Appendix 1:Model parameters for the agent-based model of farmer adoption of conservation practices

The following sections present the model used in this study following the ODD (Overview, Design concepts and Details) protocol (Grimm et al. 2006; Grimm et al., 2010).

Purpose

This model is designed to investigate the impact of alternative policy approaches and changing land tenure dynamics on farmer adoption of conservation practices intended to increase the water quality.

State variables and scales

The modeled environment consists of a two-dimensional grid space representing the abstract agricultural landscape of the Sandusky watershed. The ABM is coupled with a water quality model; therefore the specifics of the water quality model are taken into consideration during the setup phase of the ABM. For a better match with the water quality model, there are 351 farmers in the ABM. The model is run for annual steps of 41 years (1970-2010). Figure 1-1 shows the class diagram of the model.

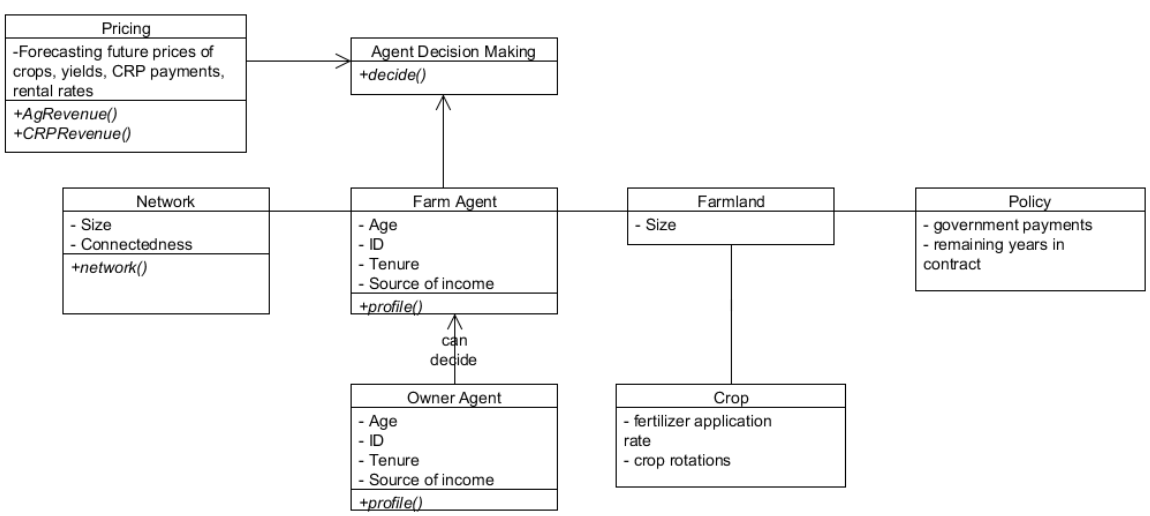

Figure 1-1: Class diagram of the ABM model

In the model, every farmer owns a farm and each has utility functions with bounded rationality. The farmers specialize in cash-crops such as corn, soybean or winter wheat. They have cash earnings from crop production or from enrollment in government programs. The farmers have different land areas, crop yields, and future crop price and yield expectations. The farmers also maintain network connections to other farmers and government agencies with varying strengths. In most ABMs, agents are defined by their spatial location (Brown et al. 2005); however, in this model the farmer agents do not change their location as time progresses. A farmer's location on the grid determines the spatial neighbors of that farmer. Some of the farmer attributes do not change during the simulations, such as the percentage of income derived from farming and connectedness to the network. However, as farmers age in every simulation run, some of them change their types. For example, after age 65 some of the traditional farmers leave the farming business and switch to be non-operator owners, or sell/rent their land to business-oriented or supplementary farmers. We assume supplementary and business-oriented farmers to not change their types as they age. This obviously also leads to an increase in the percentage of non-operator owners among the farmer population (Figure 3B, main text), as well as production area under their control (Figure 1-2).

