Journal of Integrated Pest Management
ISSUES
OPEN ACCESS

Going the Distance: How Does Market Access Affect Demand for IPM Packages?

Amy Buckmaster,[1] Jeffrey Alwang,[1,2] Everett Peterson,[1] AND Mauricio Rivera[3]

[1]Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, 250 Drillfield Drive, Blacksburg, VA 24060.
[2]Corresponding author, e-mail: alwangj@vt.edu.
[3]Fundación Hondureña de Investigación Agrícola, Departamento de Proteccion Vegetal, Contiguo Instituto Patria, La Lima, Cortes, Honduras.

J. Integ. Pest Mngmt. 5(1): 2014; DOI: http://dx.doi.org/10.1603/IPM13013

ABSTRACT. A challenge facing integrated pest management (IPM) technology transfer programs is to identify where to conduct outreach. As IPM is a knowledge-intensive management process, effective training usually requires sustained interactions between extension professionals and target farmers. Efforts to disseminate IPM are constrained by limited extension budgets and therefore should focus on areas with the greatest promise for adoption per cost of program delivery. This article presents a simple means of evaluating the potential promise for IPM information dissemination based primarily on distance to input and output markets and other factors such as access to irrigation and rainfall and household and farm characteristics. The method is applied to rural Honduras, where an active IPM research program has sought guidance on where to focus its dissemination efforts.

Key Words: IPM extension, Honduras, transportation cost, vegetable, profitability

Integrated pest management (IPM) can be an attractive alternative for small-scale farmers in developing countries. IPM can reduce input costs, improve quality and market prices of farm output, and protect human health and environmental quality through use of less toxic alternatives to highly toxic pesticides. A challenge facing IPM technology transfer programs, however, relates to the location of production with respect to input and output markets (Mauceri et al. 2007, Ricker-Gilbert et al. 2008). As IPM is knowledge intensive, effective training usually requires sustained interactions between extension professionals and target farmers. Efforts to disseminate IPM are constrained by limited extension budgets and therefore should focus on areas with the greatest promise for adoption per cost of program delivery. Often, little thought is given to this decision, and education programs tend to be distributed based on convenience or into areas where they complement other efforts such as ongoing agricultural development projects. This article presents a simple means of evaluating the potential promise for dissemination of IPM information based primarily on access to input and output markets. This method is applied to Honduras, where an active IPM research program has sought guidance on where to focus its dissemination efforts.

Cropping patterns and farming systems vary globally, and this variability is manifest in spatial differences in crop varieties and diversity, planting intensity, input use, and other factors. These outcomes are partly determined by access to input and output markets. Access to input markets determines the effective prices of fertilizers, pesticides, and other purchased inputs and thus affects farming decisions (Norton et al. 2010). Access to output markets affects decisions through their impacts on prices received by producers (Dorosh et al. 2003). Across a country, farmers use different production technologies, input mixes, and management practices. For example, farms located near markets are able to use purchased inputs such as fertilizers and pesticides more intensively and can produce more high-valued products for sale. Farming intensity is usually higher, on-farm diversity is lower, and market linkages are stronger for farms located near markets. In more isolated areas, market interactions are less frequent, farming intensity is low, and farm families are more likely to be self-sufficient (Grigg 2005). As a result, farmers in distant areas often plant staple food crops with little use of purchased inputs.

Generally, IPM strategies reduce use of chemical inputs (especially pesticides) and may reduce farmer reliance on input markets. Introduction of IPM in developing countries can influence farmer decision making. IPM combines pest biology, technology, and environmental information to reduce pest damage to the lowest economically viable level while protecting environmental and agricultural resources (National Road Map for Integrated Pest Management 2004). In the context of the geography of production discussed above, demand for IPM is likely to be high in areas near markets, especially in areas where production of horticultural crops for sale in markets is economically viable. In more isolated areas, IPM holds the promise of reducing dependence on purchased inputs, but lower intensity of production and the crop mix in these areas may prevent farmers from benefiting from emerging IPM technologies.

Transportation-intensive crops such as horticultural products usually require heavy applications of pesticides and, as a result, research has generated many IPM technologies for them (see, for example, http://agrilinks.org/events/ipm-horticultural-crops-tropical-world and http://www.ipmnet.umd.edu/). Because transportation-intensive crops tend to be located near markets, it is easier to disseminate information on IPM technologies and more farmers may be interested in implementing IPM in these areas (Mauceri et al. 2007, Ricker-Gilbert et al. 2008). These factors would lead to lower training costs per adopting participant and higher demands for IPM services such as lower-toxicity pest controls, information on scouting for insect pests, use of biological controls, and others. Conversely, training costs are likely be higher in less densely populated areas far from markets where fewer farmers produce perishable goods (Alwang et al. 2005, Mauceri et al. 2007). These factors make IPM less viable in such areas.

