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# Development of a farmer typology of agricultural conservation behavior in the American Corn Belt

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# ABSTRACT

Farmers' decisions about adopting conservation practices are inherently dynamic, affected by changes in environmental, economic, and social conditions, including interactions with other farmers. Water quality models that are used to assess agricultural policy interventions, such as the Soil and Water Assessment Tool (SWAT), lack the dynamic social component of farmer's decisions. While agent-based models (ABM) can represent and explore these decision dynamics, ABMs have not been connected to water quality models that can measure environmental outcomes of farmer decisions. Connecting ABMs and SWAT could advance the development of targeted conservation policies. Toward this aim, we developed a typology of Corn Belt farmers based on farmer characteristics that could be employed in an ABM and be relevant to water quality outcomes. Because our typology was developed for use in an ABM and to link to an existing water quality model (SWAT), it had distinctive simplicity (to optimize utility of the ABM) and relevance to characteristics modeled by SWAT. To identify farmer characteristics, we reviewed the literature on conservation practices that could be represented in SWAT models and their adoption by Corn Belt farmers. We found that land tenure arrangements, farm size, source of income, and information networks were consistently identified as farmer characteristics that influence conservation practice decision-making, were simple and relevant. Employing these characteristics, we identified four types of farmers to populate an ABM that will be linked to SWAT: (1) "Traditional": small operations relying primarily on on-farm income; (2) "Supplementary": small operations relying primarily on off-farm income; (3) "Business-oriented": medium to large operations relying primarily on on-farm income and well connected to information networks; (4) "Non-operator": absentee and/or investor farmland owners with limited connection to local information networks. This typology represents the heterogeneity of Corn Belt farmers relevant to their adoption of conservation practices. It gives us the conceptual framework for an ABM that can be linked with SWAT to explore coupled social and biophysical processes within Corn Belt agroecosystems, focusing on alternative approaches to targeting conservation policy to effectively reduce sediment and nutrient runoff.

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### 1. Introduction

Agriculture continues to be a major contributor to water pollution, soil degradation, climate change, and biodiversity loss. The highly cultivated watersheds of the Corn Belt are major sources of non-point source pollution (Nassauer et al., 2007; National

http://dx.doi.org/10.1016/j.agsy.2014.05.007 0308-521X/© 2014 Elsevier Ltd. All rights reserved. Research Council, 2010; Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). Agricultural runoff is often the cause of algal blooms, poor water clarity, and summer hypoxia (low oxygen) in the Gulf of Mexico (Ribaudo and Johansson, 2006) and Lake Erie (Hawley et al., 2006). Hypoxia has severely impacted commercial and sport fisheries, with trophic cascades affecting aquatic and coastal food webs (Carpenter et al., 1998).

Federal policy strongly affects the management choices of American farmers and thus the landscape characteristics and water quality of farms and downstream ecosystems. Farmers are defined in this analysis as owners or renters of farmland where cash crops are grown. The US Farm Bill, which is renewed approximately every five years, is the federal policy that most directly affects

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agricultural land use and practice. Since the 1930s, the Farm Bill has included specific soil and water conservation programs, as well as support for production of certain crops (Nassauer and Kling, 2007). Yet, Farm Bill support for crop production has substantially and consistently outweighed incentives for conservation (Doering et al., 2007).

Developing more effective agricultural policies necessitates a better understanding of the motivations and underlying socio-economic circumstances of farmers (National Research Council, 2010). However, these attributes are not homogenous or static among farmers responding to conservation policies.

The relationship between farmers' decisions about adoption of conservation practices and water quality outcomes is part of a complex coupled human and natural system and, as such, coupled social–biophysical models can be valuable tools for better targeting federal investments (Jackson-Smith et al., 2010). Such approaches can incorporate farmer decisions in exploring whether or not substantial changes in water quality can be expected as a result of specific policy interventions. Knowledge of the socio-economic factors that influence farmers' conservation-related decisions is essential for the construction of such a model.

Typologies have been suggested (Kostrowicki, 1977; Duvernoy, 2000; Valbuena et al., 2008) as a means to effectively represent the heterogeneity of farmers' motivations and socio-economic circumstances related to conservation behavior. This paper describes the basis for a farmer typology that we developed for use in an agent-based model (ABM) to be coupled with the Soil and Water Assessment Tool (SWAT) and employed to compare how different policy interventions may affect spatial patterns of adoption of conservation practices and by modeling their impacts on downstream water quality (Fig. 1). SWAT is a river basin scale water quality model, developed and maintained by the US Department of Agriculture to assess the water quality benefits of conservation practices (Gassman et al., 2007; Osmond, 2010). This model is a distributed and spatially explicit continuous-time water quality model that divides watersheds into subbasins (Arnold et al., 1998). It is a process-based model of surface hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and groundwater that can simulate the effects of climate and land use changes on nutrient and sediment delivery from watersheds that is used widely for evaluating and predicting impacts of conservation practices (Arabi et al., 2008).



**Fig. 1.** Using a farmer typology in a coupled human and natural system of farmers' adoption of conservation practices and effects on water quality. We constructed our farmer typology using farmer characteristics relevant to adoption of conservation practices that are applicable in SWAT models and we built this typology to be implemented in an ABM.

Because our typology was intended as a basis for an ABM that we would link with SWAT (Daloğlu et al., in press), we developed it to be distinctly parsimonious – defining a small number of types that are highly relevant to the Corn Belt agricultural policy and cropping system we were investigating – and distinctly focused on management characteristics modeled by SWAT. Typologies are key components of ABMs, computational methods that model decentralized decision-making in a given heterogeneous system to predict emergent characteristics.

## 1.1. Geographic setting of farmer types

Our study site, the Sandusky Watershed, Ohio drains into Lake Erie (Fig. 2), and is typical of the Corn Belt, which occupies portions of the states of Ohio, Indiana, Illinois, Iowa, Minnesota, Michigan, Missouri, Nebraska, and South Dakota. Consequently, we developed a policy-relevant farmer typology by reviewing and synthesizing the literature on the adoption of conservation practices by farmers in the Corn Belt. The highly cultivated watersheds of the Corn Belt are major sources of non-point source pollution in Lake Erie (Hawley et al., 2006), as well as the Mississippi River and its tributaries (Ribaudo and Johansson, 2006).

Farmers specialize in cash-crop (corn, soybean) production – the focus of this farmer typology, with livestock production less common (USDA, 2009). In the Sandusky Watershed, like much of the Corn Belt, most farmers rent at least some of the land they farm, and about half declare their primary occupation to be non-farming (Table 1). While most farms in the Corn Belt and the Sandusky Watershed are small (less than 180 acres), large farms (more than 500 acres) make up a much larger proportion of the total area harvested and large-scale, commercial farms dominate the land-scape (Fig. 3).