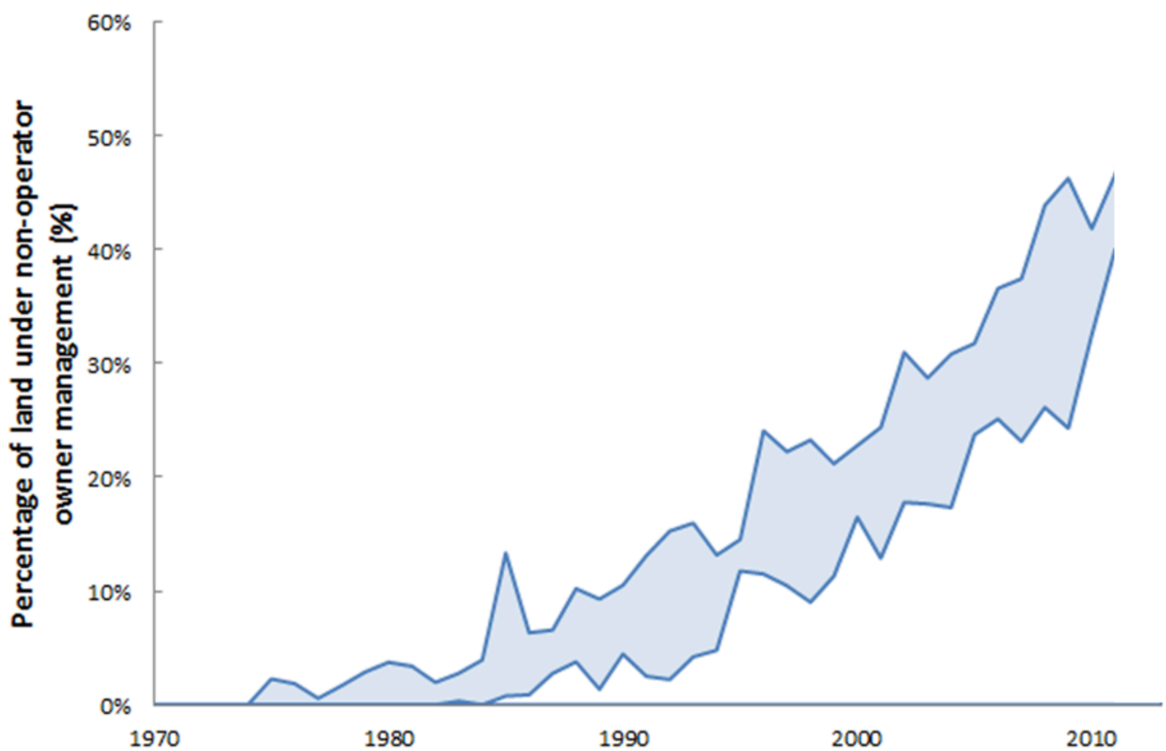

Figure 1-2: Percentage of land under non-operator owners' control increases. 25 ABM simulation runs fall between two lines of the same color.

Process overview and scheduling

The diagram in Figure 1-3 gives the process overview and scheduling of the model. For each simulation, farmers annually update their adoption decisions under the influence of agricultural policy, changing land tenure dynamics, their preferences, and their neighbors' decisions. The agent loop is equally important as the landscape update, which is the key mechanism that affects the water quality component of the coupled system (Figure 1-3).

During the simulation phase, each farmer agent is provided with a behavioral model that guides the decision-making process. With the behavioral model and farmer attributes, the farmer agents decide whether to adopt a specific conservation practice or not. The results from the farmer agent decision update the management landscape.

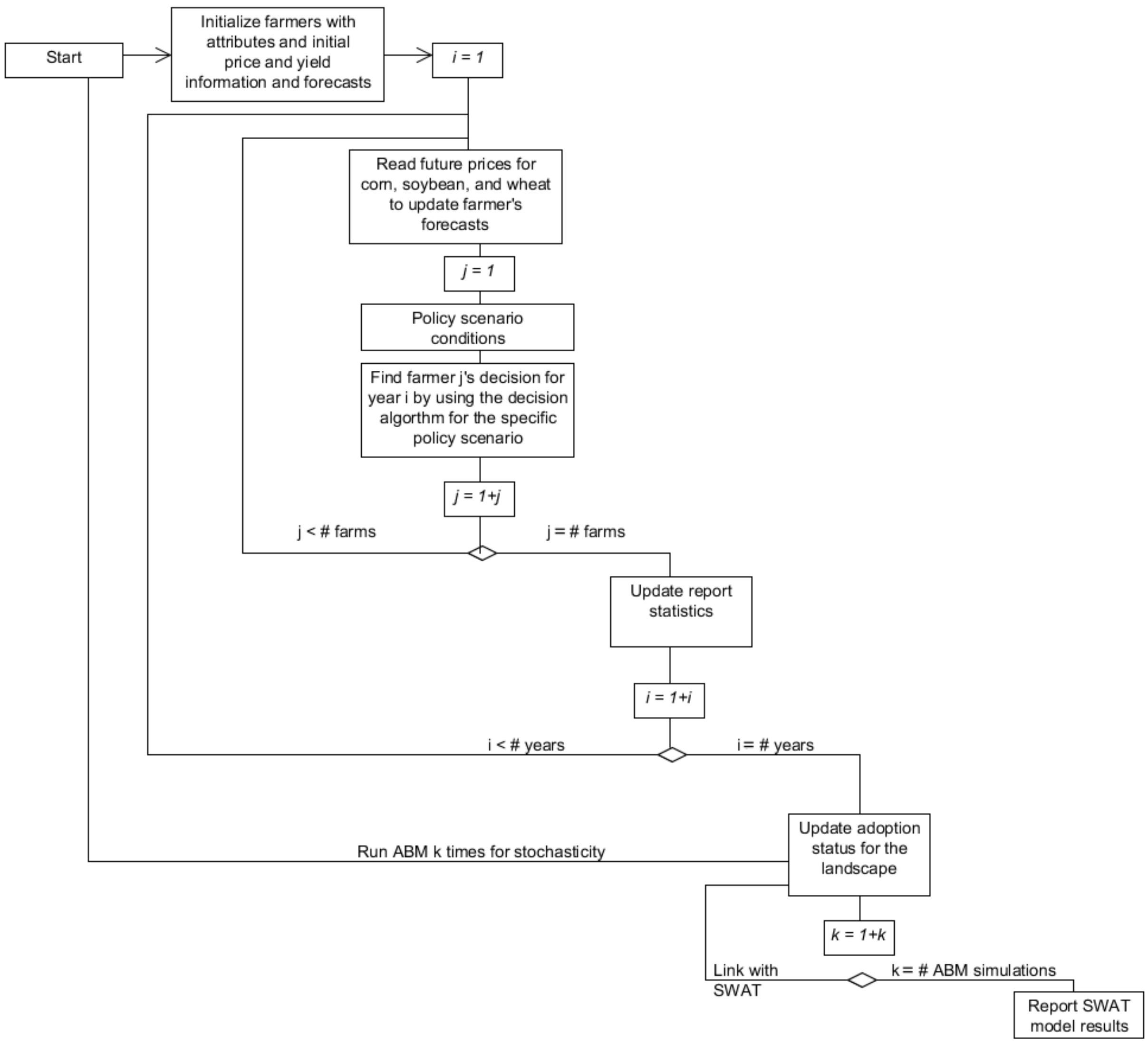

Figure 1-3: Process overview and scheduling for a model run.

