ODD+D Protocol[1] for the Scenario "Organic Farming Certification Process with Diverse Participant Motives"

Model URL: https://github.com/chrfrantz/OrganicFarmingSocialValuesSimulation

Outline (→ template)		Guiding questions	Examples	Own ODD+D Model description
I) Overview	I.i Purpose	I.i.a What is the purpose of the study?	Research question incl. test of hypothesis, **system understanding, theory development, quantitative predictions, management or decision support, communication and learning (participatory modeling)**	System understanding, Policy testing The model specifically looks at the potential compliance outcomes of an organic framing scheme that is composed of certifiers that administer certifications, operators that apply for certifications and inspectors that serve as monitoring agents. Specific to applicants are diverse participation motives, which are subject to analysis. Associated research questions include: "To what extent do participation motive compositions influence compliance outcomes for organic farmers within an organic farming certification scheme?" "To what extent influence varying levels of sanctioning the compliance outcome?"
		I.ii.b For whom is the model designed?	**Scientists, students/teachers, decision makers, stakeholders**	Scientists, policy analysts, policy & decision makers
	I.ii Entities, state variables, and scales	I.ii.a What kinds of entities are in the model?	Agents / individuals (humans, institutions): types and subtypes, spatial units (grid cells), environment, collectives (groups of agents)	Agents as individuals

[1] Birgit Müller, Friedrich Bohn, Gunnar Dreßler, Jürgen Groeneveld, Christian Klassert, Romina Martin, Maja Schlüter, Jule Schulze, Hanna Weise, Nina Schwarz, Describing human decisions in agent-based models – ODD + D, an extension of the ODD protocol, Environmental Modelling & Software, Volume 48, 2013, Pages 37-48, ISSN 1364-8152, https://doi.org/10.1016/j.envsoft.2013.06.003

		I.ii.b By what attributes (i.e. state variables and parameters) are these entities characterized?	Of Agents: identity number, age, sex, maximum age, memory, location, level of resources, **ownership of land,** (political) opinion, occupation, **decision model (only mention the name of the strategy, which is explained later on), one agent represents one individual / one household / one farm / all individuals of one specific type**, of spatial units: location, a list of agents in a cell, **land owned by farmer**, descriptor of environmental conditions (elevation, vegetation cover, soil type), current land use of collectives: list of agents, specific actions Units of measurement	Role type, behavioral stereotype (as determinant for decision making), status of agent as non-certified, applying or certified
		I.ii.c What are the exogenous factors / drivers of the model?	**Disease, climate, lake water level, land cover change, tectonic disturbances, invasive species, legislation**	Variation of agents by number, role and stereotype distribution (see below); Variation of sanctioning behaviour into soft, medium or hard; Activation of peer monitoring
		I.ii.d If applicable, how is space included in the model?	**Not included, spatial implicit, spatial explicit, georeferenced (GIS)**	No explicit spatial representation
		I.ii.e What are the temporal and spatial resolutions and extents of the model?	One time step represents one year and the simulations were run for 100 years, one grid cell represents 1 ha and the model landscape	One simulation time step corresponds to a day in the simulation; no explicit spatial representation.

			comprises 1000 x 1000 ha	
	I.iii Process overview and scheduling	I.iii.a What entity does what, and in what order?	Self-explanatory names of the model's processes, **including decision making processes,** pseudo-code of the schedule, synchronous / asynchronous update	The operation depends on the role type: Certifiers: - Certifiers process incoming messages, including require for certification, reports by inspectors or operators about operator compliance - They then decide per incoming message whether to approve applications for certifications, and respond to reported violations by suspension, revocation or ignoring the reported violation. Inspectors: - Random selection of operators for inspection. - Number of assessments depends on initial parameterization. Operators: - Assessment as to whether application for certification is useful - They then operate in their corresponding role with or without certification (and decide to do so either compliant or non-compliantly) - Engage in monitoring of fellow agents (if activated) and reporting of non-compliance - Memorizing experience (e.g., successful non-compliant operation) Agents are scheduled sequentially in random order, shuffled each round
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?		We model agent behavior using concepts of social value orientation (SVO) (Griesinger and Livingston, 1973), specifically drawing on prosocial and individualistic attitudes, alongside a novel behavioral conception based on mimetic behavior.
		II.i.b On what assumptions is/are the agents' decision model(s) based?	**<u>Established theories</u> (micro-economic models: homo oeconomicus, full / bounded rationality; cognitive models: social psychology,**	Decision-making is based on rationality, where rationality is interpreted based on preferences embedded in the specific social value orientation of an individual. For selected behavioral stereotypes (based on SVO) the model relies on memorization, e.g., to assess the probability of success for non-compliant behavior. The framing of agent's

