



Analysis

Spatial patterns of organic agriculture adoption: Evidence from Honduras

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ABSTRACT

In low potential agricultural areas like the Honduran hillsides characterized by soil degradation and erosion, organic agriculture can provide a means to break the downward spiral of resource degradation and poverty. We use original survey data to analyze the factors influencing the decision to convert to organic agriculture. Previous studies have emphasized the role of spatial patterns in the diffusion and adoption of agricultural technologies in general and organic agriculture in particular. These spatial patterns can result from a variety of underlying factors. In this article we test various potential explanations, including the availability of information in the farmer's neighborhood, social conformity concerns and perceived positive external effects of the adoption decision, in a spatially explicit adoption model. We find that farmers who believe to act in accordance with their neighbors' expectations and with greater availability of information in their neighborhood network are more likely to adopt organic agriculture. Furthermore, perceived positive productivity spillovers to neighboring plots decrease the probability of adoption. We discuss the implications of our findings for the dissemination of sustainable agricultural technologies in low-potential agricultural areas in developing countries.

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1. Introduction

In many regions in developing countries, rural households depend on marginal lands to make a living. Low-potential agricultural areas include for example hillsides that are heavily exposed to soil erosion and degradation (Ruben and Pender, 2004). Often poor rural households lack the resources to invest in chemical fertilizers thus finding themselves trapped in a downward spiral of low soil fertility, low agricultural productivity, poverty, and low investment capacities (Blackman et al., 2007; Marenja and Barrett, 2007; Ruben and Pender, 2004; Wollni et al., 2010). In this context, organic farming that relies on soil conservation measures and organic manure to restore and maintain soil functions could potentially provide a promising approach to break the vicious cycle of poverty and resource degradation. In particular, for households that already use low levels of external inputs switching costs to organic agriculture are very low and often conversion goes hand in hand with an increase in yields resulting from the application of improved soil management practices (Bolwig et al., 2009). In

addition, if farmers gain access to organic markets, they can potentially benefit from premium prices paid for organic produce (Giovannucci and Ponte, 2005).

Previous research has analyzed the factors influencing the decision of farmers to convert to organic agriculture (e.g. Hattam et al., 2012; Läßle and Kelley, 2013; Läßle and van Rensburg, 2011; Musshoff and Hirschauer, 2008; Schmidtner et al., 2012).¹ Several adoption studies yield evidence for the importance of information access and particularly the role of informal information sources for organic farmers (Burton et al., 1999; Genius et al., 2006; Morone et al., 2006) and the relevance of motivational factors such as environmental concern for the adoption decision (Best, 2010; Mzoughi, 2011). Furthermore, a growing number of studies focus on the role of spatial effects in the adoption process and find evidence for the spatial clustering of organic farming (Bichler et al., 2005; Bjorkhaug and Blekesaune, 2013; Eades and Brown, 2006; Frederiksen and Langer, 2004; Nyblom et al., 2003). This evidence, however, is mostly based on data from developed countries, including e.g. county level data from Germany (Schmidtner et al., 2012), as well as farm level data (Lewis et al., 2011) and plot level data (Parker and Munroe, 2007) from the US. While research on the spatial patterns of organic agriculture adoption in developing countries

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¹ Also see Padel (2001) for a review of adoption studies focusing on organic farming.

is scarce, there is increasing evidence on the role of neighborhood effects and social interactions² in the adoption of agricultural technologies more generally (Bandiera and Rasul, 2006; Best et al., 1998; Case, 1992; Conley and Udry, 2010; Holloway et al., 2002; Staal et al., 2002). Most of these studies find positive spatial and social interaction effects indicating that agricultural decisions of neighboring farmers are not independent of each other.

Manski (2000) criticizes that while many studies detect positive correlations in the agricultural decisions of neighbors, they usually do not shed much light on the underlying processes explaining the spatial patterns of technology adoption. Spatial dependence in technology adoption decisions is usually attributed to agglomeration economies associated with cost reductions that result from greater availability of knowledge and high-quality extension, when neighboring farmers are also adopters (Lewis et al., 2011; Schmidtnr et al., 2012). The importance of informal information exchange is likely to be especially high in low potential areas characterized by a general scarcity of information and by long distances to main markets and commercial centers. In the absence of formal information sources, knowledge on new technologies has to be obtained through informal channels from neighbors and friends. However, besides agglomeration economies associated with access to information, other factors may be of relevance in these settings that also contribute to the observed spatial patterns of technology adoption. For example, farmers may derive increased utility from social conformity and therefore make their adoption decision contingent on their neighbors' acceptance (Läpple and Kelley, 2013; Moser and Barrett, 2006). Furthermore, perceived externalities of the adoption decision, such as positive or negative productivity effects on neighboring plots, may influence the farmer to postpone adoption until more farmers in the neighborhood have adopted (Knowler and Bradshaw, 2007; Lee, 2005).

A deeper understanding of the processes and factors contributing to the spatial concentration of observed outcomes is of paramount importance to refine policy instruments for the dissemination of agricultural technologies in developing countries (Holloway and Lapar, 2007; Manski, 2000). In particular, it is crucial to understand whether the adoption decision is influenced mainly at the individual level and thus can be directly influenced by extension agents and service provision aimed at overcoming the barriers to adoption at the household level. Or, alternatively, whether the decision is to a large extent influenced by processes that take place at the level of communities and social networks, where members engage in social learning shaping collective expectations and norms and where coordination problems may arise (Lee, 2005; Manski, 2000). Understanding the role of individual versus collective forces in the diffusion of sustainable agricultural technologies can help policy-makers to prioritize between programs that target either individual households or neighborhood networks and communities to effectively induce behavioral changes.³