In Honduras, IPM research has been conducted by the Fundación Hondureña de Investigación Agrícola (FHIA). FHIA receives funding from the United States Agency for International Development (USAID) through projects such as ACCESO and the IPM Innovation Laboratory (IPM-IL—formerly the IPM Collaborative Research Support Project [CRSP]). FHIA also receives funding from an endowment established by United Brands and USAID, and other donors. FHIA develops new IPM technologies and adapts existing ones to specific agro-climatic conditions through field trials and feedback received through its extension service. This arrangement fulfills stated goals of FHIA and the IPM-IL: reducing pesticide use, increasing farmer income, and improving livelihoods of the poor (Sparger et al. 2011). The ACCESO project, implemented by the consulting firm FINTRAC, works in six departments in western Honduras, and is linking small-scale farmers with markets in the hope that incomes will grow and food security will increase (http://www.usaid-acceso.org/). A challenge facing this project is to identify areas where IPM is appropriate. In western Honduras, although many farmers enjoy relatively good market access, access falls dramatically with distance owing to low-quality roads and challenging topography. Some of the most isolated farmers in all of Central America are found in western Honduras (Jansen et al. 2006).

Objectives

It is important that FHIA and other research and extension services understand where IPM vegetable extension will be most effective. Because crop choice and technology adoption are essentially choices made by farmers, it is necessary to understand farmer demands for IPM information and services. The objectives of this article are to understand how distance from markets affects farmer production decisions and how farmer demands for IPM technologies vary over space. This information will be used to identify specific areas where IPM vegetable extension is likely to have largest impacts and provide guidance to ACCESSO-related outreach efforts.

FHIA's IPM Program

A wide variety of IPM practices are currently being used in Honduras. Some basic IPM practices are—new seed varieties with higher yield potential and resistance to diseases, scouting for pests before spraying, and use of raised seed beds. Raised seed beds are prevalent in Honduras, and several extension agents identified them as one of the first IPM practices they recommend to small farmers; by raising the bed, it is easier to maintain disease-free material for transplant. Slightly more expensive techniques include the planting of a natural barrier (such as Maize, *Zea mays* L.) around the crop to reduce insect migration into the targeted field, and use of biological controls (natural enemies that combat unwanted pests) and pheromone-baited traps to monitor pest populations. Drip irrigation is important because it allows for efficient water management and proper rates of application of soluble fertilizer. Several advanced techniques are available but are not widely used in Honduras. These include mechanized irrigation (very high fixed costs as well as requires access to electricity), grafting, and covered production. Covered production, using insect-preventing mesh, can be expensive because the mesh only lasts for one or two crop cycles and then must be replaced. Covered production is popular in neighboring Guatemala, and extension agents are hopeful it will become more widespread in Honduras. Scientists at FHIA have conducted IPM research on *Solanum melongena* L., eggplant; *Capsicum annuum* L., pepper; *Allium cepa* L., onion; and *Solanum lycopersicum* L., tomato (Sparger et al. 2011). These crops comprise 0.17, 0.13, 0.39, and 0.08% of Honduras' total area under cultivation and contribute 0.26, 0.55, 3.04, and 0.19% to total agricultural value. Despite their relatively low contribution to agricultural value, these crops are increasingly being planted by small-scale farmers, and their production represents an important pathway out of poverty (http://www.usaid-acceso.org/). The Honduran agricultural sector is dominated by maize, *Phaseolus vulgaris* L., common bean, and *Coffea arabica* L., coffee. These crops constitute 33, 10, and 24% of total area under cultivation and contribute 8, 3, and 22% to total agricultural value (Sparger et al. 2011), but small-scale production of high-valued horticultural crops is viewed as an important poverty-reduction strategy. Tomatoes and onions are produced primarily for domestic consumption while peppers and eggplants are produced for export.

Traditional agricultural exports in Honduras are *Musa paradisiaca* L., banana; coffee; *Theobroma cacao* L., cacao; and other processed commodities. Nontraditional exports include vegetables and some exotic fruits. Onions represent 0.3% of nontraditional exports, and are important in the local diet with 97% of production consumed domestically (Instituto Nacional de Estadística 2008). Eggplant is purely for export and plays no role in the local cuisine. Currently, eggplant exports constitute about five percent of the total value of nontraditional exports (Instituto Nacional de Estadística 2008). Peppers, both hot and sweet, also play little role in the local cuisine and have been produced mainly for the export markets. They have shown much promise by growing steadily from 11% of nontraditional exports in 2005 to >23% in 2008 (Instituto Nacional de Estadística 2008).

