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Meike Wollni
Camilla Andersson

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Spatial patterns of organic agriculture adoption: evidence from Honduras

Meike Wollni and Camilla Andersson[1]

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.

Keywords: neighborhood effects, social conformity, spatial autoregressive probit model, organic agriculture, technology adoption, Central America

JEL classification: O13, O33, Q12, Q16

[1] Contact information:
Meike Wollni, mwollni1@uni-goettingen.de
Camilla Andersson, camilla.andersson@agr.uni-goettingen.de

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 (Ruben and Pender 2004, Blackman et al. 2007, Marenya and Barrett 2007, 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 are "organic by default" (Bolwig et al. 2009) 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. 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 decision of farmers to convert to organic agriculture (e.g. Best 2010, Läpple and van Rensburg 2011, Mzoughi 2011, Hattam et al. 2012, Schmidtner et al. 2012, Läpple and Kelley 2013). A growing number of these studies focus on the role of spatial effects in the adoption process. Empirical evidence suggests that positive spatial effects exist in the case of organic agriculture adoption. This evidence, however, is mostly based on data from developed countries, including 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 is scarce, there is increasing evidence on the role of neighborhood effects and social interactions in the adoption of agricultural technologies more generally (Case 1992, Best et al. 1998, Holloway et al. 2002, Staal et al. 2002, Bandiera and Rasul 2006, Conley and Udrey 2010). 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, Schmidtner 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 (Moser and Barrett 2006, Läpple and Kelley 2013). 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 (Lee 2005, Knowler and Bradshaw 2007).

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 (Manski 2000, Holloway and Lapar 2007). 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 (Manski 2000, Lee 2005). Understanding the role of individual versus collective forces in the diffusion of sustainable agricultural technologies can help policymakers to prioritize between programs that target either individual households or neighborhood networks and communities to effectively induce behavioral changes.

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. Afterwards we describe the research area and the empirical data. Section four details the methodological approach used to analyze the data. Descriptive and econometric results are presented in sections 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 (Schmidtner et al. 2012, Lewis et al. 2011, Parker and Munroe 2007). 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, 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. On the other hand, 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. Accordingly, we are likely to find spatial concentration of organic agriculture to the extent that these location factors are spatially correlated.

A second group of factors that may explain spatial clustering of organic agriculture are agglomeration economies. 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 (Foster and Rosenzweig 1995, Bandiera and Rasul 2006, Conley and Udry 2010). 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 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).

Finally, 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 (Bolwig 2009, Blackman and Naranjo 2012). 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.

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:

(1) $$\int_0^\infty E\left[U_{it}^{Or}(\pi_{it}^{Or}, TC_{it}\left(I^{Or}\left(a_j\right)\right), S, \Delta\pi_j)\right] e^{-rt}dt - \int_0^\infty E\left[U_{it}^{Co}(\pi_{it}^{Co})\right] e^{-rt}dt > 0$$

with

(2) $$\pi_{it}^{a} = p_{it}^{a}(a_j, D) q_{it}^{a}\left(F, I^{a}\left(a_j\right), E\left(a_j\right), L_{it}^{a}\left(a_j\right)\right) - w_{it}^{a}(a_j, D) L_{it}^{a}(a_j)$$

where U_{it} is utility of farmer *i* in period *t* 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:

- 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,
- 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, and
- Other agglomeration economic effects $p_{it}^a(a_j)$, $w_{it}^a(a_j, D)$ and $L_{it}^a(a_j)$ affecting availability, quality and prices of inputs and outputs.

Note that while *F* and *D* are spatially correlated effects, the remaining effects 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 mainly interested in disentangling the effects of $I^a(a_j), S, \Delta\pi_j, D$ and *F* from other spatially dependent effects and study their impact on activity choice.

3. 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.

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. If a selected household was unavailable for the interview, the household was replaced with another household from the list. 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.