Fig. 2. Map of the geographic setting of farmer types, showing the Corn Belt (dashed) and the Sandusky Watershed, OH.

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#### Table 1

Characteristics of farmers in the Corn Belt and the Sandusky Watershed, OH. Source: USDA (2009).

	Corn Belt			Sandusky, OH				
	Farms (%)	Acres (%)		(%)	Farms (%)	Acres (%)		(%)
Full owner	50.9	16.6			50.4	14.8		
Part owner	39.9	72.4	Owned	43.0	43.0	77.0	Owned	35.6
			Rented	63.9			Rented	60.6
Tenant	9.2	8.8			8.6	8.7		
Primary occupation								
Farming	47.9				44.6			
Other	52.1				55.4			
Male	89.2	95.3			91.4	96.5		
Female	10.8	4.7			8.6	3.5		
Principal operator worked days off, any >200 days	63.70				65.6			
	36.30				34.4			
Used conservation practices	34.10				46.3			

# 1.2. Farmer characteristics

Among the many factors that influence farmers' decisions regarding conservation practices, we focused on farmer characteristics most immediately relevant to conservation practices affecting water quality and applicable in SWAT. We found that land tenure arrangements, farm size, source of income, and information networks were identified as farmer characteristics that influence conservation practice decision-making. Many empirical studies have been conducted to describe the relationship between the adoption of conservation practices and farmer-specific variables such as age, education, land tenure, and farm size. Some emphasize attitudes and motivations (Lynne et al., 1988; Ryan et al., 2003), and some emphasize other social, economic and structural variables (Nowak, 1983; Tosakana et al., 2010; Napier et al., 2000; Napier and Bridges, 2002; Lemke et al., 2010). Unfortunately, no one variable has been identified as universally influencing the diffusion and adoption of conservation practices. Knowler and Bradshaw (2007) reviewed empirical studies from around the world in an attempt to identify such a universal variable; however, they were unable to do so due to differences in geography, relevant agricultural policies and statistical methods employed by the different studies reviewed. Similarly, after reviewing 55 US studies on the adoption of best management practices, Prokopy et al. (2008) conclude that there is no single factor that consistently affects decisions. Although a number of studies have found farm income to be an important consideration, that alone cannot explain the adoption decisions of a farmer under every circumstance



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(Chouinard et al., 2008). Camboni and Napier (1993) conclude that adoption decisions are generally more influenced by structural variables such as farm size, income source, farm specialty, debtto-asset ratio and participation in government programs than by personal variables such as environmental problem awareness, farming experience and education.

For a typology to be used in an ABM, which requires simplicity to explore dynamic interactions among agents (Axelrod, 1997), we selected a minimum number of widely studied farmer characteristics that would be relevant to the conservation practices intended to affect water quality. As such, we eliminated variables such as education, age, attitudes/motivations, environmental awareness, and farming experience that generally have been found to be less relevant to these practices.

# 2. Methods

#### 2.1. Agent-based models

ABMs are computer-based models that can be used to represent decentralized decision-making and interactions of heterogeneous social agents on multiple scales. ABMs consist of one or more types of agents (e.g., different types of farmers), as well as an environment in which these agents are embedded. The models are useful for running computational experiments to assist in reasoning about systems that are inherently dynamic and uncertain (Bankes, 1993). That is, ABMs are not prescriptive, and their purpose is not to predict the system outcome, but rather to identify relationships among agents and particular variables as well as how these relationships affect system behavior. Because ABMs are computational models, they are formal, unambiguous, and thus, replicable and testable (Miller and Page, 2007). They are powerful tools for modeling coupled human and natural systems (Liu et al., 2007; An, 2012).

Agent definitions can include various characteristics, preferences, memories of recent events and social connections, abilities to carry out particular behaviors, decision-making rules, heuristics, and other mechanisms to generate individual agent responses to inputs from other agents and from the environment. ABMs can also include social networks of various kinds that define interaction topologies based on group memberships, business contacts and common information sources (Lopez-Pintado, 2008; Kuandykov and Sokolov, 2010). They can demonstrate the dynamics of agent behavior, as agents use rules to determine which other agents to interact with, how to interact with them, and how to interact with the environment.

The 'bottom-up' nature of ABMs– defining the model at the level of individual decision makers (agents) and their interactions with each other and with the environment – differentiates them from other simulation techniques (Gilbert, 2008). Because ABMs can capture spatial interactions among agents, they can reflect robustly the diffusion of information in social networks (Baerenklau, 2005; Happe et al., 2008; Kaufmann et al., 2009) making them especially well-suited to model how heterogeneous farmer characteristics affect spatial patterns of adoption decisions.

An ABM is most informative when it is comprised of a small number of variables that allow for better transparency and a deeper level of understanding (Axelrod, 1997). Therefore, we aimed for parsimony in developing the farmer typology to be linked with SWAT.

#### 2.2. Typology studies

Building a typology based on empirical literature can present potential limitations if they are oversimplified in an ABM. In that case model implications may be more theoretical than policy-relevant (Valbuena et al., 2008). In his seminal study, Kostrowicki (1977) argues that the variables selected for the construction of typologies are more important than the classification technique applied. Valbuena et al. (2008) highlight the importance of choosing variables that reflect the socio-economic situation and context of decision makers.

To test the effects of policy-relevant characteristics of farmer decisions, the typology developed should be focused on bringing insight to responses to policy. Because farmer typologies have often been tested using survey data from a specific locality (e.g., Kraft et al., 1989; Bohnet et al., 2011), their conclusions may not be broadly applicable. To address this limitation, we sought a simple, synthetic set of policy-relevant farmer characteristics to be employed in a more generally applicable ABM.

Farmer typologies developed in the Netherlands (Valbuena et al., 2008), Chile (Carmona et al., 2010), Greece (Daskalopoulou and Petrou, 2002) Argentina (Duvernoy, 2000), and Australia (Bohnet et al., 2011), as well as the United States (Hoppe et al., 2007; Briggeman et al., 2007; Lambert et al., 2007) have been useful when program managers and policy makers have been able to differentiate between landowners with different land-management motivations and management capacities that influence their behavior (Emtage et al., 2007). The geographic scale of such studies varies from continental (Andersen et al., 2006; Terluin et al., 2010) to national and regional. For example, Hoppe et al. (2007) categorized US farmers based on farm sales and operator occupations, using the results of the Agricultural Resource Management Survey (ARMS) administered by the National Agricultural Statistical Services (NASS) to understand the factors that influence decisions regarding conservation practices. Lambert et al. (2007) used this same typology in another national study employing random utility regressions to examine which farmer characteristics promote the adoption of conservation practices; they found that farmers are heterogeneous in their response to conservation policy depending on their characteristics. Another example of a national farmer typology is a characterization of US farm households based on household economic theory (Briggeman et al., 2007). Typologies developed to characterize farmers within a region include Kraft et al. (1989), who constructed a typology to study southern Illinois farmers' goals and views on soil conservation. However, none of the typologies constructed for US farmers have been developed for use as the basis for an ABM.