We extend the existing literature in two major ways. First of all, we seek to disentangle the underlying factors that contribute to explaining spatial patterns in organic agriculture adoption. We do this by integrating factors related to social conformity, perceived externalities of adoption, access to information, and location proxies into a spatially explicit adoption model. Secondly, while most studies on the spatial effects of organic agriculture adoption have been conducted in developed countries, our study is based on data from Honduran hillside farmers. It thus contributes to enhancing our understanding of the factors shaping

organic agriculture adoption in a developing country context. Our research area is characterized by low agro-ecological potential, high levels of land degradation, and persistent poverty. In this context, the adoption of organic agriculture practices can potentially provide an avenue out of the "resource degradation poverty trap" (Barrett et al., 2002). Yet, information about technologies and markets from formal information sources is scarce, and therefore, informal information networks like neighbors and fellow farmers are likely to play a crucial role in the transmission of information about new technologies. Similarly, in traditional communities like the ones in our research area, where many farmers depend on subsistence agriculture and informal insurance networks, non-conformity with social norms and expectations can have tangible repercussions on farmers' livelihoods. The remainder of this article is organized as follows. The next section discusses the role of spatial effects in organic agriculture adoption from a conceptual perspective. Section three details the methodological approach used to analyze the data. Afterwards we describe the research area, the empirical data, and the variables included in the analysis. Descriptive and econometric results are presented in section five. Finally, section six derives policy implications and concludes the article.

2. The Role of Spatial Effects in Organic Agriculture Adoption

A growing body of literature focuses on the role of spatial patterns in the adoption of agricultural technologies. In particular, various studies have found that the adoption of organic agriculture is spatially clustered (Lewis et al., 2011; Nyblom et al., 2003; Parker and Munroe, 2007; Schmidtnr et al., 2012). A variety of underlying spatially correlated processes and factors can potentially contribute to explaining these observed spatial patterns in technology adoption outcomes. First and foremost, agglomeration economies may explain spatial clustering of organic agriculture. Agglomeration economies stem from reduced production costs, better access to skilled labor, information, and improved service and input supplies for individual firms associated with the spatial concentration of firms pursuing similar activities. Krugman (1996) and Fujita et al. (1999) describe the relevance of agglomeration economies in the context of non-agricultural industries. Porter (2000) in his work focuses specifically on knowledge spillovers that accelerate the spread of innovations in industry clusters. This has triggered a growing body of literature on social learning and network effects in agricultural technology adoption in developing countries (Bandiera and Rasul, 2006; Conley and Udry, 2010; Foster and Rosenzweig, 1995). According to this literature, the more farmers in the individual's information neighborhood have adopted the new technology, the more information about the new technology is available to the individual. As a result, the fixed costs of learning can be substantially reduced for individual farmers (Lewis et al., 2011). These positive information externalities are likely to be especially relevant in information-scarce environments as is often the case in remote, low-potential areas in developing countries. Furthermore, they may be especially relevant in the case of knowledge-intensive technologies, such as low-external-input and organic agriculture (Lee, 2005). Consequently, if information about particular agricultural technologies is spatially clustered, we can expect to observe spatial patterns in the diffusion and uptake of these practices.

Besides agglomeration economies resulting from knowledge spillovers, previous studies have stressed the role of social conformity considerations in the technology adoption decision of farmers in developing countries. In traditional rural societies there is often strong social pressure regarding compliance with desired behavior and cultural norms (Platteau, 2000). The compliance with these norms and expectations may influence a farmer as much or even more than profit considerations (Moser and Barrett, 2006). Especially in low-potential areas, social networks at the village level are often of vital importance for farmers in case they experience a negative shock. Social conformity in

² Positive social interaction effects refer to the effects that result from communication and information exchange between individuals. Several authors, instead of using geographic proximity, have used survey data on communication patterns between households as a basis to construct an information neighborhood matrix (e.g. Conley and Udry, 2010).

³ See Manski (2000) for a more comprehensive discussion of this argument.

this context becomes an important strategy to cope with potential risks, and non-compliance can be very costly for the individual. Moser and Barrett (2006) seek to capture the effect of social conformity on technology adoption in Madagascar and find that under the assumption of constant learning effects, social conformity effects are indeed significant. However, they measure existing village norms by the percentage of adopters at the village level, which may also capture a range of other underlying, spatially correlated effects. For the case of organic agriculture, social acceptance has been found to play an important role in the adoption decision of farmers in a developed country context (Läpple and Kelley, 2013).

In addition, there may be direct spillover effects of certain agricultural practices on neighbors' plots or for the community as a whole. Such positive externalities are extensively discussed by Knowler and Bradshaw (2007) for the case of conservation methods applied in agriculture. For example, the use of integrated soil management techniques such as living barriers or the application of organic manure reduces erosion and increases soil fertility, which to a certain extent also affects neighboring plots. Furthermore, it reduces leakage into rivers improving water quality for the whole community (Knowler and Bradshaw, 2007). Such externalities are relevant in the context of organic agriculture, which replaces chemical fertilizer applications with an increased use of integrated soil management and conservation practices (Blackman and Naranjo, 2012; Bolwig et al., 2009). Knowler and Bradshaw (2007) argue that farmers cannot fully internalize the positive effects of conservation practices which will lead to adoption rates that are below the socially optimal level. The effect of externalities on the adoption decision is ambiguous. On the one hand, if farmers believe that their adoption has positive effects that are captured by their neighbors, they may experience disutility from the feeling that others free ride on their efforts and thus delay adoption until more farmers in the village have adopted. On the other hand, if farmers have altruistic preferences, they may experience additional utility from benefiting others and thus in fact be more likely to adopt.

Finally, in the context of agriculture, agro-ecological conditions, such as soil type, topography and microclimate, are important factors that are spatially clustered and influence the costs and benefits associated with a particular production system (Schmidtner et al., 2012). Some agro-ecological conditions, such as flat land and certain soil types, are more conducive to intensive agriculture, whereas steep slopes and hilly terrain do not lend themselves to intensification and mechanization. Farmers in areas with lower potential for intensification therefore have lower opportunity costs and may be more likely to adopt organic agriculture. Empirical studies by Bichler et al. (2005) and Pietola and Lansink (2001) for example reveal that organic farms are more likely to be located in regions with lower soil quality and in areas with lower average yield potential. Moreover, agro-ecological conditions and location will directly influence the possibilities of a farmer to implement and derive benefits from organic agriculture. Organic markets are likely to be more mature for some crops than for others in a particular region. If farmers are located in an area that features growing conditions apt for products that command organic premiums, they will have greater economic incentives to convert to organic agriculture. Similarly, if they are located closer to potential market outlets where premium prices are granted, this will also positively affect their incentives to adopt organic agriculture (e.g. Koesling et al. (2008) find that organic farmers are often located closer to urban areas). Accordingly, we are likely to find spatial concentration of organic agriculture to the extent that these location factors exhibit a spatial pattern.