4. Empirical framework

As described above, farmers are assumed to adopt organic agriculture if the net benefit derived from adoption U_{it}^{Or} is larger than the net benefit derived from conventional agriculture U_{it}^{Co}. 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 taken in nearby locations (LeSage and Pace 2009). This spatial pattern can be generated by various underlying factors including agro-ecological conditions, the availability of information, social conformity concerns and externalities of the adoption decision, as discussed in section two. To control for unobserved spatial and neighborhood-related variables, we use a Bayesian spatial autoregressive probit model (see e.g. Holloway et al. 2002) that is specified as

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

where y^* reflects the net utility, $U_{it}^{Or} - U_{it}^{Co}$, 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 $y^* < 0$. Furthermore, Wy is a spatial lag term representing a linear combination of the y-values taken by neighboring households. In this context, W represents a spatial weight matrix that defines the nature and extent of the neighborhood that is assumed to be relevant in the adoption process. In our analysis, all households that live within two kilometers are defined as neighbors and are weighted according to their inverse distance.[2] 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. Model

[2] Best et al. (1998) find that a radius of 2-3 km is reasonable for technology spillovers (see also Holloway et al. 2002). Holloway and Lapar (2007) recommend comparing alternative specifications of the spatial weight matrix. To test for the robustness of our results we thus run the model with different specifications of the spatial weight matrix including (1) a cut-off of 3 km, (2) the five closest households, and (3) the ten closest households.

parameters ρ, β and y^* are estimated using Marcov 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).[3]

The spatial lag term in the model controls for unobserved variables that exhibit a spatial pattern and are correlated with the outcome variable. As discussed in previous chapters, we additionally control for several factors that can potentially explain spatial clustering of organic agriculture adoption. For this purpose, we collected a rich data set including farmers' perceptions that allows us to control for these factors explicitly.

To capture agro-ecological and locational 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.

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

[3] 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

neighborhood network[4], 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. In particular, farmers were asked whether they believe that their neighbors would appreciate or disapprove if they used sustainable agricultural practices on their plots.[5] 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 new technologies, e.g. because they use innovative practices themselves or they have expressed interest in new practices, the adoption decision will be taken under the assumption of being socially conform – either because others are already using new technologies, or because they might appreciate to benefit from learning spillovers.

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

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[4] The farmer's neighborhood network is defined based on the spatial weight matrix, i.e., all farmers located within a radius of two kilometers.

[5] The options were: „very much appreciates“, „appreciates“, „is indifferent“, „disapproves“, „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“.

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.

Besides these variables that are likely to be associated with spatial patterns in adoption decisions, the vector *X* contains a number of control variables expected to influence the farmers' decision to engage in organic agriculture. These include the expectation of positive productivity effects on own plots, literacy and age of the household head and the availability of family labor among others. 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. Summary statistics of the variables included in the econometric model are presented in the next section and in Table A in the appendix.

5. Results

5.1. Descriptive results

We define households as adopters of organic agriculture if they do not use synthetic fertilizers and pesticides and additionally indicated that they sell their output as "organic" to differentiate it from conventionally produced products. Using this definition, we exclude farmers who are "organic by default", i.e. farmers who do not use chemicals simply due to liquidity constraints, from the adopter category. 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 households classified as organic farmers additionally have crops on separate plots that they grow conventionally. Among conventional farmers, 11% use no synthetic fertilizer classifying them as "organic by default", because they could not afford to purchase external inputs during the past growing season. As an alternative means to maintain and improve soil fertility, 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 significantly more likely to establish living barriers on their plots and to apply organic manure. On the contrary, the application of crop residues is similarly common among organic and conventional farmers. Similarly, contour planting, an effective practice to reduce soil erosion, is applied equally by 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.

>> Table 1 about here <<

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 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.