Farmers are diverse in their structural characteristics related to conservation decisions. This diversity, coupled with the assumption that conservation practice adoption is guided by economic rationality, has been suggested as the reason for errors in conventional farm-level models of US agricultural policy (Nowak, 1987; Nowak and Cabot, 2004). As Happe et al. (2008) point out, failure to consider farmer diversity and interaction among farmers in designing agricultural policies often leads to program failure. ABMs can fill this gap by demonstrating the effects of diversity and interactions.

# 3. Results and discussion

We identified four policy-relevant farmer characteristics that are consistent throughout the literature related to conservation decisions of Corn Belt farmers: land tenure arrangements, farm size, income source, and information networks. These farmer characteristics are best choices for parsimony and relevance as required by ABMs. Because this typology populates an ABM that will be linked to SWAT, the capabilities of SWAT were decisive in constructing the parsimonious typology. Therefore, we categorized these conservation practices in three broad, SWAT-applicable cat-

egories: "non-structural", "structural", and "land retirement" practices (Table 2).

#### 3.1. Land tenure arrangements

Tenure arrangements indicate the extent of ownership and control of farmland, which can directly affect adoption of conservation practices. In this analysis we have three land tenure arrangements for defining farmer types: full owner, part owner, and non-operator (Table 3). With full ownership, the farmer owns all of the land in operation, whereas part owners own only a portion of the operated land with the remainder rented from others. 'Non-operator owners' rent out all of their land and do not operate any farmland themselves. Non-operator owners may include both 'absentee landowners', individuals who live outside the county where they own farmland but who may be or have been involved in farming (Petrzelka et al., 2009), as well as 'investors', non-operator owners who describe themselves as never having farmed and who may not necessarily live outside the county where they own farmland (Nassauer et al., 2011).

In general, US agriculture has undergone a steady decline in full ownership and a rise in part and non-operator ownership (Wunderlich, 1993; Duffy, 2008). This rapidly growing proportion of non-operators, both absentee landowners and investors, deserves focused attention. The ARMS database reflects how this phenomenon has affected the Corn Belt, as represented by the Sandusky Watershed (Table 1). There, only 14.8% of the total farmland acreage is owned by full owners, compared to 27.4% owned by part owners, 46.7% rented by part owners, and 8.7% rented by tenants who rent all the land they farm and own no farmland. In other words, more than half of the land farmed in the Sandusky watershed is owned by someone other than the operator. While it is possible that some of those owners are farmers who simply choose not to operate some of their land, it is reasonable to assume that non-operators own land rented by others.

Most empirical research concludes that operators control decisions regarding production and adoption of conservation practices on farmland owned by non-operators (Constance et al., 1996; Soule et al., 2000; Arbuckle, 2010). However, with growing proportions of farmland owned by non-operators, current policy and future expectations that Corn Belt farmers generally own the land they farm may change as well, and non-operators may have more influence on decisions.

While conventional wisdom suggests that owner-operated land is better preserved and managed because renters generally have no long-term stake in the environmental quality and sustainability of the land they rent, actual experience is mixed (Prokopy et al., 2008; Petrzelka et al., 2009; Nassauer et al., 2011; Fuglie, 1995; Bultena and Hoiberg, 1983). Soule et al. (2000) suggest that the relationship between tenure arrangements and adoption of conservation practices varies with the type of practice in question. For example, renters are more likely to adopt practices that are profitable in the short term, such as non-structural practices, whereas owners are more likely to adopt practices that have long-term implications and require capital investment, such as installing structural practices, which include filter strips and grassed waterways (Soule et al., 2000; Caswell et al., 2001).

Recently, studies have highlighted the need to study the growth of subgroups of non-operator owners, like absentee landowners and investors. Absentee landowners generally have not been involved in land management decisions, deferring to their renters (Duffy, 2008; Petrzelka and Marquart-Pyatt, 2011; Petrzelka et al., 2012, 2009; Soule et al., 2008; Wells and Eells, 2011). On the other hand, in a study of 549 Iowa farmers (Nassauer et al., 2011), 54.5% of investors (farmland owners who described themselves as never having farmed) stated that they made daily decisions regarding farm operations. Compared with operators, investors were notably more likely to adopt certain structural and non-structural practices that enhance environmental quality. The study concluded that investors' limited experience with management requirements of some conservation practices could explain their positive attitudes toward these practices. Petrzelka and Marguart-Pyatt (2011) found that those absentee landowners who did participate in land management decisions favored adopting conservation practices more than their renters.

A review of the literature reveals that enrollment in land retirement programs is less prevalent among absentee landowners than operator landowners. Petrzelka et al. (2009) report that absentee landowners lag operator landowners by 64% in land retirement program enrollment in the Great Lakes Basin. In contrast, Nassauer et al. (2011) found investors to have higher land retirement program enrollment rates compared with active farmers across lowa. At present, non-operator owners tend to leave production and conservation decisions to their renters, who tend to make decisions that support short-term profitability.

## 3.2. Size of farm (owned and rented land)

Farm size, or acres of harvested cropland, varies across the US (see, for example, Hoppe et al., 2007), and has been one of the most-explored variables in adoption studies (Rahm and Huffman, 1984; Nowak, 1987; Belknap and Saupe, 1988; Caswell et al., 2001; Napier et al., 2000). For example, Hoppe et al. (2007) reveal that large-scale farms with annual sales of \$250,000 or more accounted for only 10% of US farms but 75% of production value in 2004. Farm size reflects both economic and social aspects of farming, and operators of small and large farms respond differently to policy and market changes (Prokopy et al., 2008). Therefore, we identified operators of small farms as a distinct category (Table 3). After reviewing 55 studies conducted in the US, Prokopy et al. (2008) conclude that farm size is positively correlated with the adoption of conservation practices more often than it is negatively correlated (i.e. Belknap and Saupe, 1988; Caswell et al., 2001; Bultena and Hoiberg, 1983; Gould et al., 1989; Soule et al., 2000; Napier et al., 2000). In general, operators of larger farms are assumed to be more willing to invest in new technologies and adopt conservation practices, because the overall benefits of adoption increase for large farms (Knowler and Bradshaw, 2007).

#### Table 2

Conservation practice categories applicable in SWAT models.

Conservation practice categories	Conservation practices	Economic and environmental benefits
Non-structural	Conservation tillage, no-till	Reduces soil erosion from both water and wind, increases organic matter and enhances water quality. Reduces labor, saves time and fuel, reduces machine wear
Structural	Filter strips, grassed waterways	Enhances water quality by trapping soil particles, nutrients and pesticides; improves water infiltration; enhances wildlife habitat. Eligible for cost-share programs
Land retirement	Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP)	Plants long-term, resource-conserving covers. Reduces soil erosion from highly erodible lands (HEL), restores wetlands. Enhances water quality and wildlife

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Table 3	
Farmer types constructed by using policy-relevant farmer characteristics.	