3. Empirical Framework

The farmer's choice to adopt organic agriculture can be perceived as an investment decision (Schmidtner et al., 2012). We formalize the

investment decision of farmers following Schmidtner et al. (2012) with some minor adjustments to fit the context of our study. The farmer is assumed to adopt organic farming if and only if:

$$E[U_i^{Or}(\pi_i^{Or}, TC_i(I^a(a_j)), S, \Delta\pi_j)] - E[U_i^{Co}(\pi_i^{Co})] > 0 \quad (1)$$

with

$$\pi_i^a = p_i^a(a_j, D)q_i^a(F, I^a(a_j), E(a_j), L_i^a(a_j)) - w_i^a(a_j, D)L_i^a(a_j) \quad (2)$$

where U_i is utility of farmer i from activity a ($Or =$ organic, $Co =$ conventional), π^a is profit from activity a , TC is the transaction cost of converting from conventional farming to organic farming, I is activity specific information availability, a_j is the activity choice of neighboring farmer j , S is deviation from the social norm, $\Delta\pi_j$ is the increase in profit experienced by farmer j as a result of farmer i 's activity choice, r is the interest rate, p is the output price, D is the distance to the market, q is the production function, F is agro-ecological factors, w is input price and L is input quantity.

The spatial effects are thus assumed to enter the adoption decision through:

- Information spillovers $I^a(a_j)$ affecting transaction costs and productivity of different activities,
- Perceived deviation from the social norms, S , affecting utility derived from adopting new practices through conformity preferences,
- Perceived productivity spillovers on neighboring plots, $\Delta\pi_j$, affecting utility derived from adopting new practices through altruistic or competitive preferences,
- Location factors, including agro-ecological conditions (F) that affect the productivity of different activities, and distance to markets (D) that affects input and output prices, and
- Other agglomeration economic effects $p_i^a(a_j)$, $w_i^a(a_j, D)$ and $L_i^a(a_j)$ affecting availability, quality and prices of inputs and outputs.

Note that $I^a(a_j)$, S , and $\Delta\pi_j$ are spatially dependent effects, i.e. the adoption decision of one farmer depends on the adoption decision of other farmers in the vicinity. In the subsequent analysis we are interested in disentangling these effects from other spatially dependent effects and study their impact on activity choice.

We assume that the decision to adopt organic agriculture is generated by a spatially dependent process, i.e. the choice observed in one location is similar to the choices made by farmers in nearby locations (LeSage and Pace, 2009). To control for such neighborhood effects potentially affecting the adoption decision, we use a Bayesian spatial autoregressive probit model (see e.g. Holloway et al., 2002) that is specified as

$$y^* = \rho W y^* + X\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n), \quad (3)$$

where y^* reflects the net utility, $U_i^{Or} - U_i^{Co}$, associated with the dichotomous choice outcomes. While the underlying utility y^* is unobserved, we observe adoption of organic agriculture ($y = 1$), if $y^* \geq 0$, and non-adoption ($y = 0$), if $y^* < 0$. Wy^* is the spatial lag of the dependent variable and involves the spatial weight matrix W , which is defined as

$$w_{ij} = \begin{cases} d_{ij}^{-1}, & 0 \leq d_{ij} \leq d \\ 0, & d_{ij} > d \end{cases} \quad (4)$$

with d_{ij} being the distance between farmer i and farmer j and d being a threshold distance beyond which neighborhood effects are assumed to be zero. The threshold distance is chosen such that each farmer in the data set has at least one neighbor and W is row-standardized for the analysis. Thus by definition, the influence of neighbor j on i diminishes with distance and with the number of other neighbors included in i 's neighborhood. Wy^* thus consists of the weighted average of neighbors'

utility and allows us to model interdependencies in farmers' adoption decisions. In this context, ρ measures the strength of interdependence, where $\rho = 0$ reflects independence (LeSage et al., 2011). Furthermore, X represents a vector of exogenous variables potentially influencing the net utility of adoption, ρ and β are parameter vectors to be estimated, and ε is a random error term assumed to follow a multivariate truncated normal distribution with mean zero, constant variance σ^2 and zero covariance between observations. In the Bayesian approach the unobserved latent utility is treated as an additional set of parameters to be estimated (LeSage et al., 2011). Model parameters ρ , β and y^* are estimated using Markov Chain Monte Carlo sampling drawing sequentially from the conditional posterior distributions. Within this procedure, we use a 10-step Gibbs sampler to obtain the vector of parameters y^* (LeSage and Pace, 2009). A detailed description of the estimation procedure for the spatial autoregressive probit model is provided in Holloway et al. (2002) and LeSage et al. (2011).⁴

Regarding the choice of d , previous studies have found that a radius of two to three kilometers is reasonable for technology spillovers in remote areas with poor infrastructural development (Best et al., 1998; Holloway et al., 2002). To select the most appropriate specification of the spatial weight matrix for our analysis, we run several models imposing different threshold values ranging from 1.5⁵ to 4 km (in intervals of 500 m) and compare these alternative models using posterior model probabilities (see chapter six in LeSage and Pace, 2009). The model with the highest posterior model probability is the preferred model, as it best fits the data and prior distributions assigned for the parameters (LeSage and Pace, 2009).⁶

4. Empirical Data

4.1. Research Area and Data

Our research was carried out in Honduras in the state of La Paz, which is located in the southwestern part of the country. The research area is characterized by hillside agriculture. Households mostly engage in the cultivation of corn and beans to fulfill their subsistence needs and in the cultivation of coffee in the more elevated areas. The sloping terrain is vulnerable to soil erosion and degradation and as a result agricultural productivity is low. The Honduran government has identified the region as one of the poorest areas in the country (Government of Honduras, 2001). Several non-governmental organizations (NGOs) and aid programs operate in the area to improve the livelihoods of rural families. These organizations usually support farmers to form groups, which they then target to disseminate information about agricultural technologies, water and soil conservation practices, health information, and market linkages (Wollni et al., 2010).