Each of these crops sustain injury from various pests. Annual average losses from insects, diseases, or other pests over the preceding 5 yr were estimated at 36% for onion, 39% for eggplant, 40% for pepper, and 47% for tomato (Sparger et al. 2011). Whiteflies are a vector for Begomoviruses and represent a major pest to tomatoes and peppers as well as, to a lesser extent, eggplants and cucurbits. Together with aphid-vectored potyviruses, Begomoviruses are responsible for between 50 and 90% of production losses in these crops within Honduras (IPM CRSP 2003). Rootknot nematode is the major pest affecting eggplants, and *Thrips tabaci* (Lindeman) is the major pest affecting onion production. Other major pests for these crops include fungi, bacterial wilt, *Thrips palmi* Karny, spider mites (*Tetranychus* spp.), and *Spodoptera* spp.

Scientists at FHIA have developed, tested, and adapted crop-specific technologies such as eggplant grafting, backpack spraying for onions, and cover crops for tomatoes. Other technologies addressing pest problems common to multiple crops such as solarization and biological control agents have been tested. Solarization involves placing a black plastic cover over a bed before planting; the heat generated by the sun kills weed seeds and other soil-borne pests. Its effectiveness depends on the particular pests, and the procedure must be evaluated and compared with alternatives on a case-by-case basis. The results of this research are now available for use by producers and are being disseminated through extension training in vegetable-producing areas. Because ACCESO focuses on many of these horticultural crops, it is important to identify areas of promise—areas where these types of IPM are likely to be widely adopted.

Materials and Methods

Adoption of IPM depends largely on its profitability relative to alternatives. Profitability determines demand for IPM and two methods can be used to identify this demand: 1) statistical analysis of the likelihood of adopting IPM; and 2) use of cost of production and marketing data to understand the profitability of IPM and, hence, the likely behavior of a representative producer (Buckmaster 2012). In cases where adoption of IPM is sensitive to distance to markets, it is important that the role of distance and its impact on the cost of inputs and farm-gate prices of products be included when estimating the demand for IPM information. Both methods allow inclusion of these effects and can easily be applied depending on available data.

Basing demands for agricultural technologies such as IPM on distance to markets has a long tradition in the economics literature. Several studies (Fafchamps 1992, Minten and Kyle 1999, Alene et al. 2008, Amaya and Alwang, 2012) have examined the role of distance to market and the increase in transaction costs for purchases and sales. These studies found that distance helps determine which crops are produced, which inputs are being used, and whether crops are sold in markets or consumed at home. Distant farmers tend toward self-sufficiency and are far less likely than near (to markets) farmers to produce perishable products (Minten and Kyle 1999). Empirical specifications of the distance-farming decisions relationship can be based on the von Thünen theory of agricultural land use (von Thünen 1966) and on models of farm-household decision making (Singh et al. 1986).

von Thünen (1966) showed that transportation costs lead to declining intensity of agricultural production farther from markets and increased production of perishable goods closer to the market (von Thünen 1966; Fig. 1). The basic von Thünen model has been modified to include variability in land quality over space, and presence of transportation infrastructure and natural boundaries. However, the basic prediction of the model is unchanged: access to market affects productive practices and, hence, demands for technologies and inputs (Shaffer et al. 2004). The farm-household model presented in Singh, Squire, and Strauss shows that farm inputs and outputs are determined

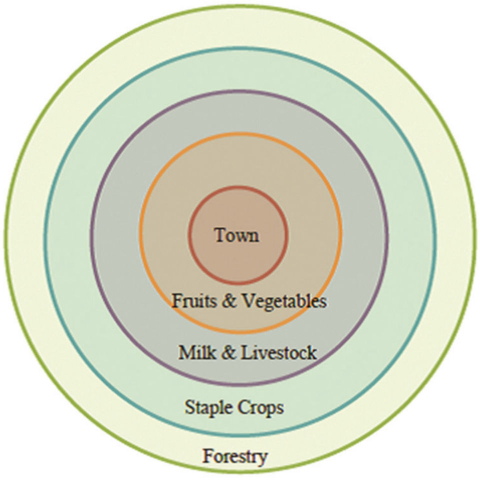

Fig. 1. A visual representation of Von Thünen's concentric rings. Source: Buckmaster (2012).

by factors affecting productivity and relative prices of inputs and outputs. As distance to market affects prices, the model predicts that demands for technologies such as IPM will vary across space.

These stylized models suggest that the net effect of distance will depend on a number of factors including cost of transportation, access to water, and factors affecting the productivity of vegetables and alternative crops, and education and capability of the farmer. Without measuring these factors, FHIA and other decision makers will only know that it will be wise to focus their horticultural IPM extension efforts in areas near markets. This article uses two means of quantifying the impact of distance on production of horticultural crops and demand for IPM. The article uses a regression analysis and a cost-budgeting analysis using linear programming (LP). Use of two methods builds confidence in the findings, as the regression analysis accounts for observed farmer practices and the LP model determines the implication of cost differentials on optimal farmer behavior. It also deepens the analysis of cost-related components affecting the geography of demand for IPM.