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	Large	N/A			
Primary source of income	On-farm	Off-farm	On-farm	Off-farm			
Information networks	Moderately connected	Moderately connected	Highly connected	Least connected			

However, the relationship between farm size and adoption of conservation practices may vary with the particular conservation practice employed (Table 2).

Data collected from 371 farmers in east Ohio show that the area farmed influences farmers' decisions to adopt conservation tillage, filter strips, and grassed waterways (Camboni and Napier, 1993). Lee and Stewart (1983) conclude that small farm size may impede adoption of non-structural practices such as conservation tillage and no-till practices, and Fuglie (1995) suggests that operators of larger farms are more likely to adopt no-till practices. Based on the 2001 USDA ARMS data, Lambert et al. (2007) conclude that adoption of non-structural practices is unaffected by production scale, but that production scale as well as implementation costs become significant when farmers need to invest in more costly structural practices.

The influence of farm size on the adoption of conservation practices can be explained in a number of ways. For example, operators of large farms may adopt structural practices such as filter strips and grassed waterways because they have the ability to spread installation or equipment costs over a large area, lowering the per-acre cost of adopting new technologies and conservation practices (Lambert et al., 2007). The risks of adopting new technologies and conservation practices also can be spread with larger farms (Lichtenberg, 2004). However, land retirement programs such as the Conservation Reserve Program (CRP) and Wetland Reserve Program (WRP) have been adopted at higher rates among small farmers (Lambert et al., 2007) because these programs reduce farmers' labor and time requirements. In general small farms are more likely to have full owners, whereas large farms are more likely to be partly owned or fully rented.

# 3.3. Source of income

Farmer income affects most decisions, including those regarding conservation practices because the adoption of which can require financial investment and can reduce short-term profitability (Caswell et al., 2001). To understand the role of income generated from farm and off-farm sources, source of income is generally categorized by measuring off-farm employment in terms of number of days the primary farm operator works off the farm for wages or a salary (National Agricultural Statistics Service, NASS), percentage of income from off-farm sources (Nowak, 1987; Loftus and Kraft, 2003), and primary occupation of farm operators (Petrzelka et al., 2009). Our typology characterizes farmer types by on-farm and off-farm income because these categories may relate to conservation adoption decisions (Table 3).

A significant proportion of Corn Belt farmers have income from off-farm sources, which may be used to stabilize and/or increase household income (Napier and Camboni, 1993; Loftus and Kraft, 2003; Briggeman et al., 2007). According to an econometric model built by Mishra and Goodwin (1997) and validated with survey results from 300 Kansas farmers, off-farm income is positively correlated with lowered risk and variability for farmer incomes. For this reason, off-farm income sources are appealing to risk-averse farmers. A study by Fernandez-Cornejo et al. (2010) shows that in 2004, more than half of US farm operators worked off the farm and more than 80% of total farm household income was earned from off-farm sources. Similarly, the US Agricultural Census for 2007 shows that 55.4% of farmers in the Sandusky Watershed had a primary occupation other than farming (Table 1). Dependence on off-farm income differs with the size of the managed farmland. While small farm households receive a significant portion of their income from off-farm sources (Hoppe et al., 2007), large farm households tend to be more dependent on farm income (Nehring et al., 2005). Households with greater dependence on farm income may feel pressure to maximize short-term profits from their land (Caswell et al., 2001; Fernandez-Cornejo et al., 2010).

Debt-to-asset ratio, the degree of financial leverage used in farmland operations, also affects motives to maximize profits as it affects farmers' risk aversion. A number of studies have argued that high debt-to-asset ratios will increase risk aversion and prevent farmers from investing in conservation practices (Belknap and Saupe, 1988; Ervin and Ervin, 1982). Certain studies also show a positive correlation between off-farm income and the adoption of conservation practices (Fuglie, 1995; Nowak, 1987; Loftus and Kraft, 2003). This suggests that farmers with greater off-farm income have greater financial flexibility and stability. Both farmers who depend on farm-generated income (Napier et al., 2000) and farmers who have supplementary income (Gould et al., 1989) have been found to adopt non-structural conservation practices (Table 2). However, based on interviews with more than 1000 farmers in Ohio, Iowa and Minnesota, Napier et al. (2000) find that farmers with higher reported gross income from farm sources have higher rates of adoption of structural conservation practices. Farmers with higher off-farm income have higher enrollment rates in land retirement programs such as the CRP and WRP, perhaps because they have limited time available for farming (Hoppe et al., 2007). In general, off-farm income provides financial flexibility to smaller farms, whereas larger farms whose operators may rely primarily on farm income may feel they have less flexibility to choose practices that reduce short-term profits.

### 3.4. Information networks

Studies of the adoption of conservation practices have long recognized information as influential. Information channels include media, observation of other farmers' fields and practices, and communication with other farmers and extension agents (Rahm and Huffman, 1984; Belknap and Saupe, 1988; Lemke et al., 2010). Access to various information networks is a crucial variable in our typology because ABMs can effectively explore the dynamics of information dissemination through spatial as well as social networks.

Information is crucial when decisions are made about conservation practices because the adoption of conservation practices is a complex process that requires trial and evaluation. In addition to extant knowledge, personal contacts influence the adoption process and significant relevant information and experience flows through networks (Nowak, 1987; Lemke et al., 2010).

Farmers need information that will allow them to estimate the costs and benefits of available alternatives. One reason for non-adoption of a new technology is uncertainty about the outcomes of adoption. Autant-Bernard et al. (2007) suggest that networks of adopters and non-adopters or potential adopters are the foremost mechanisms for reducing this uncertainty, and that frequent contact among adopters and non-adopters deepen relationships and promote information exchange. They suggest that geography is crucial in the diffusion process, providing an environment for the transmission of knowledge, experience, and technology.

In agriculture, the physical proximity of adopters is considered to affect the decision-making process (Hägerstrand, 1967), and the 'neighborhood effect' has been studied extensively (Baerenklau, 2005; Case, 1992). Farmers are known to update their decisionmaking strategies by using their prior experience and by observing what their neighbors have done (Saltiel et al., 1994). As Rogers (2003) states, direct observation of what others have done is very important in adoption decisions and can provide potential adopters with persuasive information about the nature of conservation practices and their potential outcomes. Imitation of neighbors' practices can be understood as a strategy to compensate for lack of knowledge (Belknap and Saupe, 1988).