			mental models; space-theory based models) <u>real-world observations</u> (mechanistic explanations / process-based understanding available; black-box, use of heuristics, statistical regression methods) <u>ad-hoc rules</u> (dummy rules, e.g. constancy assumption) <u>combinations</u> of theory and observations	behavior in terms of SVO is generalized from empirical data based on interviews collected as part of previous work by Carter and Siddiki (2021). The decision-making model is thus informed both from a theoretical and empirical perspective.
		II.i.c Why is a/are certain decision model(s) chosen?	**Data (non-) availability, pattern-oriented modeling, reference to other studies, theoretical considerations**	The decision models are chosen based on the available empirical data, the insights from which map well into the SVO stereotypes, and are furthermore complemented by theoretical embedding (e.g., Heckathorn, 1990).
		II.i.d If the model / a submodel (e.g. the decision model) is based on empirical data, where does the data come from?	**Participatory approaches (role playing games), household surveys, interviews, direct observations, statistical census, archives, GIS, field or lab experiments**	The data comes from interviews previously performed by Carter and Siddiki (2021) and is explicitly lists relevant data in the article associated with the simulation.
		II.i.e At which level of aggregation were the data available?	**Household / individual level, group level**	Data were available in aggregate form for agricultural operations.
	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?**	**Name subjects (individuals agents / households, on communal level, top down decision maker) and objects of decisions, e.g.: Form of land use, distribution of labor, choices of buying and selling**	Subjects of decision-making are the embedded roles, such as operators, certifiers, and inspectors. Objects of decision-making are For operators: - Applying for or abandoning certification - Compliance - Peer monitoring (if activated) For certifiers: - Approval of certification request - Suspension of certification - Revocation of certification For inspectors:

				- Random choice of inspected entities
		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?	**Rational choice (classical optimization approach, utility maximization), bounded rationality (satisficing approach), no objectives (routine based, trial and error)**	Rational behavior is utility-maximization in the SVO sense. The model contains opportunistic agents that seek to minimize cost related to monitoring and maximize operational profits; mimetic agents follow behavior in their social environment; prosocial agents persistently engage in monitoring and behave compliantly.
		II.ii.c How do agents make their decisions?	**Decision tree, utility function, random choice**	Generally, decision-making is based on the agents' respective SVO. For the operationalization of opportunistic agents, this relies on memorized behavioral outcome.
		II.ii.d Do the agents adapt their behavior to changing endogenous and exogenous state variables? And if yes, how?	**Adaption of resource extraction level in dependence of ecological state of resource**	Agents adapt their behavior depending on success of non-compliance; agents further rely on their social environment to guide their decision-making, and are thus susceptible to decision changes.
		II.ii.e Do social norms or cultural values play a role in the decision-making process?	**Cultural norms, trust**	Other than the theoretically implied preferences of the SVO, normative behavior exclusively applies to mimetic agents who copy their surrounding behavior.
		II.ii.f Do spatial aspects play a role in the decision process?	**Space-theory based models**	No.
		II.ii.g Do temporal aspects play a role in the decision process?	**Discounting, memory**	Agents maintain a memory of past interaction and store in how far non-compliant behavior was identified and sanctioned.
		II.ii.h To which extent and how is uncertainty included in the agents' decision rules?	**Not at all / stochastic elements mimic uncertainties in agents' behavior / agents explicitly consider uncertain situations or risk**	Dynamic behavior has a stochastic component. For example, determining behavior of opportunistic agents relies uses the observed cheating level as parameter for the random number generator. Mimetic agents' behavior is similarly includes stochasticity.
	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?	**Change of aspiration levels depending on past experiences**	Learning is implemented based on memory about successful behavior. Memory is bounded by allowing agents to retain a fixed number of recent experiences.