The decision-making algorithm consists of inputs from profit generated from the agricultural activity, enrollment in government programs, the farmer preferences for conservation practices depending on farmer type, and sometimes information from their spatial neighbors and other farmers in their social network. Every agent in the model uses the same decision algorithm with different parameters due to the heterogeneity of agents' preferences. Depending on their tenure arrangements, decision makers could either be the owner or the tenant. Because of this flexibility, this model is also used to investigate the possible impact of growing proportions of farmland owned by non-operator owners and their influence on conservation decisions.

Design Concepts

- **Emergence**: The agricultural landscape of conservation practices emerges from the individual decisions of farmers, which are informed by their economic activities, social and spatial networks, preferences, and policies that they follow.
- **Adaptation**: Farmers adapt and update their decisions depending on price and yield expectations for future years. Depending on their types, farmers have differing network connectivity, which influences their conservation decisions. Farmers update their conservation practice adoption decisions by interacting and observing other farmers and due to changes in the agri-environmental policies and markets.
- **Prediction**: Farmers have expectations for future yields, crop prices, and rental rates offered for land retirement programs by using the historic information. Farmers use these forecasts for their adoption decisions every year.
- **Sensing**: Farmers know their production yields every year and their profit from that year's production. Farmers also know whether their neighbors, both in their spatial and social networks, adopted a practice.
- **Interaction:** Farmers interact to exchange information on adoption of conservation practices. Every farmer type has varying network strength and connectivity.
- **Stochasticity:** The model has stochasticity built in several ways. Conservation practice selection decision is stochastic, as the farmers are most likely to select the highest ranked practice. However, as the farmers are not modeled as purely rational decision makers, the highest ranking conservation practice is not always chosen. Moreover, to better represent the decision environment, the submodels also have stochastic parameters to represent the uncertainty and variability observed in nature. By using the agent decision-making algorithm over the model run of 41 years, each agent has a sequence of conservation practices adopted and resultant landscape changes.
- **Collectives**: Farmers are connected in two ways. In the spatial networks, farmers are connected to their immediate spatial neighbors. In social networks, farmers are connected to other farmers with varying strengths and connectivity. Network connections allow farmers to observe whether other farmers in their network have adopted a conservation practice.
- **Observation**: The model produces the conservation adoption patterns at the end of each simulation.
- **Learning**: Bayesian inference used for updating price and yield expectations of farmers is a form of learning.

Initialization

At the beginning of each model simulation, 351 farmers are created to represent the total of approximately 7500 farmers in the Sandusky watershed. Because the ABM is linked to SWAT, properties of SWAT are decisive. In SWAT, there are 351 agricultural HRUs, smallest computation components; therefore in ABM we have 351 agents. The initial agent characteristics are given in Table 1-1. The farmer typology built in Daloğlu et al. (2014) informs the farmer preferences for conservation practices typologically.

The agricultural structure of the study area is defined by the number of farmers and their production areas. The parameters defining each farmer such as age, ownership of the land, percentage of income generated by agricultural activity, and land tenure arrangements are assigned from a normal distribution within a range that is informed by regional statistics provided by National Agricultural Statistics Service (NASS). Then, each farmer agent is associated with its appropriate type (Table 1-2).

Property	Meaning	The Model
Reactive	Responds to changes in the environment	Yes
Autonomous	Have control over its own actions	Yes
Temporally continuous	Continuous agent behavior	Yes
Communicative	Communicates with other agents	Yes
Mobile	Changes location from one to another	No
Flexible/Learning	Actions are not scripted, can change	Yes
Character	Believable personality with emotions	No
Interactive physically	Decisions affect other agents	Yes
Interactive socially	Decisions affect other agents	Yes
Goal oriented	Responsive to the environment	Yes

Table 1-1: Farmer agent properties

	Farmer types			
Policy-relevant farmer characteristics	Traditional	Supplementary	Business-oriented	Non-operator owners
Land Tenure	Full owner	Full/Part owner	Part owner	Non-operator owner
Farm Size	Small	Small	Medium to Large	N/A
Primary Source of Income	On-farm	Off-farm	On-farm	Off-farm
Information Networks	Moderately connected	Moderately connected	Most connected	Least connected

Table 1-2: Farmer types constructed by using policy-relevant farmer characteristics.

Input

In every simulation run, the model reflects changes in the political and economic environment such as changes in agricultural policy and crop prices.

Submodels

Farmers are autonomous decision makers regarding conservation practice adoption. Below are the sub-model explanations that control farmers' adoption decisions. The algorithm includes subcomponents that model the profitability of the farm business, influence of farmer preferences, and connectedness of the farmers, both socially and spatially. A special attention is given to agricultural profit calculations and the social connectedness of the agents, as they play significant roles in agents' decision-making.

At each time step, which can be interpreted as a year, every farmer makes decisions regarding conservation practice adoption. Farmers can choose to adopt none or a combination of the practices. The practices available to farmers tackle the non-point source pollution by controlling the pollution source (nutrient management), trapping the soil particles before they reach water bodies (structural practices, i.e, filter strips), promoting long-term conservation covers (land retirement, CRP), and reducing soil disturbance (non-structural practices, i.e., conservation tillage and no-till systems) (Table 1-3).