>> Table 2 about here <<

In our research area, access to agriculture-related information is fairly limited and to a large extent is exchanged through informal channels of information. In our sample, 47% of the farmers indicated that they primarily receive information about 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 13% of the households in our sample indicated that they have information about prices of agricultural products, and even less, 6% of the households, indicated that they have information about new market opportunities.

Descriptive results comparing the availability of information among organic and conventional farmers can be found in Table 2. 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. On the average, organic farmers received extension on 3.6 different topics, while conventional farmers received extension on only 1.7 different topics. In addition, we measure the extent of information available in the farmer's neighborhood network. Results show that more information is available in the neighborhood networks of organic farmers, where neighbors received extension on a total of 41.7 topics, on the average. In comparison, members of the neighborhood networks of conventional farmers received extension on 36.5 topics, on the average.

Furthermore, descriptive results show that the majority of farmers is quite optimistic about the attitudes of their neighbors towards their adoption decision (see Table 3). 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 3 about here <<

Table 3 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.

5.2. Econometric results

Table 4 presents results from the spatial autoregressive probit model. As explained above we use a spatial weight matrix that defines all households within two kilometers as neighbors and weights them according to their inverse distance. To test for the robustness of our results we try several different specifications of the spatial weight matrix including (1) a cut-off of three kilometers instead of two, (2) defining the five closest households as neighbors, and (3) defining the ten closest households as neighbors. Findings are robust across the different specifications[6], and thus, in the following we only present and discuss results from the original weight matrix. To explore the underlying processes that could lead to spatial clustering of organic agriculture adoption we focus on the potential explanatory variables that are related to information availability, social conformity, positive externalities and location.

With respect to information availability, we find, 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.

[6] Results will be provided by the authors on request.

Moreover, 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.

Furthermore, we included two variables related to the perceived productivity effects of the adoption decision. As expected, farmers who expect positive productivity effects on their own land are more likely to adopt organic practices. On the other hand, the belief that adoption would have 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.

Regarding the location variables, neither agro-ecological suitability nor the distance to the main market center have a significant effect on the adoption decision. This could in part be due to counteracting effects associated with location resulting in both positive as well as negative influences on the probability of adoption. Finally, some of the household characteristics have a significant effect on adoption. We find that older and literate farmers, 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.

Our results show that even when controlling for social conformity and externality effects as well as location and information related variables the spatial lag term is statistically significant at the ten percent level of significance, indicating that spatial effects matter in the adoption of organic agriculture among hillside farmers in Honduras. The positive sign of ρ implies that a farmer is more likely to adopt if neighboring farmers are also adopters. Based on these findings, we conclude that ρ is capturing underlying spatially dependent processes that are not fully captured by the exogenous variables in our model.

>> Table 4 about here <<

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 marginal effects. 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*. To what extent changes in the neighborhood affect the adoption probability of household *i* depends on the spatial proximity, which is defined in 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 spatial spillover effects. The largest total effects are associated with group membership and perceived productivity effects of the adoption decision.

Membership in organizations increases the likelihood to adopt organic agriculture by 22 percentage points, providing evidence for the importance of access to information and assistance for the adoption decision. In line with this finding, we find positive and significant marginal effects for both the information available to the individual farmer and the information available in the neighborhood network. For each additional extension topic, a farmer's likelihood of adoption increases by 2 percentage points if the household received the extension and by 0.3 percentage points if any network member received the extension. Furthermore, the perceived productivity effects of the adoption decision strongly influence the probability of adoption. While the perception of positive productivity effects for the own plot increases the likelihood of adoption by 21 percentage point, the perception of such positive productivity effects for neighboring plots reduces the likelihood of adoption by 27 percentage points.

>> Table 5 about here <<

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 percent of the households practice organic agriculture. Like in previous studies conducted in Europe or the U.S., we find that these households are not equally distributed across space, but that adoption follows a spatial pattern. Several underlying factors that may explain such spatial pattern 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 riskprone 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.