Statistical Analysis. Multiple data sources are available to investigate the relationship between distance to market and planting IPM-oriented crops. Three potential data sources were evaluated: 1) the Honduran Encuesta Nacional de Hogares Sobre Condiciones de Vida (ENCOVI), a nationwide survey of 8,175 households performed in 2004 as part of the MECOVI program sponsored by the World Bank, Inter-American Development Bank, and the United Nations; 2) the Honduran Encuesta de Hogares de Propósitos Múltiples (EPHPM), a survey of 21,630 households performed in 2007 by the Honduran government; and 3) a data set from International Food Policy Research Institute (IFPRI) research on rural development and sustainable agriculture in the Trifinio region of Honduras, Guatemala, and El Salvador (International Food Policy Research Institute 2007). The first two surveys have large sample sizes and detailed information on household demographics and income sources, but lack adequate information on agricultural production and distances to markets.

The IFPRI survey was selected because it obtained information on demographics, household composition, consumption, income, farming practices, and credit use from 493 households in the three countries. Although the data contain a relatively small number of observations from a particular region, they have in-depth information on farming practices including crops produced and technologies used. It was also geo-referenced so information on location and distance to markets is available.

Based on previous empirical studies and the conceptual framework, two econometric models were estimated: the probability that a household produces fruits and vegetables for own consumption, not sales (Production model); and the probability of producing fruits and vegetables for sales (Sales model). These models were estimated as probit models. For the Production model, the dependent variable takes a value of one if the household produced only for home consumption and zero if it produced for sales or did not produce vegetables. In the Sales model, the dependent variable takes a value of one if the household produced and sold vegetables and zero if it did not sell vegetables. These outcomes are regressed against a set of independent variables. For this type of dependent variable, a limited dependent variable model is useful and a probit model is well-suited for this estimation (Wooldridge 2009). The estimated coefficients from the model provide information on how changes in the independent variables affect the probability of observing an outcome.

The explanatory variables included are time in minutes from the household to the main road, annual rainfall in the municipality where the household is located, altitude where the household is located, total land farmed by the household, the presence of irrigation on the farm, the age of the household head, the age of the head of the household squared to account for a potential nonlinear relationship between age and probability of adoption (for example, both young and very old farmers may be less likely to adopt compared with a middle-aged farmer), a country indicator for Honduras, the gender of the head of the household, and lastly, the head of the household's membership in a producer organization. These variables were included because they are consistent with the theory discussed above and have been found by other studies to affect production of vegetable crops and marketing decisions. In the case of zero–one dummy variables, the coefficients are interpreted as the discrete change in the probability of observing the outcome given a change from zero to one in the independent variable. For example, the coefficient on the gender of the head shows the difference between the probability of observing a positive outcome for a female- compared with a male-headed household.

Budgeting-Linear Programming Model. As a supplement to the statistical estimation, this study used cost of production data combined with a small survey of transport providers to calculate the relationship between distance to the market and the profitability of different crops produced using different technologies. The transport survey was conducted by FHIA during January through February 2012 at three major vegetable markets in the Comayagua Valley, a major vegetable-producing region. It involved interviews from a sample of 20 truckers. Participants were asked about cost of transport per distance for different products and different road qualities. Information was also obtained on labor and fuel costs, and equipment purchase and maintenance.

The cost information was input into an LP model. This model optimizes net returns for a representative farm household from alternative farming "activities" subject to constraints on land, labor, and food security. The structure of the model was determined based on the extensive literature on the determinants of vegetable production, and the results of the statistical estimation.

The activities in the model include five crops (maize, beans, tomatoes, onions, and potatoes) produced using three different technology levels (Table 1). The three technology levels reflect different intensities of potential IPM use (Table 2). The revenue from each of the five crops is included as selling activities in the model. The objective function maximizes the difference between the revenues and the costs of production subject to the model constraints (Buckmaster 2012). Household consumption is included as a constraint to account for the amount of maize and beans the household is consuming. Distance to market is reflected through transportation activities, and as distance to market increases, the cost of transporting crops and inputs increases. These costs are reflected in the model.

Data for the LP model are obtained from a variety of sources, including production budgets, interviews with farmers, extension agents, agricultural professionals, and the survey from the Trifinio region of Central America mentioned above. Information from the

Table 1. Variables in LP model

Label	Variable
PML	Produce maize—low technology
PMM	Produce maize—medium technology
PMH	Produce maize—high technology
PBL	Produce beans—low technology
PBM	Produce beans—medium technology
PBH	Produce beans—high technology
PTL	Produce tomatoes—low technology
PTM	Produce tomatoes—medium technology
PTH	Produce tomatoes—high technology
POL	Produce onions—low technology
POM	Produce onion—medium technology
POH	Produce onion—high technology
PPL	Produce potatoes—low technology
PPM	Produce potatoes—medium technology
PPH	Produce potatoes—high technology
RPML	Rotation—produce maize—low technology
RPMM	Rotation—produce maize—medium technology
RPMH	Rotation—produce maize—high technology
CM	Consume maize
CB	Consume beans
SM	Sell maize
SB	Sell beans
ST	Sell tomatoes
SO	Sell onions
SP	Sell potatoes
TM	Transport maize
TB	Transport beans
TT	Transport tomatoes
TO	Transport onions
TP	Transport potatoes