Farmers' adoption decisions have temporal consequences. That is, if a farmer enrolls in land retirement programs and signs a CRP contract, the commitment is a multi-year commitment, where in case of contract breach a penalty has to be paid. Similarly, adoption of structural practices such as filter strips requires a multi-year commitment as well because farmers receive economic incentives from the government. Adoption decisions of non-structural practices and nutrient management plans, however, are made on a yearly basis, and do not entail a penalty. In this model, we assume every farmer to be eligible for land retirement enrollment and every farmer who adopts structural practices to be eligible for 50% cost share incentive provided by the government.

Adoption of structural and non-structural practices, land retirement enrollment, and participation in nutrient management plans are voluntary decisions. Each farmer determines whether to enroll in land retirement programs (such as CRP), to adopt certain conservation practices, or choose not to adopt any practice, depending on their farm's overall objective. The overall objective is a combination of multiple objectives that include the profitability of the business, attitudes towards different conservation practices depending on farmer type, and influences of the spatial and social network. These objectives, each represented by a specific function, are combined in a single function that represents the overall utility of the farmer (Equation 1.1).

Every period, the overall utility to a farmer for every conservation practice adoption option (e.g., no conservation practice at all, single conservation practice adoption or a combination of conservation practices) is calculated. The list of conservation practices and their combinations are given in Table 1-3.

i	Conservation practice
0	None
1	Non-structural practices (no-till)
2	Structural practices (filter strips)
3	Land retirement programs (CRP)
4	Nutrient management plans
5	Non-structural practices (no-till) & Structural practices (filter strips)
6	Non-structural practices (no-till) & Nutrient management plans
7	Structural practices (filter strips) & Nutrient management plans
8	Non-structural practices (no-till) & Structural practices (filter strips) & Nutrient management plans

Table 1-3: Available conservation practices and their combinations to farmers.

The decision algorithm combines all of the available information to the farmer and integrates for the adoption decision. This mechanism includes the profit generated from agricultural production, availability of government programs and policies, influence of the farmers' neighbors and farmers' intrinsic attributes. These are all combined within a utility function, $F_{decide}(i,j)$ for the conservation practice combination *i* and farmer *j*, which is a combination of 4 sub-functions (Equation 1.1).

Once the farmer calculates utility of each conservation practice, the values of utility are transformed into choice probability using logit model. Logit framework allows us to incorporate both uncertainty in decision-making and the bounded rationality of the farmers as it assigns probabilities to different options, where the probability of an inferior option could be non-zero (Equation 1.2).

$$F_{decide}(i,j) = b_1 F_{econ}(i,j) + b_2\, F_{profile}(i,j) + b_3\, F_{social}(i,j) + b_4\, F_{spatial}(i,j) \qquad (1.1)$$

$$\text{Selection\_probability}\ (i,j) = e^{\,F_{decide}(i,j)} / \Sigma e^{\,F_{decide}(i,j)} \qquad (1.2)$$

In every period, for every farmer (*j*), $F_{decide}(i,j)$ is calculated for all possible combinations of the conservation practices (*i*). In this function $F_{econ}(i,j)$ represents the agricultural profit generated with production, $F_{profile}(i,j)$, the intrinsic attributes of the farmer towards the given conservation practice combination, which is determined by its type, $F_{social}(i,j)$, the influence of the farmer's social network and $F_{spatial}(i,j)$, the influence of the spatial network, i.e. the farmer's neighbors. $F_{social}(i,j)$ and $F_{spatial}(i,j)$ are also influenced by the farmer typology. The weights (b) for each component are informed by the farmer typology and determined using a matrix method (Appendix C). One of the important modeling choices that incorporate the differences between the different farmer types is the assignment of the weights (b). These weights are assigned in such a way that the farmer types whose income source is solely farming, and the types with profit maximizing mindset (i.e., business-oriented farmers) put more emphasis to $F_{econ}(i,j)$, while farmers with more connection to the landscape (i.e., traditional farmers) put more emphasis on $F_{profile}(i,j)$. Because non-operators do not live in the county in which they own land, or they do not have a farming background, they are not connected to the information networks have no b values for $F_{spatial}$ and F_{social}. More details on each component of the $F_{decide}(i,j)$ function is given in subsequent sections.

1. Agricultural Profit Dynamics, $F_{econ}(i,j)$

Farmers generate revenue by enrolling in land retirement programs and allocating land to the CRP or by crop production. If the farmer enrolls in land retirement programs, a fixed payment depending on the farm size and CRP rental rate is paid at the beginning of each year the farmer allocates land for retirement programs. There will be no further agricultural revenue generated from production for the farmer in that case, and that payment will be equal to $F_{econ}(i)$. Otherwise, the farmer's expected earning is calculated using the farm size, the price and yield of the crop that the farmer expects to get, governmental support for enrolling agricultural programs, and costs associated with production and conservation practice adoption. Single period profit function of a farmer producing a single crop is written below in two forms representing policy scenarios of with crop revenue insurance and without crop revenue insurance. In our models, the commodity payments such as direct payments are not represented explicitly.

$$F_{econ}(i,j) = p(A-F)Y(z) + gF + rA - c \tag{1.3}$$

without crop revenue insurance program

$$F_{econ}(i,j) = p(A-F)Y(l, z) + gF + rA - c - p(l) \tag{1.4}$$

with crop revenue insurance program

where $F_{econ}(i,j)$ is profit, p is farmer's expected crop price (corn, soybean or winter wheat), A is the production area (acres), Y is the farm's expected effective yield per acre, g denotes per acre economic incentive associated with structural practice adoption, F is total land allocated for structural practices, r is the CRP per acre payment to the farmer, z is a measure of fertilizer input on the farm, c is the total cost of production including cost of conservation practice adoption, p is the per acre premium rate for crop revenue insurance, and l is the level of insurance purchased. In this model we assume 75% coverage level for revenue insurance.