Given the dearth of public extension services, NGOs and technical cooperation projects are virtually the only external sources of information for farmers in the area. While the coverage of organizations and projects is relatively high in the area, inconsistencies in the information provided to farmers can potentially arise as a result of different agendas followed by the organizations. NGOs and cooperation projects usually offer a certain range of technologies and practices determined by the source and purpose of donor funding. Conflicting advice may lead to confusion among farmers, who often do not have access to reliable sources of information to verify the advice received. In particular,

different attitudes and beliefs concerning the optimal management of land resources on the hillsides may prevail in the communities. These beliefs may have evolved over time as a result of traditional knowledge and experimentation or they may be influenced by information sources external to the communities, like NGO programs, that aim to change farmers' behavior towards more productive and/or more sustainable production practices. While extension services during the last thirty years have undergone a paradigm change from recommending intensification and the removal of all crop residues from plots towards conservation agriculture and erosion-reducing measures in the hillsides, this paradigm change has taken place much slower in the mind of farmers. During our conversations, farmers often expressed concern about the attitude of other village members towards their agricultural practices. In particular, farmers may be frowned upon if they do not clean their plots, i.e. if they leave crop residues on their land to cover the soil.⁷

For the analysis we collected original survey data from 241 farm households in 2007. Households were randomly selected based on a multi-stage cluster sampling. In the first stage, six municipalities located within the state of La Paz were randomly chosen. Subsequently, we randomly selected 20 villages and in each of the villages twelve farm households. Farm households were selected from a list that was compiled in collaboration with village leaders, NGOs and extension agents. Interviews were conducted face-to-face at or near the homestead of the household and lasted for approximately 1 h. If a selected household was unavailable for the interview, the household was replaced with another household from the list. All interviews were carried out by six locally recruited enumerators who were knowledgeable about the area and the activities performed by rural households. All of them had prior experience conducting surveys, were trained in a two-day intensive workshop, and assisted in the pre-test to provide feedback on perceived problems. A standardized questionnaire was used to obtain information on farmers' agricultural production and marketing activities. In addition to the interviews, geographic coordinates of the households were recorded. Data was entered into a statistical program and cleaned. Two households had to be removed from the data set because of missing spatial data resulting in a total sample of 239 households for the analysis.

During the interviews farmers were asked to indicate whether they grow their produce organically, i.e. without applying agro-chemicals, and whether they sell their output as "organic" to differentiate it from conventionally grown products in the market.⁸ We define households as adopters of organic agriculture, if they responded to both questions with yes. Overall, we find that 20% of the households in our sample engage in organic agriculture. Table 1 explores the agricultural practices applied by farmers in each of the production systems. In accordance with the stipulations of organic agriculture, most organic farmers do not use any synthetic fertilizers. Only about 11% of the farmers classified as organic indicated to apply agro-chemicals to crops grown conventionally on separate plots. Among the farmers classified as conventional, 11% did not use any synthetic fertilizer during the past growing season.⁹ As an alternative means to maintain and improve soil fertility and reduce erosion, integrated soil management practices, including the application of organic manure or crop residues as well as the establishment of living barriers, can be used by organic as well as conventional farmers. Descriptive results in Table 1 indicate that organic farmers are

⁴ The empirical analysis is implemented using the `sarp_g` procedure in the "Econometrics Toolbox" provided by J. P. LeSage and available at <http://www.spatial-econometrics.com/>, last updated 3/2010.

⁵ 1.5 km is the smallest threshold distance we can test given our data, because if we choose $d < 1.5$ km not every household in the data set has a neighbor (and hence, the spatial weight matrix cannot be row standardized).

⁶ According to LeSage and Pace (2009), it is not possible to use formal tests of significant differences between the log-likelihood functions of models with different spatial weight matrices, because they are non-nested. An important advantage of Bayesian posterior model probabilities is that they do not require models to be nested.

⁷ A similar reluctance of farmers to leave crop residues on their land was reported by Gauthier (2000) for Indonesia and by Fiedler (1994) for East Africa. In those studies farmers expressed their concern that crop residues left in the field are associated with attracting rodent pests and therefore not appreciated by other community members.

⁸ Some of the farmers sell to international markets, where a third-party certification is required. However, most of the households in our sample sell in local markets, where labeling is an informal process carried out by farmer groups or NGOs and no certification fee or official auditing process is implemented.

⁹ These farmers mostly could not afford to buy agro-chemicals during the past growing season. Even those farmers in our research area, who apply agro-chemicals, usually apply less than the recommended dosage due to liquidity constraints.

Table 1
Agricultural practices used by farmers.

	Organic (N = 47)		Conventional (N = 192)		Pearson's chi ² test	
	Mean	Std. dev.	Mean	Std. dev.	value	p
No synthetic fertilizer	0.89	0.31	0.11	0.31	119.63	0.000
Applies living barriers	0.74	0.44	0.52	0.50	7.70	0.006
Applies crop residues	0.51	0.51	0.48	0.50	0.10	0.747
Applies organic manure	0.72	0.45	0.16	0.37	60.22	0.000
Applies contour planting	0.43	0.50	0.30	0.46	2.62	0.106

significantly more likely to establish living barriers on their plots and to apply organic manure. On the contrary, the application of crop residues and contour planting are similarly common among organic and conventional farmers. The more widespread use of organic manure and living barriers among organic farmers could potentially lead to positive spillover effects on the soil quality of neighboring plots.

4.2. Description of Variables

On the right-hand-side of the econometric model, we include a range of variables potentially explaining organic agriculture adoption. As described in Section 2, we are particularly interested in information, social conformity, positive productivity spillovers and location variables that may contribute to neighborhood effects in the adoption decision. For this purpose, we collected a rich data set including farmers' perceptions that allows us to control for these factors explicitly.