The LP model selects production and marketing practices to maximize revenues net of input costs. These variables in this table were selected based on a review of the production literature. The costs and returns from the activities were calculated from various sources as detailed in the text (Buckmaster 2012).

survey on labor availability, land holdings, and production processes was used to calibrate the LP model. The five crops included in the LP analysis were selected based on information availability, their ability to be grown in the same geographic area, and the fact that both ACCESO and FHIA consider them to be target crops. FINTRAC budgets for the ACCESO project were used to create the cost of production coefficients in the LP model.

The LP model complements the statistical analysis by computing how distance affects the optimal use of farming technologies. This optimality depends on the cost of inputs and the price received for outputs net of transportation costs (Table 3). Cost per truckload for staple crops was estimated to be US$0.814/km; transportation cost for perishable crops is estimated at US$1.243/km, with particularly sensitive vegetables (i.e., tomatoes and onions) having an additional transportation premium. As an example, the cost of transporting one pound of maize 1 km (US$0.000814) is calculated by dividing US$0.814 by 1,000 (the amount a small pick-up truck can transport at a time). Transportation costs were also analyzed for sensitivity; the hypothetical distance to market was varied from 16 to 160 km to examine changes in model outcomes. The transportation costs were estimated based on a "moderate" road quality; the results thus understate the impacts that declining road quality will have in more remote areas.

Definitions of the low-IPM, medium-IPM, and high-IPM technology are based on available information from Honduras. Cost of production and yield information for low- and medium-IPM technologies were obtained through PROMIPAC—an IPM extension agency housed at Zamorano University in Honduras. PROMIPAC retains budgets for farmers at different levels of IPM use. High-IPM costs of production are based on production budgets from FINTRAC and represent a farm using FINTRAC's recommended IPM package (FINTRAC 2012). A farm following a FINTRAC production budget has a high degree of access to inputs and financial resources required to implement multiple IPM practices at once (Table 3).

Results

Statistical Results. The statistical analysis provides information on how changes in the independent variables affect the probability of producing and selling vegetables. Use of two separate models, one with Production without sales (the Production model) and other Production with sales (the Sales model), makes it possible to compare impacts of the independent variables on the probability that an agricultural household produces fruits and vegetables for consumption with the impacts on the probability of producing fruits and vegetables for sale at the market. Literature shows that the less likely a household is to sell vegetable crops, the less likely it will be to adopt IPM or apply IPM recommendations (Alwang et al. 2005).

Model 1 results show that time to the main road is positively related (and statistically significant at the 5% level) to fruit and vegetable production (Table 4). As the time to the main road (relative isolation) increases, the probability of producing fruits and vegetables for consumption (but not sales) increases by 0.09%. Rainfall and altitude are not statistically significant. Age of the head of the household is significant in this regression, suggesting that a household with an older head of the household is less likely to produce fruits and vegetables for consumption only. The variable reflecting total land area farmed is positively related to fruit and vegetable production (not sales) and significant at the 5% level. Access to irrigation is negatively related to fruit and vegetable production, implying that farm households that irrigate are less likely to produce fruits and vegetables only for consumption. Households with irrigation are, however, more likely to produce fruits and vegetables for the market (Table 4).

The Sales model tests the impact of the independent variables on the probability that a household produces fruits and vegetables for the market. The coefficient of time to the main road shows that an increase in time to the main road has a negative impact on the likelihood of producing fruits and vegetable to be sold at market by 0.04%. This finding indicates that isolation is negatively related and possibly constraining to participation in fruit and vegetable markets. Distance lowers demand for IPM technologies. Very young and very old heads of household are less likely to produce fruits and vegetables for sale in the market. This follows expectations, as the very young may be too inexperienced to effectively participate in the market, and the very old may not be healthy enough to manage market participation.

Interestingly, the amount of land farmed is negatively associated with fruit and vegetable sales, as a hectare increase in the amount of land farmed results in a 0.98% reduction in the likelihood of fruit and vegetable production for the market. Larger farms tend to specialize in staple crop and livestock production as opposed to horticultural crop production. Irrigation is positively (and significantly at the 5% level) associated with fruit and vegetable production and a farm with irrigation is 15.9% more likely to produce fruits and vegetables for sale at the market compared with those without irrigation.

Model results were used to determine the distance from the market where the probability of producing vegetables for sale in the market became lower than 10%. The model shows that this distance is between 40 and 50 km from the market. Beyond 50 km, the likelihood of production for sales falls below 10%, and demand for IPM would obviously be quite low. These findings were confirmed by the results of the cost accounting (LP) exercise.