Agricultural crop production generates revenue (market price multiplied by production size and expected yield). Agricultural profit dynamics also include government payments (such as payments to incentivize structural practice adoption), insurance indemnities if enrolled in crop revenue insurance program, and cost production including maintenance, input, and labor costs as well. To represent the agricultural production cost, a current farm budgeting model developed by Ohio and Iowa State Universities is adopted and adjusted to previous years using historic consumer price index.

Practices that farmers adopt influence the size of the production area and expected yield; therefore they affect the expected agricultural profit. For example, when a farmer implements structural practices, the size of the filter strip is subtracted from the total size of the farm. Moreover, with nutrient management plans the expected yield decreases. Therefore, F_{econ} value for each conservation practice available in Table 1-3 is calculated separately.

Expected Price and Yield: Expected prices and yield values heavily influence the resulting farm profit. These parameters are based on previous year's price and yield values and updated by each farmer influenced by their farmer type.

In the model, for actual crop yields and prices historical values are used (available at http://usda.mannlib.cornell.edu and http://www.farmdoc.illinois.edu). In any given time, based on the actual previous crop yields and prices, farmers use Bayesian inference to form price and yield expectations. While a farmer's yield expectation is in the form of a point prediction, a probability distribution is formed for crop prices by taking the price expectation as the mean. Bayesian inference is a statistical approach used to update farmer's existing expectations against observed values of crop price and yield. The Bayesian inference allows farmers to be connected to agricultural markets and at the same time 'learn' with experience. Moreover, with Bayesian inference, we can represent the heterogeneity of farmers by setting different parameters for updating their priors for crop prices and yields depending on the farmer type. For example, traditional farmers are more anchored so that realization of outliers do not affect their expectations much while business-oriented farmers are better at following the fluctuations in the market.

Bayesian inference algorithm is run every year, hence farmers' perceptions for crop prices and yields change annually. At the beginning of each year, farmers use publicly available price and yield information from the previous year, their experiences and personalities to form future price and yield expectations.

2. Intrinsic typology attributes, $F_{profile}$ (i,j)

Farmer typology developed informs $F_{profile}$ values for each farmer type and conservation practice (Daloğlu et al. 2014). $F_{profile}$ *(i,j)* lets farmers to adopt economically infeasible practices because of their attitudes and preferences such as being a good citizen of the environment (Table 1-4). The synthesis of the adoption literature supports the $F_{profile}$ values, which change for every practice and every farmer type. In other words, $F_{profile}$ is the variable representing the socio-economic attributes of the agents including the source of income, impact of farm size and land tenure arrangements in adoption decisions (Table 1-5).

Farmer Type	Land Management Attitudes
Traditional	- favor non-structural practices because of potential reduction in labor requirements → high $F_{profile}$ values - financial investment requirement leads to lower adoption rates for structural practices → low $F_{profile}$ values - secure income provided by land retirement programs is appealing → high $F_{profile}$ values
Supplementary	- favor non-structural practices because of potential reduction in labor requirements → high $F_{profile}$ values - substantial off-farm income leads to higher adoption rates for structural practices → high $F_{profile}$ values - secure income provided by land retirement programs is appealing → high $F_{profile}$ values
Business-oriented	- favor non-structural practices because of potential reduction in labor requirements → high $F_{profile}$ values - long-term plans and dependence on soil quality leads to higher structural practice adoption → high $F_{profile}$ values - focused on profitability, leading to low enrollment rates in land retirement programs → low $F_{profile}$ values
Non-operator owner *Absentee landowners*: own the land but do not reside on or operate it (Petrzelka et al., 2011) *Investors*: describe themselves as never having farmed (Nassauer et al., 2011). Mutually exclusive subtypes.	- favor non-structural and structural practices because of potential contribution to increased water quality → high $F_{profile}$ values - absentee landowners favor land retirement programs → high $F_{profile}$ values - investors have lower enrollment rates for land retirement programs → low $F_{profile}$ values

Table 1-4: Farmer typology and its influence on $F_{profile}$ values (adapted from Daloğlu et al. 2014)

The $F_{profile}$ value for each farmer type and conservation practice is determined using prioritization matrix method and the synthesis of the adoption literature (Table 1-4, Daloğlu et al. 2014). The prioritization matrix, also known as criteria matrix, provides a way of sorting a diverse set of items into an order of importance. It also enables their relative importance to be identified deriving a numerical value of the importance of each variable.

i	$F_{profile}$				
	Traditional	Supplementary	Business-oriented	Investor	Absentee Landowner
0	0.90	0.36	0.28	0.00	0.00
1	0.68	0.49	0.74	1.00	1.00
2	0.00	0.06	0.20	0.37	0.60
3	1.00	1.00	0.00	0.48	0.17
4	0.43	0.17	0.43	0.13	0.12
5	0.10	0.22	0.36	0.55	0.72
6	0.51	0.17	1.00	0.30	0.31
7	0.08	0.17	0.28	0.55	0.62
8	0.07	0	0.31	0.86	0.63

Table 1-5: $F_{profile}$ values

3. *Social and spatial network, $F_{social}(i,j)$ and $F_{spatial}(i,j)$*

To represent interactions between agents, there are several artificial social network structures such as lattice, small-world, scale-free and random networks. As little to no data is available for the historical and current social network structure of the farmers we chose to rely on artificial network structures. After a comparison of widely used social network structures, Hamill and Gilbert (2009) suggest a simple but at the same time sociologically realistic network structure. To represent the varying network connectedness of agents displayed in the farmer typology, this social network is suitable.

