework for Agent Based Models to simulate spatially explicit structural change in agriculture, Methodological and technical documentation, Version 1.0; Institute for Food and Resource Economics, Universtiy Bonn

		III.iv.b What are the model parameters, their dimensions and reference values?	as above: see detailed information
		III.iv.c How were submodels designed or chosen, and how were they parameterized and then tested?	as above: see detailed information

References:

Grimm, V., Berger, U., DeAngelis, D.L., Polhill, J.G., Giske, J., Railsback, S.F., 2010. The ODD protocol: a review and first update. Ecological Modelling 221 (23), 2760-2768.