LP Model. Using the production cost, revenue, and transportation cost data for the representative farm household, the distance at which each crop activity later used in the LP model results in US$0 profit for the farm is determined algebraically. This is done by setting net profit equal to 0 in the equation below and solving for distance.

$$\text{Net profit (\$)} = \text{revenue per kg (\$)} - \text{production cost per kg (\$)} - (\text{transportation cost per kg [\$]})\,(\text{distance in kilometers})$$

Table 2. IPM technology descriptions by crop for production activities included in LP model

	Low-IPM technology	Medium-IPM technology	High-IPM technology (Fintrac recommended package—includes some or all)
Maize	Rainfed Extension-recommended application of fertilizer and pesticides Local (open pollinated) seed variety	Improved fertilizer application Scouting High-yielding seed varieties	Drip or mechanized irrigation Covered production Soluble fertilizer Reduced application of chemicals Use of various natural enemies Border crops (cowpea)
Beans	Rainfed Extension-recommended application of fertilizer and pesticides Local seed varieties	Improved fertilizer application Scouting High-yielding seed varieties	Drip or mechanized irrigation Covered production Soluble fertilizer Reduced application of chemicals Use of various natural enemies Border crops (cowpea)
Tomato	Rainfed Extension-recommended application of fertilizer and pesticides	Raised beds Soluble fertilizer Drip irrigation Natural barriers (maize)	Drip or mechanized irrigation Covered (mesh) production Soluble fertilizer Reduced application of chemicals Use of various natural enemies Natural barriers (maize) Raised seed beds
Onion	Rainfed Extension-recommended application of fertilizer and pesticides	Reduced pesticide and fungicide application Soluble fertilizer Drip irrigation Raised beds	Drip or mechanized irrigation Covered production Soluble fertilizer Reduced application of chemicals Use of various natural enemies Natural barriers (maize) Raised seed beds
Potato	Rainfed Extension-recommended application of fertilizer and pesticides	Biological controls (trichoderma) Soluble fertilizer Improved spraying techniques (calibrated from FHIA research)	Drip or mechanized irrigation Covered production Soluble fertilizer Reduced application of chemicals Use of various natural enemies Natural barriers (maize)

As described in text, costs of production for each activity were calculated using information from a variety of sources (Buckmaster 2012). Sparger et al (2011) presents a complete description of improved spraying techniques. The natural enemies vary from crop to crop and costs were calculated based on FINTRAC budgets.

Maize and beans are profitable at much larger distances from the market compared with tomatoes, onions, or potatoes (refer to Buckmaster 2012 for specific results). Tomatoes, onions, and potatoes tend to be produced close to where they can be sold. This finding is consistent with von Thünen's theory as presented earlier. The farthest distance a vegetable crop is profitable is 34 km from the market; beyond 28–34 km, no market-oriented fruit and vegetable production will occur.

Sensitivity analyses were conducted to examine the influence of access to inputs by systematically varying the hypothetical distance to the market. Results show little sensitivity, as input transport costs represent a relatively small proportion of total production costs and only very large variations in input costs affect technology choice. Distance to the output market rather than distance to the input market drives changes in crop mix and demand for IPM technologies.

Farms that are near to or far from the market select some medium and/or high-IPM crop activities. The distant farm produces maize and beans only, but medium and high-IPM technology beans and hybrid maize produced with purchased fertilizers and pest control methods are the most profitable according to the model. Farms farther from the market have reduced access to input markets and therefore benefit from production practices that use fewer inputs (as IPM practices do). However, information access likely varies with distance to market. Distant farms have less access to information about IPM, making IPM technologies less common the farther the farm is from the market. The results suggest that if these obstacles to information can be overcome, IPM will be adopted by maize and bean-producing households far from markets. Typically, IPM information comes through farmer field schools, exposure to model farms or farmer field days, pamphlets and paper materials, and interaction with other farmers (Mauceri et al. 2007), and far farms by nature of their location have less access to these information sources. Recent research shows that farmers in developing countries are obtaining information from electronic sources, but most of the evidence is related to market access and prices being obtained electronically (Amaya and Alwang 2012). The authors are unaware of IPM being adopted widely after IPM messages are transmitted by electronic means. This is a clear area of potential promise for spread of information in the future.

Several conclusions can be drawn about the geography of crop production in western Honduras, and these conclusions have implications for the design of an IPM outreach program. First, as distance to the main road increases, production of fruit and vegetables for sale in the market decreases. Farmers nearer to markets are most likely to demand IPM technologies especially when these technologies are

Table 3. Estimated transportation costs by crop

Crop	Transportation cost	US$/truckload/km	US$/pound/KM
Maize	Base value for staple crops	0.814	0.000363
Beans	Base value for staple crops	0.814	0.00363
Tomato	Base value for vegetables + 50% cost premium	1.243 + (1.243) (0.50) = 3.00	0.000848
Onion	Base value for vegetables + 25% premium	1.243 + (1.243) (0.25) = 2.50	0.00692
Potato	Base value for vegetables	1.243	0.000554

Transportation costs were calculated using FHIA survey of 20 vegetable transporters conducted in Comayagua Valley, January through February, 2012. The assumption is the truck capacity is one ton regardless of the crop. Tomato and onion transport costs were adjusted for perishability. Estimated costs were incorporated into LP model.