Several variables are used to capture farmers' access to information. First of all, to control for individual access to extension, we include a variable on the number of topics that the farmer has received extension on. Secondly, to account for the information that is available in the farmer's neighborhood network,¹⁰ we sum up the total number of topics that farmers in the neighborhood network have received extension on. We expect that both, direct access to extension, and the amount of information available within the farmer's neighborhood network, increase the likelihood that the farmer will adopt organic agriculture. In addition, we control for membership in farmer groups, which represents an important indicator for the farmer's access to information and extension.

To capture the effect of social conformity concerns, we include a dummy variable that equals one if farmers believe that their neighbors have a positive attitude towards their technology choices.¹¹ In particular, farmers were asked whether they believe that their neighbors would appreciate or disapprove if they used sustainable agricultural practices on their plots.¹² We expect that farmers will be more likely to adopt organic agriculture if they feel that their choices would be socially accepted in their neighborhood. We thus assume that the decision to adopt organic agriculture depends on a farmer's perception regarding the attitude of the neighbors towards his or her practices rather than on actual adoption levels in the community. If a farmer believes that neighbors will be open-minded and approving of him or her using sustainable technologies, e.g. because they use such practices themselves or they have expressed interest in these practices, the adoption decision will be taken under the assumption of being socially conform – either because others are already using similar technologies, or because they might appreciate to benefit from learning spillovers.

Regarding externality effects, we asked farmers whether they think that the application of sustainable practices on their plot would have positive, negative, or no productivity effects on their neighbors' plots.

¹⁰ The farmer's neighborhood network is defined based on the spatial weight matrix, i.e., all farmers located within a radius of 1.5 km.

¹¹ Please note that the definition of neighborhood here was left up to the interviewed farmer and thus may differ from the neighborhood specified in the spatial weight matrix.

¹² The options were equivalent to: "very much appreciates", "appreciates", "is indifferent", "disapproves", and "very much disapproves". The dummy variable used in the analysis is equal to one if the farmer answered either of the two categories "very much appreciates" or "appreciates".

Based on this question, we include a dummy variable equaling one if the farmer thinks that positive spillover effects exist, zero otherwise. The effect of this variable is ambiguous a priori and depends on farmers' preferences. For instance, if a farmer derives utility from benefiting his neighbor (altruistic motivation), the perception of positive spillovers will have a positive effect on the likelihood of adoption. However, if a farmer derives disutility from her neighbor free riding on her efforts (competitive motivation), it will have a negative effect on the likelihood of adoption.

To capture agro-ecological variation across households, we include a dummy variable that equals one if the household is located in an area classified as "valley soils". This classification is based on Simmons and Castellanos (1968) and represents areas with fertile soils and flat terrain, i.e., the areas with most agricultural potential in the region. We expect that households located in these higher-potential areas may be less likely to adopt organic agriculture due to higher opportunity costs of agricultural intensification. In addition, we include a variable on the distance to the main market center reflecting access to input and output markets. Being located closer to the main market center may increase the probability of adoption due to better access to organic market outlets, but at the same time, it may increase the opportunity costs of adoption as farmers have better access to markets in general.

Besides these variables that are likely to be associated with spatial patterns in the adoption decisions, the vector X contains a number of control variables expected to influence the farmers' decision to engage in organic agriculture. First of all, we control for farmers' beliefs regarding potential effects associated with the adoption of sustainable practices. These include three dummy variables that equal one if the farmer thinks that there are positive productivity effects on own plots, positive health effects for the family, and positive effects on the environment, respectively.¹³ We expect that farmers who associate positive productivity, health and environmental effects with sustainable practices are more likely to adopt organic agriculture. Furthermore, we include variables on age, literacy and gender of the household head and on the availability of family labor. We expect households with greater availability of family labor and low opportunity costs to be more likely to adopt organic agriculture, which requires farmers to carry out labor-intensive practices on their farms. In addition, we include wealth-related indicators like ownership of assets and credit access, which are expected to have positive effects on farmers' investment capacity and ability to bear risk and thus on the probability of adoption. We also include farm size, which is often used as a proxy for wealth and in particular access to capital in adoption studies in developing countries (Feder et al., 1985). Empirical evidence so far shows that the effect of farm size on the decision to adopt organic agriculture is ambiguous. Previous studies have found both larger farmers (e.g. Koesling et al., 2008) as well as smaller farmers (e.g. Khaledi et al., 2010) to be more likely adopters of organic farming. Summary statistics of the variables included in the econometric model are presented in Table 2 in the next section.

5. Results

5.1. Descriptive Results

Our survey data reveals that access to agriculture-related information is fairly limited in our research area and to a large extent exchanged through informal channels of information. In our sample, 47% of the farmers indicated that they primarily receive information about

¹³ Farmers were asked in the interview whether they believe in positive, negative, or no effects. The dummy variables equal one if the farmer believes in positive effects, zero otherwise. Regarding environmental effects, the questionnaire included two separate questions, one on the resources of the community and one on the global environment. Given that these were highly correlated we integrated them into one dummy variable that equals one if a positive effect at the community level and/or the global level is perceived.

Table 2
Summary statistics of independent variables.