In addition to spatial proximity and neighborhood observation, other information networks provide channels through which farmers can obtain information on conservation practices and new technologies. For example, Loftus and Kraft (2003) found that farmers who paid frequent visits to a National Resources Conservation Service (NRCS) office obtained more information on filter strips and had higher rates of adoption of this practice. Similarly, Tucker and Napier (2002) discovered that farmers who had greater access to information networks and education programs were more aware of the non-economic benefits of conservation practices and had higher adoption rates. In addition, Prokopy et al. (2008) showed that access to social networks is one of the most influential variables influencing adoption. They also found that not all farmers are exposed to information at the same level. In other words, there is a variation in the level of network 'connectedness' among farmers, which ultimately affects the patterns of conservation practice adoption in a given locale. Similarly, Petrzelka et al. (2009) showed that financial constraints did not significantly affect decision-making for absentee landowners in the Great Lakes Basin, but that lack of communication and information networks did.

Social ties to the renter also lead to greater participation in decision-making by non-operator landowners. Stronger social ties are indicated by more continuous rental years, longer periods of having known the renter, and longer lease lengths. Moreover, previous research has shown that as the spatial distance between the landowner and the renter increases, the frequency of communication decreases (Arbuckle, 2010). Petrzelka and Marquart-Pyatt (2011) point out that renters communicate differently with absentee landowners than with non-operators that live within the county. Namely, absentee landowners are not as connected as local farmers to information networks, which may hinder the ability of absentee landowners to access information, including information on conservation practices. Similarly, when explaining the gap between high interest in conservation practice but low participation, Petrzelka et al. (2009) suggest lack of communication between absentee landowners and natural resource agencies as well.

# 3.5. Farmer typology

Using the farmer characteristics described above, we constructed a simple mutually exclusive four-part typology to be employed in the ABM (Table 3):

#### 3.5.1. Traditional farmers

Farmers of this type are full owners of small farms (less than 180 acres or 73 ha), operating only the land they own. Farming is their primary occupation, and they depend primarily on income generated from farm production. Both operator and spouse spend a significant amount of time working on the farm (Briggeman et al., 2007). They are attentive to financial concerns, but they also value preserving their rural lifestyle (Kraft et al., 1989).

In general, smaller farms are associated with lower farm income. Therefore, traditional farmers require a longer time period to pay off conservation investments (Caswell et al., 2001), and this could discourage adoption of practices that require a high initial investment and a relatively longer pay-off period. Consequently, structural conservation practices such as grassed waterways and filter strips may have lower adoption rates among traditional farmers. However, traditional farmers have the highest enrollment rates in land retirement programs such as CRP and WRP (Hoppe et al., 2007). Both the secure income and low labor requirements of land retirement programs may make them attractive to traditional farmers, who also favor non-structural practices such as conservation tillage that reduce overall labor requirements (Hoppe et al., 2007; Napier, 2009).

#### 3.5.2. Supplementary farmers

Supplementary farmers have small farms (less than 180 acres) and substantial off-farm income. They may be retired or part-time farmers whose off-farm income sources may include part-time or full-time jobs. These farmers do not depend solely on earnings generated from farming activities, and this substantially affects their management and conservation decisions. In addition, unlike traditional farmers, supplementary farmers may rent or own the farmland they operate, although most own all the land they farm.

Supplementary farmers favor adopting non-structural practices such as conservation and no-till, because these practices are less costly and less labor intensive (Gould et al., 1989; Fernandez-Cornejo et al., 2010). As they earn most household income from off-farm sources, supplementary farmers are more willing to use conservation practices that reduce the area that must be cultivated for example filter strips (Loftus and Kraft, 2003; Lynch et al., 2002). Supplementary farmers also have high enrollment rates in land retirement programs such as CRP and WRP (Hoppe et al., 2007) that are not labor intensive and provide a secure income source.

#### 3.5.3. Business-oriented farmers

Business-oriented farmers operate at least 180 acres and most likely rent at least part of the land they farm. They are highly dependent upon farm income since farming is their primary occupation (Hoppe et al., 2007). Fernandez-Cornejo et al. (2010) found an inverse relationship between off-farm income and farm size measured with gross annual sales, showing operators with large operations to be less dependent on off-farm income sources. Business-oriented farmers are also less dependent upon conservation payments, but more dependent upon commodity-related federal programs such as agricultural disaster payments and direct payments (Hoppe et al., 2007; USDA, 2011).

Because business-oriented farmers focus more on farm yield and profitability, they tend to concentrate on high-value cash grains and hence adopt information and management intensive conservation practices that increase short-term returns from production. Compared with other types of farmers, business-oriented farmers are more likely to adopt conservation tillage and, because of their focus on farm production they are also more likely to adopt structural practices (grassed waterways, filter strips) (Bultena and Hoiberg, 1983; Lambert et al., 2007). Considering that they are more motivated by short-term profits than traditional and supplementary farmers, business-oriented farmers' decisions about

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whether to enroll land in the CRP and WRP may be limited by their need for land for production.

## 3.5.4. Non-operator owners

Non-operators are owners of the land, but they are not the primary day-to-day decision makers regarding production and management. Non-operator owners include absentee landowners and investors. Absentee landowners own the agricultural property but do not reside on or operate it, they tend to live in urban areas, away from their farmland (Petrzelka and Marguart-Pyatt, 2011), whereas investors describe themselves as never having farmed, but may live on or near their farmland (Nassauer et al., 2011). Petrzelka et al. (2009) find that nearly half of the owners of farmland in the Great Lakes Basin do not operate the land that they own. They also show that 603 absentee landowners in the survey sample owned relatively small farms (100-285 acres). In a survey sample of 549 Iowa farmers, Nassauer et al. (2011) observed that Iowa farmland investors owned farms similar in area to those of other farmers. Petrzelka et al. (2009) also state that less than half of the household income of absentee landowners in the Great Lakes Basin was generated from farmland, and Constance et al. (1996) show that absentee landowners tend to depend less on farm income than local non-operator landowners.

As absentee landowners live out of the county, and investors describe themselves as never having farmed, both groups may be less connected to local information networks and less aware of environmental problems and government programs, compared with operator landowners. Therefore, Petrzelka et al. (2009) found that absentee landowners lag behind operator landowners in adoption of land retirement programs (CRP and WRP). However, Nassauer et al. (2011) found that Iowa farm investors reported higher CRP and WRP enrollment rates than other Iowa farmers. Owners may be more likely to adopt structural practices because these practices require capital investment (Soule et al., 2000; Caswell et al., 2001). Nassauer et al. (2011) note that, compared to active farmers, investors are more positively inclined to adopt certain structural practices and Petrzelka et al. (2009) underline the positive attitudes of absentee landowners to certain conservation practices and their benefits.