Hamill and Gilbert (2009) base their network structure on the analogy of social circles. In the social network, agents are permitted to have links with other agents who can reciprocate. The agent population is divided into two circles with small and large social reaches. This network structure allows representing individuals who are more connected than rest of the population by placing them in the social circle that has larger social reach. When the social reach is larger, the size of the personal network would be larger as well. In our model, business-oriented agents are located in a social circle that has larger social reach than supplementary and traditional farmer agents which results in increased number of connections for business-oriented farmers. This network structure also allows us to connect business-oriented farmers more to other business-oriented farmers. Non-operator owners (investors and absentee landowners) are initially not connected to the social network. However, to demonstrate the potential impacts of information networks on non-operator owner decision, we simulate a scenario that assumes absentee landowners connect to the social network whereas investors connect to both spatial and social networks as they live close to the farmland that they own. Through the information networks (spatial and social networks), farmers observe their neighbors' adoption decisions.

Both $F_{spatial}(i,j)$ and $F_{social}(i,j)$ are calculated for every farmer for every possible conservation practice given in Table 1-2. $F_{spatial}$ represents the percentage of Moore neighbors (the eight cells surrounding a central cell on a two-dimensional square lattice) adopting a certain conservation practice. Moore neighbors of a farmer comprise the immediate eight spatial neighbors that every farmer has, except the farmers on the edge if two-dimension grid space.

$$F_{spatial}\,(i,j) = Neighbors(i,j) \,/\, \Sigma Neighbors(i,j) \qquad (1.5)$$

where Neighbors(i,j) is the number of Moore neighbors that adopted the conservation practice combination j. That is, $F_{spatial}\,(i)$ is a measure of popularity of conservation practice combination *i* in the immediate neighborhood of the given farmer. Higher the popularity of a conservation practice in spatial sense, higher the probability of the farmer adopting that conservation practice.

F_{social} represents the percentage of neighbors adopting a certain conservation practice. Similarly, F_{social} is calculated for every possible conservation practice listed in Table 1-3. Connectedness in the social network is not uniform among the farmers. The number of connections of a farmer depends on its type. Moreover, among the farmers of a given type, the number of connections may differ, representing the heterogeneity of the farmers within the same type. However, the variation in the number of connections among the farmers of the same type is smaller than the variation between farmers of different types. For example, business-oriented farmers have higher number of social connections than the other farmers on average, while the connections of the business-oriented farmers are mostly to other business-oriented farmers. Traditional and supplementary farmers have lower number of connections. In a similar manner as $F_{spatial}\,(i,j)$, $F_{social}\,(i,j)$ measures the popularity of the conservation practice combination i among the parts of the social network that are connected to the given farmer. $F_{social}\,(i,j)$ can be written as follows:

$$F_{social}\,(i,j) = Network\,(i,j) \,/\, \Sigma Network\,(i,j) \qquad (1.6)$$

where Network(i,j) is the number of farmers that selected the conservation practice adoption *i* within the farmer *j*'s social network.

Non-operator owners (investors and absentee landowners) are not initially connected to spatial and social networks. Therefore, initially they have no influence of information networks on their conservation adoption decisions. When increased involvement of non-operator owners in decision-making is simulated, absentee-landowners are only connected to the social network and investors are connected to both spatial and social networks. For non-operator owners, social networks are assumed to be NGOs and government agencies leading to a positive influence.

Policy Scenarios

We simulated four scenarios intended to form a bridge between the science of land management and policy development (Table 1-6). The primary goal of these plausible policy scenarios is to be prospective and informative rather than projective or prescriptive of the future (Nassauer and Corry, 2004).

		NON-OPERATOR INVOLVEMENT	
CROP REVENUE INSURANCE		NO	YES
	NO	1 *Baseline* Simplified representation of existing land tenure and policy context	2 *Non-operator owners involvement* Increased non-operator involvement in land management decisions
	YES	3 *Crop revenue insurance* Only operators are decision makers and crop revenue insurance is available as a risk management tool	4 *Crop revenue insurance with non-operator owner involvement* Both operators and non-operators owners are decision makers and crop revenue insurance is available as a risk management tool

Table 1-6: Land management strategies tested under different agricultural policy and structure scenarios

The *Baseline scenario* (1) represents a simplified version of existing land tenure where operators (traditional, supplementary and business-oriented farmers) are responsible for conservation practice adoption decisions and non-operator owners have no involvement in production and conservation decisions. In this scenario existing crop insurance programs are not represented and crop revenue insurance is not offered in lieu of commodity payments.

The *Non-operator owner involvement scenario* (2) simulates the potential impact of non-operator owners being more involved in decisions about conservation practice adoption. This premise follows recent research that demonstrated positive attitudes of non-operator owners for certain conservation practices (Petrzelka et al., 2009; Nassauer et al., 2011). In this scenario, we assume natural resource agencies and NGOs reach out to non-operator owners and effectively inform them about existing and available conservation practices.

The *Crop revenue insurance scenario* (3) follows the latest US Farm Bill discussions about providing federally subsidized crop revenue insurance rather than commodity production subsidies. This scenario does not assume that conservation compliance is required for land to be eligible for crop revenue insurance. In this scenario, only operators are decision makers and they purchase crop revenue insurance at 75% coverage level for all the land that they manage including the rented land. Crop revenue insurance provides an accessible risk management tool to operators and at the same time encourages an increased production area.

The *Crop revenue insurance with non-operator owner involvement scenario* (4) presents the plausible changes both in land tenure and policy by assuming non-operators owners as active decision makers when crop revenue insurance is offered in lieu of commodity payments. Crop revenue insurance provides a safety net and indirectly motivates both operators and non-operator owners to increase their production area.