		II.iii.b Is collective learning implemented in the model?	**Evolution, genetic algorithms**	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?**		Individuals sense their social environment and their compliance behavior to inform their behavior (see section II.ii). While the sensing process is not erroneous per se, the stochastic component is a potential for erroneous sensing.
		II.iv.b What state variables of which other individuals can an individual perceive? **Is the sensing process erroneous?**	**(Multiple) resources (including working power, monetary resources, other income resources) and behavior of other agents**	Individuals can observe compliance or violation behavior in their social environment, the activation of which is subject to parameterization based on participation motives.
		II.iv.c What is the spatial scale of sensing?	Local, network, global (whole model space)	Agents can observe all agents in their social environment, the structure of which is described in Section II.vi
		II.iv.d Are the mechanisms by which agents obtain information modeled explicitly, or are individuals simply assumed to know these variables?	Sensing is often assumed to be local, but can happen through networks or can even be assumed to be global.	The scope of observation is parameterized at the onset of the simulation; the mechanisms operate on the fixed network structure without exposing agents explicitly. Agents can "read" information relevant for their decision making.
		II.iv.e Are costs for cognition and costs for gathering information included in the model?		The cost of gathering is implicitly included in the SVO operationalization. Monitoring is costly, and thus avoided where possible by opportunistic individuals.
	II.v Individual Prediction	**II.v.a Which data uses the agent to predict future conditions?**	**Extrapolation from experience, from spatial observations**	Agents have no explicit predictive capability beyond experiential and observation learning that can inform future decision-making based on memorization.
		II.v.b What internal models are agents assumed to use to estimate future conditions or consequences of their decisions?		N/A
		II.v.c Might agents be erroneous in the prediction process, and how is it implemented?	**(External) uncertainty, (internal) capability of the agent**	N/A
	II.vi Interaction	II.vi.a Are interactions among agents and entities assumed as direct or indirect?	Direct interactions, indirect interactions (mediated by the environment / **the market, auction)**	Interactions are direct.

		II.vi.b On what do the interactions depend?	**Spatial distances (neighborhood), networks, type of agent**	Social network relationship as initialized at simulation onset.
		II.vi.c If the interactions involve communication, how are such communications represented?	**Explicit messages (Matthews et al., 2007)**	Explicit messages in the form of type-specific classes (e.g., reporting, sanctioning).
		II.vi.d If a coordination network exists, how does it affect the agent behaviour? Is the structure of the network imposed or emergent?	Centralized vs. decentralized, group based tasks	The structure, general parameterization, role-specific social environments is imposed based on empirical data extracted from Carter and Siddiki, 2021. The agent behavior is affected inasmuch as it affects observational scope as discussed in Section II.iv. The network structure is static.
	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?	Social groups, human networks and organizations	Individuals are affected by observational scope (see II.vi). Aggregations are only relevant from an analytical perspective.
		II.vii.b How are collectives represented?	Collective as emergent property vs. as a definition by the modeler (separate kind of entity with its own state variables and traits)	No explicit representation.
	II.viii Heterogeneity	**II.viii.a Are the agents heterogeneous? If yes, which state variables and/or processes differ between the agents?**	**Would an exchange of one agent with another at the beginning have an effect on the simulation?**	Structural heterogeneity exists for agents of different roles, expressed in their behavioral function. Agents of a given role are heterogeneous on variable-value level.
		II.viii.b Are the agents heterogeneous in their decision-making? If yes, which decision models or decision objects differ between the agents?		The heterogeneity applies to different roles, and amongst operators, is determined by the associated SVO stereotype as discussed in Section II.ii.b.
	II.ix Stochasticity	II.ix.a What processes (including initialization) are modeled by assuming they are random or partly random?		Decision-making with respect to compliance is mediated by stochastic components, see Sections II.ii.h and II.iv.a.
	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?		Data is collected on round level, at the end of each round.
		II.x.b What key results, outputs or characteristics of the model are emerging from the individuals? (Emergence)		- Cooperation levels stratified across and within different agent roles and SVO stereotypes. - Monitoring and enforcement levels.