# 4. Conclusion

Farmer typologies are critical for representing diversity in farmers' decision-making characteristics and mechanisms in social models designed to aid policies targeting specific conservation practices. Different policy interventions for promoting conservation practices that reduce sediment and nutrient runoff may appeal to different farmer types. The typology presented here, based on a synthesis of the adoption literature and the identification of policyrelevant farmer characteristics (land tenure arrangements, size of farm, source of income, and information networks), comprises a heuristic set of four mutually exclusive types that differs from the existing USDA farmer typology (Hoppe et al., 2007; Lambert et al., 2007) in that it includes a previously non-differentiated but important group, non-operator owners. Moreover, the selection of only characteristics that would be relevant both to policy and to the SWAT model to represent the diversity of Corn Belt farmer adoption ensured the classification was parsimonious, as required by ABMs. Incorporating this farmer typology and associated heterogeneity into a larger coupled human and natural system model in which ABMs are linked with SWAT has helped inform the assessment of impacts of policy interventions (Daloğlu et al., in press). Using the ABM populated by this typology makes it possible to simplify and represent the diversity of Corn

Belt farmers with regards to their land management decisions over a large geographic area (Daloğlu et al., in press).

Considerable changes in the structure of US agriculture and the global socio-economic situation over the past decade have had a profound impact on soil and water conservation policies and programs. Grain prices have increased continuously (Napier, 2009) and are likely to continue to do so, leading to increased rental rates (Secchi et al., 2008). In response to high grain prices, farmers have attempted to maximize production by taking land out of conservation, thereby jeopardizing previous conservation efforts (Napier, 2009; Cox et al., 2011). If farmers, especially business-oriented farmers, continue to opt for maximization of profits, more set-aside land can be expected to be brought back into production, thereby increasing soil erosion rates and again raising water quality issues in places where previous policies had achieved some environmental quality progress.

The analysis of our farmer typology developed to link ABMs with SWAT demonstrates how different farmer types may be drawn to different conservation practices and policies depending on the relative importance of tenure arrangement, production size, income source, and information networks. Non-operators, including both absentee landowners and investors, can be expected to have an increasing influence on conservation outcomes as they own increasing amounts of farmland. This increased influence makes land management and conservation decisions to be less predictable in social models due to the limited number of empirical studies focusing on non-operator owners. Non-operators generally have had only limited involvement in on-farm decision-making in the past. However, as more and even most farmland begins to be owned by non-operators, their involvement may change, and surveys indicate their willingness to adopt conservation practices. Our ABM typology linked with SWAT may allow policymakers to anticipate the implications of this potential change in non-operator involvement, as well as other plausible scenarios in US agricultural policy (Daloğlu et al., in press).

The typology presented here, based on characteristics relevant to the adoption of conservation practices by Corn Belt farmers. should enable policy makers to better assess the allocation of conservation program payments and potential impacts of agricultural policy on landscape. Since this typology is operationalized for use in ABMs that will be linked to SWAT, we focused on conservation practices applicable in SWAT and categorized them as non-structural, structural and land retirement. However, from prior studies we know that SWAT is sensitive to management practices such as fertilizer management especially application time and rate (Daloğlu et al., 2012). The adoption literature is not rich with empirical data about fertilizer management. Thus, to build better-informed linked models to investigate the impact of farmer behavior on water quality, there is a need for improved field data on fertilizer management and for these data to be linked to farmer characteristics.

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#### References

- An, L., 2012. Modeling human decisions in coupled human and natural systems: review of agent-based models. Ecol. Model. 229, 25–36.
- Andersen, E., Verhoog, A.D., Elbersen, B.S., Godeschalk, F.E., Koole, B., 2006. A Multidimensional Farming System Typology. SEAMLESS Integrated Project, EU 6th Framework Programme, Contract No. 010036-2.

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- Arbuckle, J.G., 2010. Rented Land In Iowa: Social and Environmental Dimensions. Iowa State University Extension.
- Arabi, M., Frankenberger, J.R., Enge, B.A., Arnold, J.G., 2008. Representation of agricultural conservation practices with SWAT. Hydrol Process 22 (16), 43042– 43055, http://dx.doi.org/10.1002/Hyp.6890.
- Arnold, J.G., Srinivasan, R., Muttiah, R.S., Williams, J.R., 1998. Large area hydrologic modeling and assessment - Part 1: Model development. J Am Water Resour As 34, 73–89.
- Autant-Bernard, C., Mairesse, J., Massard, N., 2007. Spatial knowledge diffusion through collaborative networks. Pap. Region. Sci. 86 (3), 341–350.
- Axelrod, R.M., 1997. The Complexity of Cooperation: Agent-based Models of Competition and Collaboration, Princeton Studies in Complexity. Princeton University Press, Princeton, N.J..
- Baerenklau, K.A., 2005. Toward an understanding of technology adoption: risk, learning, and neighborhood effects. Land Econ. 81 (1), 1–19.
- Bankes, S., 1993. Exploratory modeling for policy analysis. Oper. Res. 41 (3), 435–449.
- Belknap, J., Saupe, W.E., 1988. Farm family resources and the adoption of no-plow tillage in Southwestern Wisconsin. North Central J. Agric. Econ. 10 (1), 13–23.
- Bohnet, I.C., Roberts, B., Harding, E., Haug, K.J., 2011. A typology of grazers to inform a more targeted approach for developing natural resource management policies and agricultural extension programs. Land Use Policy 28 (3), 629–637.
- Briggeman, B.C., Gray, A.W., Morehart, M.J., Baker, T.G., Wilson, C.A., 2007. A new US farm household typology: implications for agricultural policy. Rev. Agric. Econ. 29 (4), 765–782.
- Bultena, G.L., Hoiberg, E.O., 1983. Factors affecting farmers adoption of conservation tillage. J. Soil Water Conserv. 38 (3), 281–284.
- Camboni, S.M., Napier, T.L., 1993. Factors affecting use of conservation farming practices in East Central Ohio. Agric. Ecosyst. Environ. 45 (1–2), 79–94.
- Carmona, A., Nahuelhual, L., Echeverria, C., Baez, A., 2010. Linking farming systems to landscape change: an empirical and spatially explicit study in southern Chile. Agric. Ecosyst. Environ. 139 (1–2), 40–50.
- Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H., 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Appl. 8 (3), 559–568.
- Case, A., 1992. Neighborhood influence and technological change. Region. Sci. Urban Econ. 22 (3), 491–508.
- Caswell, M.F., Fuglie, K., Ingram, C., Jans, S., Kascak, C., 2001. Adoption of Agricultural Production Practices: Lessons Learned from the US Department of Agriculture Area Studies Project. US Department of Agriculture, Economic Research Service, Washington, DC.
- Chouinard, H.H., Paterson, T., Wandschneider, P.R., Ohler, A.M., 2008. Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. Land Econ. 84 (1), 66–82.
- Constance, D.H., Rikoon, J.S., Ma, J.C., 1996. Landlord involvement in environmental decision-making on rented Missouri cropland: pesticide use and water quality issues. Rural Sociol. 61 (4), 577–605.
- Cox, C., Hug, A., Bruzelius, N., 2011. Losing Ground. The Environmental Working Group.
- Daloğlu, I., Cho, K.H., Scavia, D., 2012. Evaluating causes of trends in long-term dissolved reactive phosphorus loads to Lake Erie. Environ. Sci. Technol. 46 (19), 10660–10666.
- Daloğlu, I., Nassauer, J.I., Riolo, R.L., Scavia, D., in press. An integrated social and ecological modeling framework – impacts of agricultural conservation practices on water quality. Ecol. Soc.
- Daskalopoulou, I., Petrou, A., 2002. Utilising a farm typology to identify potential adopters of alternative farming activities in Greek agriculture. J. Rural Stud. 18 (1), 95–103.
- Doering, O.C., Kling, C.L., Nassauer, J.I., Scavia, D., 2007. Agricultural policy choices. In: Nassauer, J.I., Santelmann, M.V., Scavia, D. (Eds.), From the Corn Belt to the Gulf: Societal and environmental implications of alternative agricultural futures. Resources for the Future, Washington, DC.
- Duffy, M., 2008. Farmland Tenure and Ownership in Iowa 2007. In: Iowa State University Extension Publication.
- Duvernoy, I., 2000. Use of a land cover model to identify farm types in the Misiones agrarian frontier (Argentina). Agric. Syst. 64 (3), 137–149.
- Emtage, N., Herbohn, J., Harrison, S., 2007. Landholder profiling and typologies for natural resource-management policy and program support: potential and constraints. Environ. Manage. 40 (3), 481–492.
- Ervin, C.A., Ervin, D.E., 1982. Factors affecting the use of soil conservation practices hypotheses, evidence, and policy implications. Land Econ. 58 (3), 277–292.
- Fernandez-Cornejo, J., Mishra, A., Nehring, R., Hendricks, C., Southern, M., Gregory, A. (2007). Off-farm income, technology adoption, and farm economic performance, Economic Research Report 36. US Department of Agriculture, Economic Research Service.
- Fuglie, K., 1995. Conservation tillage and pesticide use in the Corn Belt. Am. J. Agric. Econ. 77 (5), 1364–1364.
- Gassman, P.W., Reyes, M.R., Green, C.H., Arnold, J.G., 2007. The soil and water assessment tool: historical development, applications, and future research directions. Trans. Asabe 50 (4), 1211–1250.
- Gilbert, N., 2008. Agent-based Models, Quantitative Applications in the Social Sciences. Sage Publications, Los Angeles.
- Gould, B.W., Saupe, W.E., Klemme, R.M., 1989. Conservation tillage the role of farm and operator characteristics and the perception of soil erosion. Land Econ. 65 (2), 167–182.