Certain model parameters are changed depending on the policy scenario being investigated. Appendix 3 has initial model parameter values and how we change these values for different scenarios.

Verification and Validation

ABMs are informative rather than predictive and useful in investigating plausible scenarios and their potential consequences. Model verification and validation are important steps that contribute to the validity of the developed ABM. Model verification is the process of determining whether the software implementation correctly represent model processes (Ormerod and Rosewell, 2009). As the ABMs are powerful in illustrating the phenomena of emergence, it is particularly difficult to determine whether an unexpected result is due to an error in the model implementation and execution (Galan et al., 2009). Therefore the verification stage of the model is particularly important. For the verification of the model, where the general aim is to make sure that the model does not have programming errors, we built the model in several levels with increasing complexity following unit testing approach (Linck and Frohlick, 2003) (Figure 1-4). The unit testing approach suggests writing some test code to exercise the program simultaneously writing the complete model code. The purpose is to construct the model in small, self-contained units and check the results and make sure they align with expected results.

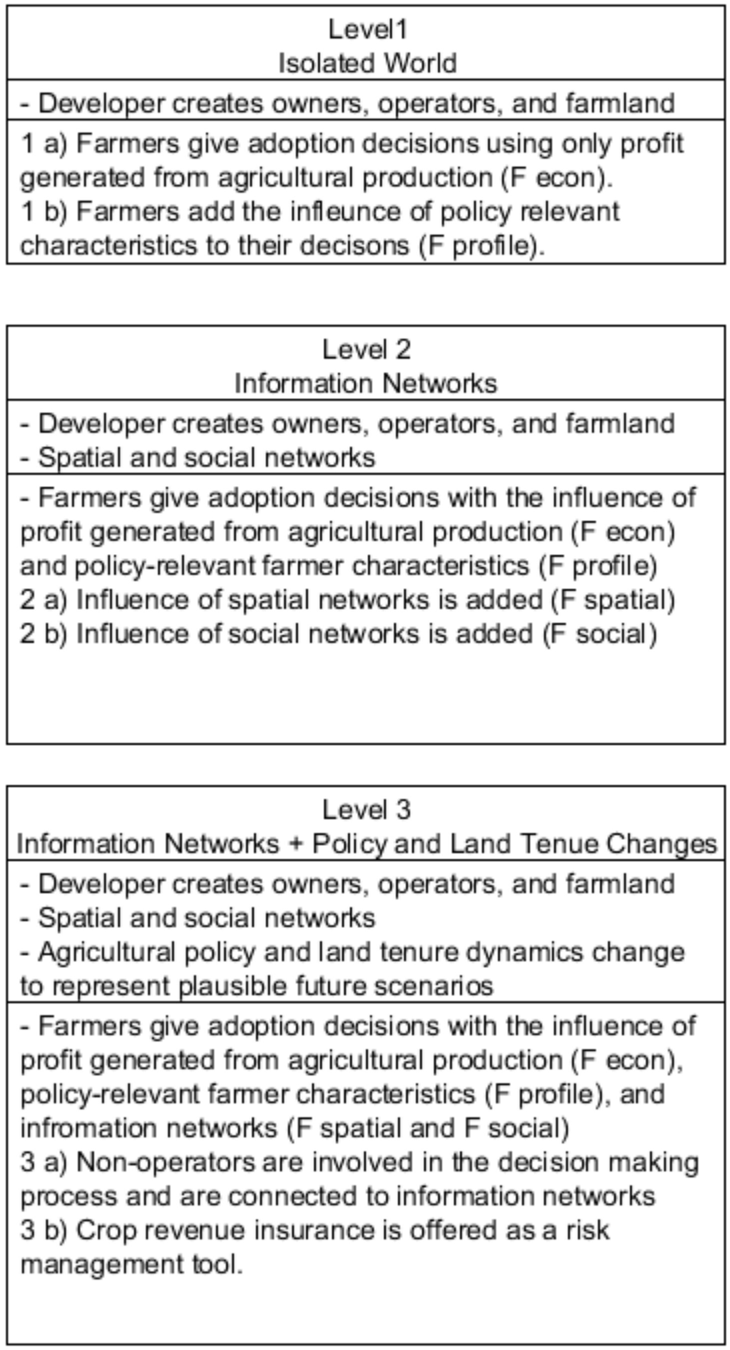

Figure 1-4: Levels of ABM as a verification tool

Model validation is the process of assessing the degree of which the model is accurately representing the real world interactions and dynamics (Ormerod and Rosewell, 2009). For the farmer typology, we synthesized the literature of conservation practice adoption (Daloğlu et al., 2014). Therefore, for model validation we used the documented trends in the Corn Belt. Synthesis of numerous studies conducted in the Corn Belt provides spatially and temporally generalizable trends to compare and validate model results. Comparison of documented adoption rates for non-structural practices (CTIC, 2012) and enrollment rates for land retirement programs such as CRP (USDA, 2013) are within the simulated adoption rates (Figures 1-5 and 1-6). For structural practices, we refer to empirical studies conducted in Ohio, which indicate 20-25% adoption rates similar to ABM results (Napier et al., 2000; Napier and Bridges, 2003).