	Organic (N = 47)		Conventional (N = 192)		Test statistic ^a	
	Mean	Std. dev.	Mean	Std. dev.	value	p
<i>Information variables</i>						
Membership in at least one village organization (0/1)	0.89	0.31	0.60	0.49	14.12	0.000
Total number of topics that household received extension on	3.64	3.42	1.73	2.52	−4.31	0.000
Total number of topics that members of the neighborhood network received extension on	41.70	19.68	36.50	18.67	−1.70	0.091
<i>Social conformity</i>						
Neighbors appreciate if I apply new practices (0/1)	0.96	0.20	0.85	0.35	3.67	0.055
Perceived spillover effects						
Positive productivity effects on neighbor's plot (0/1)	0.15	0.36	0.29	0.45	3.72	0.054
<i>Location variables</i>						
Distance to city of Marcala (in km)	11.83	6.74	14.54	8.60	2.01	0.046
Located on "valley soil" (high quality soil, flat terrain) (0/1)	0.26	0.44	0.40	0.49	3.21	0.073
<i>Control variables</i>						
Positive productivity effects on own plot (0/1)	0.26	0.44	0.28	0.45	0.13	0.722
Positive health effects associated with practices (0/1)	0.21	0.41	0.27	0.45	0.81	0.418
Positive environmental effects associated with practices (0/1)	0.19	0.40	0.32	0.47	1.71	0.089
Age of household head	50.26	13.01	45.44	13.20	−2.25	0.025
Household head can write (0/1)	0.83	0.38	0.80	0.40	0.19	0.666
Number of household members	6.23	2.54	5.49	2.04	−2.13	0.034
Female-headed household (0/1)	0.30	0.46	0.20	0.40	1.96	0.161
Household has salaried employment (0/1)	0.11	0.31	0.11	0.32	0.03	0.874
Household head works on farm (0/1)	0.87	0.34	0.79	0.41	1.58	0.209
Land size (in tareas ^b)	25.19	29.99	24.13	25.85	−0.25	0.806
Household has taken out loan during past year (0/1)	0.38	0.49	0.28	0.49	−1.44	0.152
Total value of assets (in 1000 Lempira)	11.06	24.27	6.16	15.61	−1.71	0.089

^a In the case of continuous variables, independent samples *t*-test is used to compare mean values. In the case of dummy variables, Pearson's χ^2 test is used to compare distributions.

^b One tarea equals 0.11 acres.

sustainable management practices from farmer organizations or development projects, 32% indicated that they receive such information from family and friends, and 21% of farmers indicated that they mostly rely on own experimentation. Furthermore, only 6% of the households in our sample indicated that they have information about new market opportunities.

Table 2 compares the availability of information between organic and conventional farmers. On the average, we find that organic farmers are significantly more often member of a farmer group. NGOs operating in the research area offer extension and technical advice through existing group structures, so that members of farmer organizations usually have better access to specific knowledge and information about new practices and technologies. In line with this finding, we can see that organic farmers received extension on significantly more topics compared to conventional farmers. In addition, results show that more information is available in the neighborhood networks of organic farmers compared to conventional farmers.

Furthermore, descriptive results in Table 2 show that the majority of farmers are quite optimistic about the attitudes of their neighbors towards their adoption decision. Overall, 96% of the organic farmers and 85% of the conventional farmers perceive a positive attitude of their neighbors. Notwithstanding high overall levels, the share of organic farmers perceiving their neighbors to have a positive attitude is significantly larger compared to conventional farmers.

Table 2 also presents farmers' beliefs regarding the productivity effects of organic agricultural practices. While there is no significant difference between organic and conventional farmers regarding the expectation of positive productivity effects for their own plot, the percentage of organic farmers who believe that organic practices have a positive effect on their neighbors' plots is significantly lower than among conventional farmers. While negative external effects of organic agriculture practices are in principle possible, e.g. if pest pressure is not adequately controlled, neither organic nor conventional farmers really expect negative productivity effects for their neighbors: only one organic farmer and two conventional farmers perceived negative external effects to be a likely outcome of the adoption of organic agricultural practices.

Last but not least, Table 2 provides information on location variables for organic and conventional farmers, respectively. On the average, organic farmers are located significantly closer to the city of Marcala, which is the main market center in the area. Furthermore, we find that organic farms are less often located in areas classified as "soils of the valley", a soil category that features flat terrain and the most fertile soils in the region. This indicates that in our research area organic farming is more frequently established in areas that are less suitable for agricultural intensification, such as hillsides, and on less fertile soils, where farmers' opportunity costs of switching to organic agriculture are lower. This is in line with similar findings from Bichler et al. (2005) and Pietola and Lansink (2001) who study conversion to organic farming in the European context. Similar evidence from a developing country context is provided by Paudel and Thapa (2004) showing that farmers in Nepal are more likely to apply sustainable farming practices on soils that are prone to erosion, landslides and leaching.

5.2. Econometric Results

Table 3 shows the results of the posterior model probabilities comparing alternative model specifications for the spatial autoregressive probit model. The results point to a 1.5 km threshold distance beyond which neighborhood effects are assumed to be zero. Comparing model parameters across specifications, we observe that as we increase *d* and thus include increasingly distant farmers into the neighborhood, ρ

Table 3
Model comparison.

Model specification	Model probabilities
W1: <i>d</i> = 1.5 km	0.5964
W2: <i>d</i> = 2.0 km	0.0894
W3: <i>d</i> = 2.5 km	0.0481
W4: <i>d</i> = 3.0 km	0.1089
W5: <i>d</i> = 3.5 km	0.0975
W6: <i>d</i> = 4.0 km	0.0597

decreases in magnitude and significance. Otherwise, results are robust across the alternative model specifications.¹⁴ In the preferred model specification ρ is statistically significant at the five percent level indicating that spatial effects matter in the adoption of organic agriculture among hillside farmers in Honduras (see Table 4). The positive sign of ρ implies that a farmer is more likely to adopt if neighboring farmers are also adopters.

With respect to information availability, results in Table 4 show, as expected, that membership in farmer groups, which is generally associated with better access to information and assistance, increases the likelihood of adoption. In line with this finding, farmers who have received extension on more topics are also more likely to adopt organic agriculture. Even when controlling for the farmer's direct access to extension, the amount of information in the neighborhood network plays an important role for the adoption decision. Results show that farmers, who have access to a neighborhood network that has received extension on more topics, have a higher probability to adopt organic agriculture. This provides evidence for the existence of positive knowledge spillovers, i.e., farmers benefit from greater availability of information in their neighborhood. Our findings are in line with results of previous studies on technology adoption in developing countries that identify informal information exchange between neighbors to be an important determinant of technology diffusion (e.g. Bandiera and Rasul, 2006; Case, 1992; Conley and Udry, 2010).