III) Details	**II.i Implementation Details**	**III.i.a How has the model been implemented?**	**Computer system, programming language / simulation platform, simulation runtime, development time**	Computer simulation is written using the programming language Java and relies on the MASON scheduler, augmented with additional features, including statistics output management, as well as parameter generation facilities (to facilitate the sensitivity analysis). Simulations were run on a Linux cluster running Ubuntu 20.04 LTS.
		III.i.b Is the model accessible and if so where?	**Homepage?(link)**	https://github.com/chrfrantz/OrganicFarmingSocialValuesSimulation
	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?	Types and numbers of entities including the agents themselves, values / random distribution of their state variables	The number of initial entities (10,000 operators, 400 inspectors, 82 certifiers) is based on empirical data from the USDA Organic Farming database as well as further information as reported in the associated article. These values are systematically varied as part of the model exploration. Affected variables, initial values and step sizes are shown in Table 5 in the associated article. SVO distributions for operators are initially equally split, but systematically varied as part of the exploration.
		III.ii.b Is initialization always the same, or is it allowed to vary among simulations?		See Section III.ii.a
		III.ii.c Are the initial values chosen arbitrarily or based on data?	References to data if any, **stakeholder choice**	See Section III.ii.a
	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?	Observed time series e.g. annual rainfall, time series generated by other models, not: parameter values, initial values of state variables	No
	III.iv Submodels	III.iv.a What, in detail, are the submodels that represent the processes listed in 'Process overview and scheduling'?	Equations, algorithms, additional information	The algorithms for operators depend on the SVO stereotype: Opportunistic operators observe their social environment to assess the value of participating the certification scheme based on the level undetected non-cooperators as observed in their social environment (for Network details see Section II.vi.d). If joining, they act non-compliantly depending the the observed cheating success in the social environment. Their monitoring depends likewise on the environmental cheating level (they act as hypocritical cooperators). Mimetic agents observe their social environment and, mediated by stochastic

				processes (see Section II.ii.h), behave accordingly. Prosocial agents consistently apply for certification, cooperate and monitor fellow agents behavior. Inspectors inspect a specified number of operators (at simulation onset) randomly each round. Certifiers are purely reactive and await application and reporting by operators and inspectors respectively and determine approval or rejection based fixed probabilities (0.75) and sanctioning rigidity (low, medium, hard), where low rigidity implies random suspension of certification; medium rigidity randomly picks between suspension and revocation; hard sanctioning implies revocation of certification. The difference between revocation and suspension for the simulation model lies in the application process: Applications after revocation succeed with a probability of 0.2, whereas applications are suspension succeed with a probability of 0.4.
		III.iv.b What are the model parameters, their dimensions and reference values?	Tables of parameters	See Table 5 in the associated article.
		III.iv.c How were submodels designed or chosen, and how were they parameterized and then tested?	Justifications, references to literature, independent implementation, testing, calibration, analysis of submodels	The submodels are based on the certification lifecycle of application, operation and monitoring modelled around the agricultural operation practices. The operations are reduced to compliance/non-compliance assessment due to the focus on regulatory compliance as part of the model. The SVO characterization is a contribution of the paper and generalized based on Carter and Siddiki's (2021) statistical findings based on operator interviews. Plausible parameterization is likewise informed by the referenced work, as well as additional direct communication with the USDA office and the publicly available USDA database, with details described in the article.

References:

Carter, D.P. and Siddiki, S. (2021), Participation rationales, regulatory enforcement, and compliance motivations in a voluntary program context. Regulation & Governance, 15: 317-332. https://doi.org/10.1111/rego.12289

Griesinger DW, Livingston JW (1973) Toward a model of interpersonal motivation in experimental games. *Behavioral Science* 18, 173–188.