Table 4. Marginal effects from probit estimates of determinants of vegetable production and vegetable sales

Independent variable	Production model			Sales model		
	Dependent variable					
	Produce (but don't sell) fruits or vegetables			Produce and sell fruits or vegetables		
	dy/dx	Std. error	P > z	dy/dx	Std. error	P > z
Time to main road (min)	0.0009	0.0005	0.042	−0.0004	0.0002	0.026
Annual rainfall (mm)	0.0002	0.0001	0.111	0.0000	0.0001	0.628
Altitude	−0.0001	0.0001	0.112	0.0000	0.0000	0.344
Household head age (yr)	−0.0198	0.0100	0.048	0.0162	0.0072	0.025
Housheold head age squared	0.0002	0.0001	0.037	−0.0002	0.0001	0.015
Total area farmed (hectares)	0.0171	0.0077	0.027	−0.0140	0.0098	0.154
Irrigation (=1 if household has access)*	−0.0997	0.0548	0.069	0.1593	0.0820	0.049
Honduras (=1 if household lives in Honduras)*	0.1527	0.0671	0.023	0.0360	0.0350	0.303
Female headed household (=1 if female headed)*	0.0611	0.0898	0.496	−0.0280	0.0243	0.249
Member of producer organization (=1 if member)*	0.0230	0.0640	0.719	0.0236	0.0293	0.422
Number of Observations = 165						

dx/dy shows the marginal effects of a change in the probability of participation (production or sales) given a one-unit change in independent variable. * is the change in probability for a discrete variable.

applicable for horticultural crops. More distant farmers may demand IPM programs for maize and beans as a means of lowering their input costs, but will not demand horticultural IPM.

Second, the econometric analysis shows that the presence of an irrigation system is positively related to fruit and vegetable market participation, holding distance to market constant. IPM extension should be geared toward areas where irrigation infrastructure exists, or located in areas where access to water is promising. This important geographical consideration can guide outreach efforts. Third, other factors including the age and gender of the head of the household head affect the probability a household participates in the fruit and vegetable market. This information can be used for further targeting of IPM education program participants.

Results from the LP analysis were consistent with the statistical analysis. The model shows that there is a specific distance beyond which fruit and vegetable production will not occur. The statistical model also showed that the more distant a household is from the market, the less likely it is to sell in the market. Once vegetables are no longer profitable, households produce staple crops for sale at market and for own consumption. Despite higher production costs, medium- and high-technology crop activities that include the IPM components for vegetables described earlier are demanded by households located relatively close to the market. More isolated farmers also demand cost-lowering technologies, but the costs of delivering the extension program to isolated farmers must be considered. The combined results show that demands for vegetable-based IPM programs are likely to be very low for farmers >28–34 km from a major market. Beyond this distance, the probability of producing fruits and vegetables for sale at market becomes very low, and IPM vegetable production technology is no longer profitable. Beyond this distance, the cost of delivering an IPM extension program clearly outweighs any benefits.

Another interesting result from the LP model is that farmers select a combination of technology levels when deciding which crops to produce. In all iterations of the LP model, a combination of low-, medium-, and high-IPM technology crop activities were found in the model's solution. This result is analogous to the stepwise procedure outlined by Byerlee and Hesse de Polanco (1986). Small-scale producers typically cannot adopt an entire IPM technology package at once. Instead they make small changes to their production processes over time. It would be prohibitively expensive for a Honduran farm household to produce all crops with high-technology processes owing to high fixed costs associated with drip irrigation and covered production (Table 2), and instead they may adopt one or several practices at a time for one or several crops, but not all. However, over time farms might gravitate toward high IPM technologies because of their productivity advantages.

This research yields important results while prompting additional research questions. These questions include—1) how does adoption of some IPM techniques lead to more complete adoption over time?; 2) what are the most effective means of promoting IPM in more distant areas; and 3) how can IPM producers brand their products to obtain higher prices in vegetable markets? Distance to the output market is clearly an important determinant of uptake of IPM. As IPM becomes more widespread in developing countries, it is important to further analyze its impact on farmers, especially the most rural and isolated. For countries with high poverty rates, policies to encourage high-value fruit and vegetable production could provide a viable pathway out of poverty.

Acknowledgments

This project was made possible by the United States Agency for International Development and the generous support of the American people through USAID Cooperative Agreement No. EPP-A-00-04-00016-00. The authors acknowledge helpful comments and support from R. Muniappan.