Moreover, our results indicate that social conformity plays an important role in the adoption decision of farmers. Farmers are significantly more likely to adopt organic agriculture, if they think that their neighbors would be approving of their decision. Thus, the acceptance of agricultural production decisions in the social environment of farmers seems to be a driving force in the diffusion of agricultural technologies. Our finding also supports the evidence found elsewhere pointing to the importance of conformity considerations in the decision-making of rural households (Läpple and Kelley, 2013; Moser and Barrett, 2006).

Furthermore, we find that the belief that adoption is associated with positive productivity effects on neighbors' plots decreases the likelihood of adoption. This suggests that farmers tend to forego agricultural investments to prevent others from free riding on their efforts. Similar arguments have been raised in the scientific debate (e.g. Lee, 2005), but to the best of our knowledge, have not yet been subject to rigorous analysis. While we provide some indicative results, further research on this topic should involve behavioral field experiments to investigate farmers' norms and preferences with respect to agricultural investments more immediately.

Regarding the location variables, the distance to the main market center has a negative effect and is statistically significant at the ten percent level. This indicates that farmers who live in more remote areas with poor access to markets are less likely to adopt organic agriculture. This is in accordance with previous adoption studies of organic practices, which have found positive effects of market access on adoption (Dimara and Skuras, 2003; Koesling et al., 2008). Controlling for other covariates, agro-ecological suitability does not have a significant effect on the adoption decision in our model.

Finally, some of the household characteristics have a significant effect on adoption. As expected, farmers who associate sustainable practices with positive health effects are more likely to adopt organic practices. In contrast, perceived positive productivity effects on own plots and perceived positive environmental effects are not significant, ceteris paribus. Furthermore, we find that older farmers are more likely to adopt organic agriculture. While modern technologies are often adopted by younger farmers, the literature on sustainable farming practices shows mixed evidence. Our findings from Honduras are in line with e.g. Parra-Lopez et al. (2007), who find that older farmers are more likely to adopt organic farming in the Spanish olive sector. A

Table 4
Results of the spatial autoregressive probit model.

Variable	Coefficient	Std. dev.	p
<i>Information variables</i>			
Total number of topics that members of the neighborhood network received extension on	0.013	0.005	0.005
Total number of topics that household received extension on	0.082	0.044	0.030
Membership in at least one village organization	0.935	0.338	0.000
<i>Social conformity</i>			
Neighbors appreciate if I apply new practices	0.989	0.489	0.011
<i>Perceived spillover effects</i>			
Positive productivity effects on neighbor's plot	−1.788	0.656	0.002
<i>Location variables</i>			
Located on "valley soil" (high quality soil, flat terrain)	−0.044	0.328	0.449
Distance to city of Marcala (in km)	−0.024	0.019	0.095
<i>Control variables</i>			
Positive productivity effects on own plot	0.436	0.426	0.145
Positive health effects associated with practices	1.247	0.668	0.023
Positive environmental effects associated with practices	−0.086	0.567	0.450
Age of household head	0.035	0.011	0.000
Household head can write	0.413	0.337	0.108
Number of household members	0.103	0.056	0.031
Female-headed household	0.256	0.312	0.207
Household has salaried employment	0.148	0.435	0.356
Household head works on farm	0.673	0.392	0.042
Land size	−0.004	0.004	0.173
Household has taken out loan during past year	0.071	0.249	0.381
Total value of assets (in Lmp.)	0.006	0.006	0.149
Constant	−5.770	1.075	0.000
Spatial lag term ρ	0.321	0.158	0.035

potential explanation is that older farmers often have lower opportunity costs and are thus willing to spend more time with labor-intensive practices, such as manual weeding, required in organic farming. This hypothesis is also supported by the finding that farmers with better access to family labor, and households in which the household head is dedicated to farming are more likely to adopt organic agriculture.

In order to derive the magnitude of the impact of the independent variables on the probability of adoption, we estimate marginal effects. As in the non-spatial probit model, marginal effects are estimated at the mean for continuous variables and for a change from zero to one for dummy variables. Yet, in the spatial autoregressive probit model, we account for both direct and indirect effects (LeSage et al., 2011). While the direct effects express the impact of a change in the independent variable of household i on the adoption probability of that same household, the indirect effects represent the cumulative effect of a change in the independent variable of neighboring households on the adoption probability of household i . This cumulative indirect effect is a result of the interdependence in decision-making: a change in the independent variable has an effect on household j 's probability to adopt organic agriculture and thereby also on household i 's probability to adopt. To what extent changes in the neighborhood affect the adoption probability of household i depends on the spatial proximity, which is defined by the spatial weight matrix. The total effect of an independent variable is thus the sum of its direct effect and its indirect spatial spillover effect (LeSage and Pace, 2009). Marginal effects estimates are presented in Table 5. Results show that for all independent variables direct effects are much larger – about twice the size – than the indirect spatial spillover effects. The largest total effects are associated with group membership, social conformity, perceived health effects and perceived productivity effects on neighbors' plots.

Membership in groups increases the likelihood to adopt organic agriculture by 26 percentage points in total. This total effect can be broken down into a direct effect of 17.4 percentage points and a cumulative indirect effect of 8.3 percentage points. The indirect effect results from the interdependencies in decision-making and affects individual i through

¹⁴ Results from the other model specifications will be provided in a supplementary appendix online.

Table 5
Marginal effects.