- Hägerstrand, T., 1967. Innovation Diffusion as a Spatial Process. University of Chicago Press, Chicago.
- Happe, K., Balmann, A., Kellermann, K., Sahrbacher, C., 2008. Does structure matter? The impact of switching the agricultural policy regime on farm structures. J. Econ. Behav. Organ. 67 (2), 431–444.
- Hawley, N., Johengen, T.H., Rao, Y.R., Ruberg, S.A., Beletsky, D., Ludsin, S.A., Eadie, B.J., Schwab, D.J., Croley, T.E., Brandt, S.B., 2006. Lake erie hypoxia prompts Canada–US study. Eos Trans. AGU 87 (32).
- Hoppe, Robert A., Korb, P., O'Donoghue, E.J., Banker, D.E., 2007. Structure and Finances of U.S. Farms: Family Farm Report, 2007 Edition. US Department of Agriculture, Economic Research Service.
- Jackson-Smith, D.B., Halling, M., de la Hoz, E., McEvoy, J.P., Horsburgh, J.S., 2010. Measuring conservation program best management practice implementation and maintenance at the watershed scale. J. Soil Water Conserv. 65 (6), 413–423.
- DC.Kaufmann, P., Stagl, S., Franks, D.W., 2009. Simulating the diffusion of organic farming practices in two New EU Member States. Ecol. Econ. 68 (10), 2580– 2593.
- Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. Food Policy 32 (1), 25–48.
- Kostrowicki, J., 1977. Agricultural typology concept and method. Agric. Syst. 2 (1), 22-45.
- Kraft, S.E., Roth, P.L., Thielen, A.C., 1989. Soil Conservation as a goal among farmers results of a survey and cluster analysis. J. Soil Water Conserv. 44 (5), 487–490.
- Kuandykov, L., Sokolov, M., 2010. Impact of social neighborhood on diffusion of innovation S-curve. Decis. Support Syst. 48 (4), 531–535.
- Lambert, D.M., Sullivan, P., Claassen, R., Foreman, L., 2007. Profiles of US farm households adopting conservation-compatible practices. Land Use Policy 24 (1), 72–88.
- Lee, L.K., Stewart, W.H., 1983. Landownership and the adoption of minimum tillage. Am. J. Agric. Econ. 65 (2), 256–264.
- Lemke, A.M., Lindenbaum, T.T., Perry, W.L., Herbert, M.E., Tear, T.H., Herkert, J.R., 2010. Effects of outreach on the awareness and adoption of conservation practices by farmers in two agricultural watersheds of the Mackinaw River, Illinois. J. Soil Water Conserv. 65 (5), 304–315.
- Lichtenberg, E., 2004. Cost-responsiveness of conservation practice adoption: a revealed preference approach. J. Agric. Resour. Econ. 29 (3), 420–435.
- Liu, J.G., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., Taylor, W.W., 2007. Complexity of coupled human and natural systems. Science 317 (5844), 1513–1516.
- Loftus, T.T., Kraft, S.E., 2003. Enrolling conservation buffers in the CRP. Land Use Policy 20 (1), 73-84.
- Lopez-Pintado, D., 2008. Diffusion in complex social networks. Games Econ. Behavior 62 (2), 573–590.
- Lynch, L., Hardie, I., Parker, D., 2002. Analyzing Agricultural Landowners' Willingness to Install Streamside Buffers. Departmental Paper: Department of Agricultural and Resource Economics, University of Maryland.
- Lynne, G.D., Shonkwiler, J.S., Rola, L.R., 1988. Attitudes and farmer conservation behavior. Am. J. Agric. Econ. 70 (1), 12–19.
- Miller, J.H., Page, S.E., 2007. Complex Adaptive Systems: an Introduction to Computational Models of Social Life, Princeton Studies in Complexity. Princeton University Press, Princeton, N.I.
- Mishra, A.K., Goodwin, B.K., 1997. Farm income variability and the supply of offfarm labor. Am. J. Agric, Econ. 79 (3), 880–887.
- Mississippi River/Gulf of Mexico Watershed Nutrient Task Force and United States Environmental Protection Agency. Office of Wetlands Oceans and Watersheds, 2008. Gulf Hypoxia Action Plan 2008 for Reducing Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and improving water quality in the Mississippi River basin. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, D.C.: U.S. <a href="https://www.style.com">https://www.style.com</a> GPO/LPS119829>.
- Napier, <sup>T</sup>.L., 2009. Grain scarcity: a new era for conservation policies and programs. J. Soil Water Conserv. 64 (1), 7A–10A.
- Napier, T.L., Bridges, T., 2002. Adoption of conservation production systems in two Ohio watersheds: a comparative study. J. Soil Water Conserv. 57 (4), 229–235.
- Napier, T.L., Camboni, S.M., 1993. Use of conventional and conservation practices among farmers in the Scioto river basin of Ohio. J. Soil Water Conserv. 48 (3), 231–237.
- Napier, T.L., Tucker, M., McCarter, S., 2000. Adoption of conservation production systems in three Midwest watersheds. J. Soil Water Conserv. 55 (2), 123–134.
- Nassauer, J.I., Kling, C.L., 2007. Changing societal expectations for environmental benefits from agricultural policy. In: Nassauer, J.I., Santelmann, M.V., Scavia, D. (Eds.), From the Corn Belt to the Gulf: Societal and Environmental Implications of Alternative Agricultural Futures. Resources for the Future, Washington, DC. Nassauer, J.I., Santelmann, M.V., Scavia, D., 2007. From the Corn Belt to the Gulf:
- Nassauer, J.I., Santelmann, M.V., Scavia, D., 2007. From the Corn Belt to the Gulf: Societal and Environmental Implications of Alternative Agricultural Futures. Resources for the Future, Washington, DC.
- Nassauer, J.I., Dowdell, J.A., Wang, Z., McKahn, D., Chilcott, B., Kling, C.L., Secchi, S., 2011. Iowa farmers' responses to transformative scenarios for Corn Belt agriculture. J. Soil Water Conserv. 66 (1), 18a–24a.
- National Research Council (U.S.) Committee on Twenty-First Century Systems Agriculture, 2010. Toward Sustainable Agricultural Systems in the 21st Century. National Academies Press, Washington, D.C..
- Nehring, R., Fernandez-Cornejo, J., Banker, D., 2005. Off-farm labour and the structure of US agriculture: the case of corn/soybean farms. Appl. Econ. 37 (6), 633–649.