References Cited

Alene, A. D., V. M. Manyong, G. Omanya, H. D. Mignouna, M. Bokanga, and G. Odhiambo. 2008. "Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya." Food Policy 33: 318–328.

Alwang, J., S. C. Weller, G. E. Sanchez, L. Calderon, C. R. Edwards, S. Hamilton, R. Williams, M. Ellis, C. Suarez, V. Barrera, et al. 2005. Developing IPM packages in Latin America, pp, 71–94. In G. W. Norton, E. A Heinrichs, G. C. Luther, and M. E. Irwin (eds.), Globalizing integrated pest management: a participatory research process. Blackwell Publishing, Ames, IA.

Amaya, N., and J. Alwang. 2012. Women rule: potato markets and access to information in the Bolivian highlands. Agric. Econ. 43: 403–413.

Buckmaster, A. D. 2012. Going the distance: the impact of distance to market on smallholder crop and technology choices. M. S. thesis, Virginia Tech, Blacksburg, VA.

Byerlee, D., and E. Hesse de Polanco. 1986. Farmers' stepwise adoption of technological packages: evidence from the Mexican altiplano. Am. J. Agric. Econ. 68: 519–527.

Dorosh, P., D. Stifel, and B. Minten. 2003. Transactions costs and agricultural productivity: implications of isolation for rural poverty in Madagascar. Markets and structural studies paper 56. International Food Policy Research Institute, Washington, DC.

Fafchamps, M. 1992. Cash crop production, food price volatility, and rural market integration in the Third World. Am. J. Agric. Econ. 74: 90–99.

FINTRAC. 2012. Agricultural solutions to end hunger and poverty. (http://www.fintrac.com).

Grigg, D. 2005. An introduction to agricultural geography. Routledge, New York, NY.

IPM CRSP. 2003. Annual workplan, year 11. (http://www.oired.vt.edu/ipmcrsp/Publications/ WorkPlans/).

Instituto Nacional de Estadistica. 2007. Encuesta nacional de hogares sobre condiciones de vida (ENCOVI). (http://www.ine.gob.hn/public_html/sociales/encuestas/ine/encovi/encovi04/survey0/index.html).

Instituto Nacional de Estadistica. 2008a. Trigésima quinta encuesta de hogares de propósitos múltiples (EPHPM). (http://www.ine.gob.hn/public_html/sociales/encuestas/ine/ephpm/septiembre07/survey0/index).

Instituto Nacional de Estadística. 2008b. Estadísticas de comercio exterior, mercancias generales, período 2005–2008. (http://www.ine.gob.hn/public_html/economicas/comex/boletines/).

International Food Policy Research Institute and Plan Trifinio. 2007. Encuesta sobre condiciones de vida 2007 SET Trifinio". International Food Policy Research Institute, Washington, DC.

Jansen H., P. Siegel, J. Alwang, and F. Pichon. 2006. Understanding the drivers of sustainable rural growth and poverty reduction in Honduras. En Breve. World Bank, Washington, DC.

Mauceri, M., J. Alwang, G. Norton, and V. Barrera. 2007. Effectiveness of integrated pest management dissemination techniques: A case study of potato farmers in Carchi, Ecuador. J. Agric. Appl. Econ. 39: 765–780.

Minten, B., and S. Kyle. 1999. The effect of distance and road quality on food collection, marketing margins, and traders' wages: evidence from the former Zaire. J. Dev. Econ. 60: 467–495.

National Road Map for Integrated Pest Management. 2004. National information system for the regional IPM centers. (http: www.ipmcenters.org).

Norton, G. W., J. Alwang, and W. A. Masters. 2010. Economics of agricultural development: world food systems and resource use, 2nd edition. Routledge, New York, NY.

Ricker-Gilbert, J., G. W. Norton, J. Alwang, M. Miah, and G. Feder. 2008. Cost effectiveness of alternative integrated pest management extension methods: an example from Bangladesh. Rev. Agric. Econ. 30: 252–269.

Shaffer, R., S. C. Deller, and D. W. Marcuouiller. 2004. Community economics: linking theory and practice. Blackwell, Ames, IA.

Singh, I., L. Squire, and J. Strauss. 1986. Agricultural household models: extensions, applications and policy. Johns Hopkins University Press, Baltimore, MD.

Sparger, J. A., J. Alwang, G. W. Norton, M. Rivera, and D. Breazeale. 2011. Designing an IPM research strategy to benefit poor producers and consumers in Honduras. J. Integr. Pest Manag. 2: A1–A9.

von Thünen, J. H. 1966. Von Thünen's isolated state. *In* Peter Hall (ed.). Pergamon Press, Oxford, United Kingdom.

Wooldridge, J. M. 2009. Introductory econometrics: a modern approach, 4th ed. Mason, South-Western, New York, NY.

Received 27 June 2013; accepted 17 February 2014.