	Direct effects	Indirect effects	Total effects	Confidence interval for total effects	
				Lower 5%	Upper 95%
<i>Information variables</i>					
Total number of topics that members of the neighborhood network received extension on	0.002	0.001	0.004	0.001	0.007
Total number of topics that household received extension on	0.015	0.007	0.022	−0.001	0.050
Membership in at least one village organization	0.174	0.083	0.257	0.079	0.488
<i>Social conformity</i>					
Neighbors appreciate if I apply new practices	0.184	0.090	0.274	0.026	0.597
<i>Perceived spillover effects</i>					
Positive productivity effects on neighbor's plot	−0.333	−0.156	−0.489	−0.928	−0.131
<i>Location variables</i>					
Located on “valley soil” (high quality soil, flat terrain)	−0.008	−0.003	−0.011	−0.188	0.166
Distance to city of Marcala in km	−0.004	−0.002	−0.006	−0.017	0.003
<i>Control variables</i>					
Positive productivity effects on own plot	0.082	0.037	0.119	−0.117	0.362
Positive health effects associated with practices	0.231	0.112	0.342	0.006	0.762
Positive environmental effects associated with practices	−0.015	−0.010	−0.025	−0.356	0.264
Age of hh head	0.006	0.003	0.009	0.004	0.017
Hh head can write	0.076	0.037	0.113	−0.061	0.300
Number of hh members	0.019	0.009	0.028	−0.002	0.061
Female-headed hh	0.047	0.023	0.071	−0.092	0.250
Hh has salaried employment	0.027	0.012	0.039	−0.205	0.266
Hh head works on farm	0.125	0.060	0.185	−0.026	0.422
Land size	−0.001	0.000	−0.001	−0.004	0.001
Household has taken out loan during past year	0.013	0.006	0.019	−0.118	0.151
Total value of assets (in Lmp)	0.001	0.001	0.002	−0.001	0.005

the effect of group membership on the neighbors' propensity to adopt organic agriculture. Also in line with this result, we find a positive and significant marginal effect for the information available in the neighborhood network. For each additional extension topic that a network member received extension on, a farmer's likelihood of adoption increases by 0.4 percentage points in total. Here also we can distinguish between the direct effect of information availability, which equals 0.2 percentage points, and the indirect effect of information availability in the neighbor's neighborhoods, which amounts to 0.1 percentage points. Similarly, if farmers believe that their adoption decision is socially conform, they are 27 percentage points more likely to adopt, of which 18 percentage points can be attributed to the direct effect and 9 percentage points to the indirect spatial spillover effect. Furthermore, perceived productivity effects on neighboring plots as well as perceived health effects strongly influence the probability of adoption. The perception of positive health effects for the family has a direct effect of 23 percentage points and an indirect effect of 11 percentage points resulting in a positive total effect of 34 percentage points on adoption. In contrast, the perception of positive productivity effects on neighboring plots reduces the likelihood of adoption by 49 percentage points, of which 33 percentage points are due to the direct effect and 16 percentage points are associated with indirect effects.

6. Conclusions

In this article we investigate the spatial patterns of organic agriculture adoption among farmers in the Honduran hillsides. The research area is characterized by high levels of erosion and soil degradation and thus by low agricultural potential. As a consequence, many households in the area are trapped in a vicious cycle of low agricultural productivity, low investment capacities, and poverty. In this context, low external input agriculture, such as organic farming, has been identified as a promising approach to break this cycle and improve soil conditions, agricultural output and thus rural livelihoods.

In our research region, currently 20% of the households practice organic agriculture. Like in previous studies conducted in Europe or the

U.S., we find that organic adopters are not randomly distributed across space, but that adoption is spatially clustered. The positive sign of ρ in our econometric analysis suggests that neighborhood effects exist and farmers are more likely to convert to organic farming if their neighbors are also adopters. Based on Bayesian model probabilities we choose a threshold distance of 1.5 km to define the neighborhood in which interdependencies are assumed to occur. While 1.5 km may seem a relatively short distance, this needs to be seen in the context of our research area, which is characterized by poor infrastructural development. In particular, mobility is limited in our sample: only six farmers own a car or motorbike, whereas 40% of the farmers own a horse or a bike. The remaining households do not own any means of transportation. Several underlying factors that may explain spatial adoption patterns have been discussed in the literature. Information spillovers and social conformity concerns are likely to be of particular relevance in a setting like our research area, where access to information is generally scarce and households depend on neighborhood networks to manage pervasive risks.

Our results show that indeed social conformity concerns matter: households are more likely to adopt organic agriculture if they believe that their neighbors would approve of their decision indicating that farmers care about the acceptance of their agricultural technology choices in their social environment. During the field visit, farmers told us that others may frown upon them if they do not maintain their plots free of crop residues. While there has been a paradigm change in the dissemination of sustainable practices at the level of extension services, this change is taking place at a much slower pace in the minds of farmers. Yet, this value change matters not only at the level of the individual farmer, but also within the community in which the individual farmer lives and interacts. This is especially so in risk-prone areas, where farmers often rely on informal neighborhood networks to cope with idiosyncratic risks. Social acceptance of one's own behavior can thus become a vital livelihood strategy.

Similarly, households that have better access to information, either directly, through their neighborhood network, or through farmer groups, are more likely to be adopters of organic agriculture. This indicates that for a knowledge-intensive technology, such as organic

farming, information availability plays an important role, at least in a region like the hillsides of Honduras, which represents a relatively information-scarce environment. Furthermore, we find evidence that farmers who perceive that their adoption decision would benefit neighboring plots, are less likely to adopt.

Taken together, these results have implications for the dissemination of sustainable agricultural technologies in low potential agricultural areas in developing countries. The importance of information availability in the neighborhood network and social conformity for the farmer's decision making suggests that extension activities that address the whole community may be more effective than targeting individual farmers to induce behavioral changes in the management of land resources. Joint neighborhood initiatives are also most appropriate to address the positive externalities of sustainable land management. While individual farmers cannot internalize the full benefits of their adoption decision and therefore tend to delay adoption, coordinated activities can help to overcome such problems of collective action. If all farmers in a neighborhood commit to establish measures against erosion or to apply organic manure that restores soil functions, individuals do not have to fear that neighboring farmers may free ride on their investments into soil structure and fertility improvements.

The results of our study should be seen as indicative evidence for the important role of information availability, social conformity concerns and productivity spillovers in the decision to adopt organic agriculture among Honduran hillside farmers. It should, at the same time, motivate further research to explore these particular aspects in more detail and in different settings. One promising avenue for future research involves behavioral field experiments to investigate farmers' norms and preferences with respect to agricultural investments more directly. Another relevant methodological extension of our work implies controlling for unobserved spatially correlated error effects in addition to neighborhood effects in the econometric estimation of the adoption decision.

Appendix A. Supplementary Data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.ecolecon.2013.11.010>.

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