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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

Table 2: Access to information and location proxies

	Organic (N=47)		Conventional (N=192)		Test statistic[a]	
	Mean	Std. dev.	Mean	Std. dev.	value	p
Location proxies						
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
Access to information						
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

[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 chi^2 test is used to compare distributions.

Table 3: Farmers' beliefs regarding externalities and attitudes of neighbors

	Organic (N=47)		**Conventional** (N=192)		**Pearson's chi² test**	
	Mean	Std. dev.	Mean	Std. dev.	value	p
Positive productivity effects on own plot (0/1)	0.26	0.44	0.28	0.45	0.13	0.722
Positive productivity effects on neighbor's plot (0/1)	0.15	0.36	0.29	0.45	3.72	0.054
Negative productivity effects on neighbor's plot (0/1)	0.02	0.15	0.01	0.10	0.36	0.549
Neighbors appreciate if I apply new practices (0/1)	0.96	0.20	0.85	0.35	3.67	0.055

Table 4: Results of the spatial autoregressive probit model

Variable	Coefficient	Std. dev.	p
Location variables			
Located on „valley soil“ (high quality soil, flat terrain)	-0.059	0.323	0.438
Distance to city of Marcala (in km)	-0.025	0.020	0.103
Information variables			
Total number of topics that members of the neighborhood network received extension on	0.013	0.005	0.011
Total number of topics that household received extension on	0.084	0.041	0.021
Membership in at least one village organization	0.815	0.313	0.001
Social conformity			
Neighbors appreciate if I apply new practices	0.661	0.416	0.047
Perceived productivity effects			
Positive productivity effects on own plot	0.781	0.375	0.019
Positive productivity effects on neighbor’s plot	-1.003	0.425	0.007
Control variables			
Age of household head	0.030	0.010	0.001
Household head can write	0.402	0.312	0.099
Number of household members	0.105	0.055	0.027
Female-headed household	0.269	0.297	0.186
Household has salaried employment	0.216	0.398	0.295
Household head works on farm	0.540	0.355	0.060
Land size	-0.004	0.004	0.210
Constant	-4.979	0.982	0.000
Spatial lag term ρ	0.261	0.191	0.089

Table 5: Marginal effects

	Direct effects	Indirect effects	Total effects	Confidence interval for total effects lower 5%	upper 95%
Location variables					
Located on "valley soil" (high quality soil, flat terrain)	-0.012	-0.001	-0.013	-0.196	0.168
Distance to city of Marcala in km	-0.005	-0.002	-0.007	-0.019	0.004
Information variables					
Total number of topics that members of the neighborhood network received extension on	0.002	0.001	0.003	0.001	0.007
Total number of topics that household received extension on	0.016	0.006	0.023	0.001	0.049
Membership in at least one village organization	0.157	0.067	0.224	0.057	0.488
Social conformity					
Neighbors appreciate if I apply new practices	0.127	0.057	0.184	-0.024	0.479
Perceived productivity effects					
Positive productivity effects on own plot	0.150	0.063	0.213	0.009	0.466
Positive productivity effects on neighbor's plot	-0.192	-0.082	-0.274	-0.577	-0.051
Control variables					
Age of hh head	0.006	0.002	0.008	0.003	0.016
Hh head can write	0.077	0.033	0.110	-0.049	0.307
Number of hh members	0.020	0.008	0.029	-0.000	0.065
Female-headed hh	0.052	0.024	0.075	-0.082	0.268
Hh has salaried employment	0.042	0.016	0.058	-0.160	0.292
Hh head works on farm	0.104	0.046	0.150	-0.032	0.396
Land size	-0.001	-0.000	-0.001	-0.004	0.001

Appendix

Table A: Summary statistics of household and farm characteristics

	Organic (N= 47)		**Conventional** (N=192)		**Test statistic**[a]	
	Mean	Std. Dev.	Mean	Std. Dev.	value	p
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

[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 chi^2 test is used to compare distributions.
[b]One tarea equals 0.11 acres.