#### I. Daloğlu et al./Agricultural Systems xxx (2014) xxx-xxx

Nowak, P.J., 1983. Obstacles to adoption of conservation tillage. J. Soil Water Conserv. 38 (3), 162–165.

Nowak, P.J., 1987. The adoption of agricultural conservation technologies – economic and diffusion explanations. Rural Sociol. 52 (2), 208–220.

- Nowak, P.J., Cabot, P.E., 2004. The human dimension of resource management programs. J. Soil Water Conserv. 59 (6), 128a–135a.
- Osmond, D.L., 2010. USDA water quality projects and the National Institute of food and agriculture conservation effects assessment project watershed studies. J. Soil Water Conserv. 65 (6), 142a–146a.
- Petrzelka, P., Marquart-Pyatt, S., 2011. Land tenure in the US: power, gender, and consequences for conservation decision making. Agric. Hum. Values 28 (4), 549–560.
- Petrzelka, P., Buman, T., Ridgely, J., 2009. Engaging absentee landowners in conservation practice decisions: a descriptive study of an understudied group. J. Soil Water Conserv. 64 (3), 94a–99a.
- Petrzelka, P., Malin, S., Gentry, B., 2012. Absentee landowners and conservation programs: mind the gap. Land Use Policy 29 (1), 220–223.
- Prokopy, L.S., Floress, K., Klotthor-Weinkauf, D., Baumgart-Getz, A., 2008. Determinants of agricultural best management practice adoption: evidence from the literature. J. Soil Water Conserv. 63 (5), 300–311.
- Rahm, M.R., Huffman, W.E., 1984. The adoption of reduced tillage the role of human-capital and other variables. Am. J. Agric. Econ. 66 (4), 405–413.
- Ribaudo, M., Johansson, R., 2006. Water quality: impacts of agriculture. In: Wiebe, K.D.G., New, N.R. (Eds.), Agricultural Resources and Environmental Indicators. Nova Science Publishers, York.
- Rogers, E.M., 2003. Diffusion of Innovations, fifth ed. Free Press, New York.
- Ryan, R., Erickson, D., De Young, R., 2003. Farmers' motivations for adopting conservation practices along riparian zones in a mid-western agricultural watershed, J. Environ. Planning Manage. 46 (1), 19–37.

- Saltiel, J., Bauder, J.W., Palakovich, S., 1994. Adoption of sustainable agricultural practices: diffusion, farm structure, and profitability. Rural Sociol. 59 (2), 333. Secchi, S., Tyndall, J., Schulte, L.A., Asbiornsen, H., 2008. High crop prices and
- conservation raising the stakes. J. Soil Water Conserv. 63 (3), 68a–73a. Soule, M.J., Tegene, A., Wiebe, K.D., 2000. Land tenure and the adoption of
- conservation practices. Am. J. Agric. Econ. 82 (4), 993–1005. Terluin, I.J., Verhoog, D., Godeschalk, F.R., 2010. The use of regional typologies in the
- assessment of farms' performance. In: Brouwer, F.M., Van Ittersum, M. (Eds.), Environmental and Agricultural Modelling: Integrated Approaches for Policy Impact Assessment
- Tosakana, N.S.P., Van Tassell, L.W., Wulfhorst, J.D., Boll, J., Mahler, R., Brooks, E.S., Kane, S., 2010. Determinants of the adoption of conservation practices by farmers in the northwest wheat and range region. J. Soil Water Conserv. 65 (6), 404–412.
- Tucker, M., Napier, T.L., 2002. Preferred sources and channels of soil and water conservation information among farmers in three Midwestern US watersheds. Agric. Ecosyst. Environ. 92 (2–3), 297–313.
- United States, Department of Agriculture, 2009. 2007 Census of Agriculture, Part 51, Geographic Area Series, vol. 1. United States Summary and State Data.
- United States, Department of Agriculture, 2011. Farm and Commodity Policy: Government Payments and the Farm Sector.
- Valbuena, D., Verburg, P.H., Bregt, A.K., 2008. A method to define a typology for agent-based analysis in regional land-use research. Agric. Ecosyst. Environ. 128 (1–2), 27–36.
- Wells, B., Eells, J., 2011. One size does not fit all: customizing conservation to a changing demographic. J. Soil Water Conserv. 66 (5), 136a–139a.
- Wunderlich, G., 1993. Land Ownership and Taxation in American Agriculture. Westview Press, Boulder.