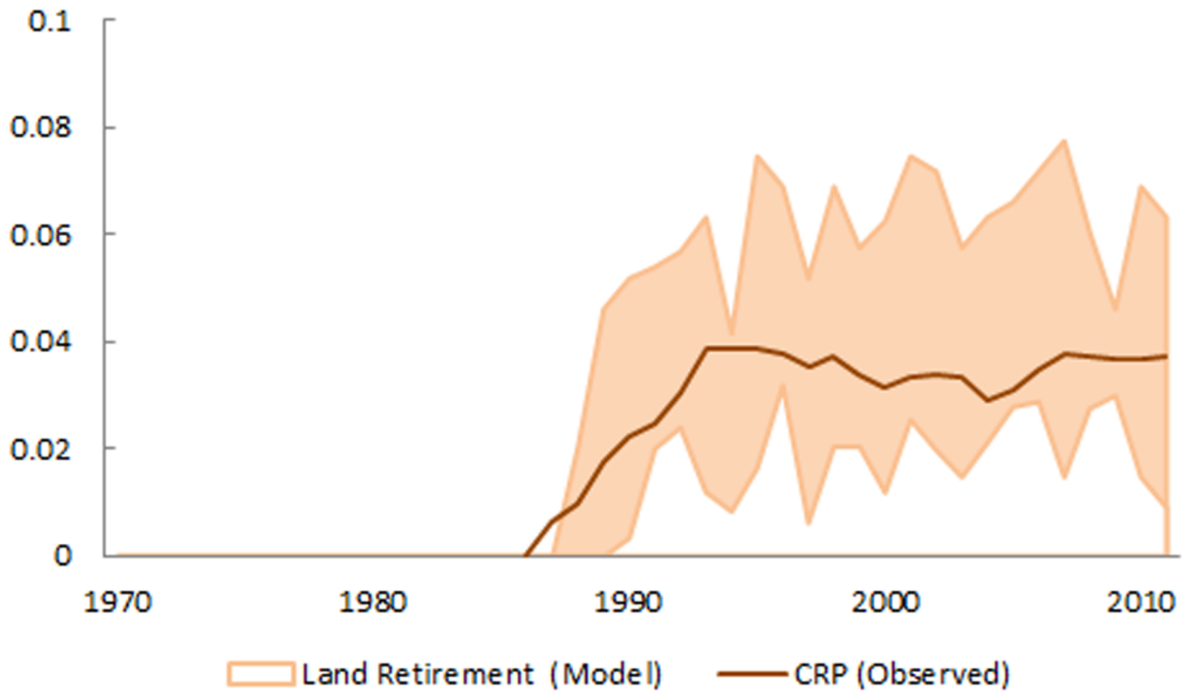

Figure 1-5: Observed and simulated enrollment rates for land retirement programs such as CRP in Sandusky watershed, OH (USDA, 2013). 25 ABM simulation runs fall between two lines of the same color.

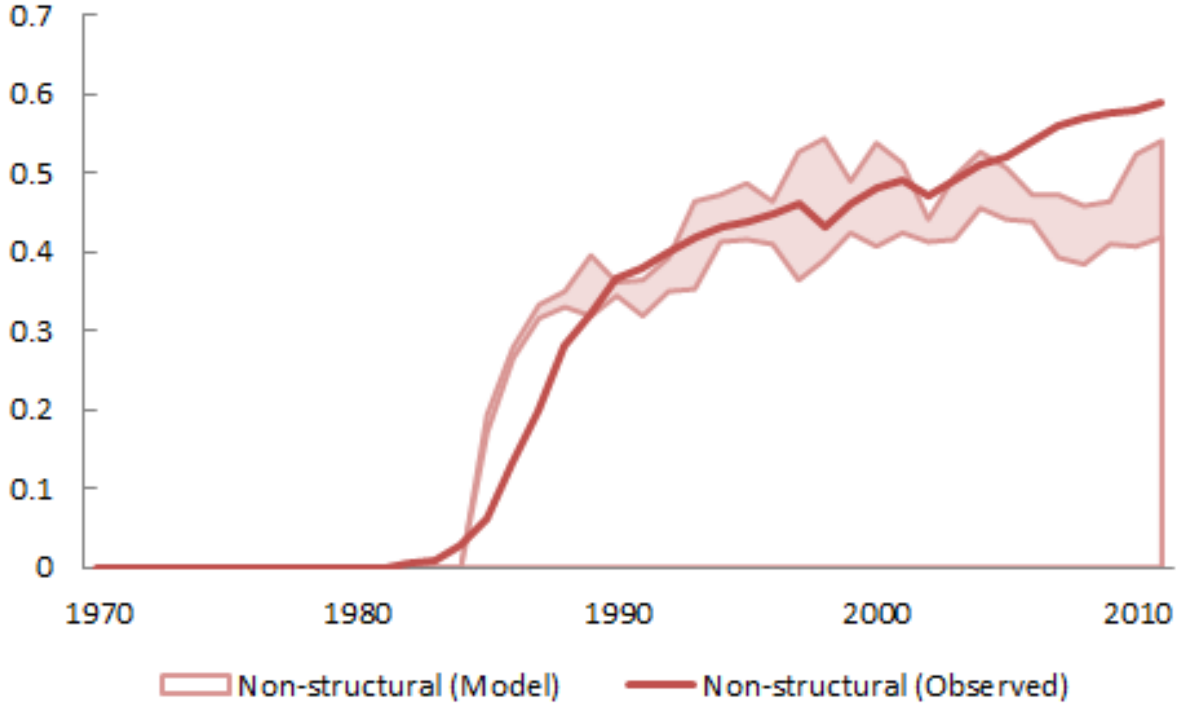

Figure 1-6: Observed and simulated adoption rates for non-structural practices such as conservation tillage and no-till in Sandusky watershed, OH (CTIC, 2012). 25 ABM simulation runs fall between two lines of the same color.

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