MODELING DIVERSE LIVELIHOOD STRATEGIES IN RURAL LIVELIHOOD SYSTEMS USING ETHNOGRAPHIC LINEAR PROGRAMMING

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Abstract

Although world population is becoming increasingly urbanized in percentage terms, absolute numbers of small-scale, resource-limited farm families continue to rise. Development efforts must continue to focus on this numerous and vulnerable sector. Strategies for survival of individual households in these livelihood systems are highly diverse. Adding to this diversity is that these households are first homes, not businesses, so goals are different from those commonly used in economic analyses. Because of the diversity and their limited resource base, the use of averages seriously overestimates aggregated potential response. In this article, we present a methodology, Ethnographic Linear Programming (ELP), designed specifically to aid in understanding and examining potential improvements for diverse rural livelihood systems. Ethnographic methodologies for data collection reduce or eliminate the need for making assumptions. For this reason, different household characteristics, primarily household composition, found in the livelihood system are built into model(s) so that results more accurately reflect the diversity found in the livelihood system. Conclusions are based on the differential response of households to the different alternatives being tested rather than extrapolating from averages. ELP is a cost-effective way of understanding varied household responses to potential changes such as introduced production technologies, infrastructure availability, and governmental policies, as well as to shocks. ELPs are constructed on standard computer spreadsheets and are user friendly. Although other objective functions may be appropriate, we have found that one of the most useful is maximization of discretionary cash subject to household food security and other minimum or maximum constraints. Household composition, seasonality of activities and gender issues of access to and control of resources are important considerations. Coefficients for these are elicited using participatory methods. Dependable yields reported by farmers are used rather than averages or expected yields. ELP is a useful tool for agricultural researchers and technology developers, policy makers, and managers of infrastructure and natural resources to help them understand the varied potential responses of diverse households to proposed modifications. ELP is a dynamic, adaptive methodology that has evolved through an iterative trial and error process. It will continue to change but is sufficiently robust to be more broadly disseminated and used. The methodology is a working tool applicable to ex ante evaluation of proposed changes and has been used by researchers in a number of countries and for several purposes.

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1. Introduction

Individual households in peasant livelihood systems are highly variable and not well suited to being averaged into typical or representative cases such as often used in analyzing them in development studies. Adding to this diversity is that these households are first homes, not businesses, so goals are different from those commonly used in economic analyses. Economic analyses of business enterprises consider that all resources contribute to the production of the business product or products and the basic objective of the firm is profit maximization. Because the peasant household is first a home, there are many more objectives to be considered than just that of "profit." Further, in peasant households, a significant portion of household resources are consumed in *reproduction* activities, so are not available for *production* activities. Reproduction activities are those involving the maintenance of the home, the household and its members. Included in most households are such tasks as food preparation, child care, washing clothes, fetching water and firewood, collecting wild plants for food or medicine, and tending small animals and home gardens. These tasks are often, but not exclusively those of women and children, and time required varies with household composition. For this reason, these activities must be explicitly accounted for in household models.

In our context, a *livelihood system* is considered to be the composite of all activities available to all households in the system from which to choose to secure their livelihoods. Livelihood systems are not synonymous with communities or regions because different households within a community may have available different activities for reasons of wealth, religion or caste. It is important to recognize these differences and to create models that are livelihood-system specific. The activities that an individual household selects from among those available in its livelihood system are the *livelihood strategies* of that household and are household specific. Within a livelihood system, households with similar composition would be expected to have similar livelihood strategies.

Because most people who undertake economic analyses are not from peasant households, the first function of modeling these systems is to *understand* 1) what is done, 2) who does what, 3) when it is done, 4) why it is done, and 5) how it is done. Assumptions, commonly used in economic modeling to substitute for missing data (or knowledge) (Just, 2002) inevitably lead to erroneous solutions and conclusions because the assumptions are based on an inadequate understanding of the system being modeled. In ethnographic linear programming (ELP), ethnographic methodologies for data collection reduce or eliminate the need for making assumptions. When models do not conform to what is being observed in the field, the modeler works with the households being modeled to ascertain what has created the unrealistic results, and adjustments are made based on the new ethnographic data (knowledge) rather than on assumptions, which often artificially adjust the model so results conform to preconceived concepts of what the system should be.

With the wide availability of laptop computers, modelers can take their models to the field to validate and calibrate them directly with the subjects involved. Once the model or models are calibrated and validated, that is, they reflect the reality found in the field, they can be used for testing alternatives such as potential improved infrastructure, different policies or new technologies. But because of the diversity among peasant households and their limited resource base, the use of averages seriously overestimates aggregated potential response. For this reason, different household compositions found in the livelihood system are built into the model(s) so that results more accurately reflect the diversity found in the livelihood system. Conclusions, then, will be based on the differential response of households to the different alternatives being tested rather than extrapolating from averages.

2. Background

A linear program (LP) is a mathematical "optimizing" procedure that has been used more than half a century (Dorfman, 1951) to maximize or minimize an objective, subject to a set of constraints. LP models have been used extensively to formulate farm plans to search for the optimal solution to a problem of allocating constrained resources—typically land, labor, and capital—to various alternative means of production.

Linear programming mathematically can be stated as:

Max (or Min): $\Pi = \Sigma_j C_j X_j$ (j = 1 . . . n)
Subject to: $\Sigma_i A_{ij} X_j <= R_i$ (i = 1 . . . m)
And $X_i >= 0$

Π is the variable objective to be minimized or maximized, C_j is the cost (debit) or returns (credit) of each of the n activities X_j , A_{ij} is the set of input or output coefficients for each activity j and resource or constraint i, and R_i is the set of m minimum or maximum constraints or restrictions.

When agricultural economists began using LP models in the 1950s (Heady 1958; Hildebrand, 1958) they used them to model farms to show farm managers how they could better allocate their resources and thereby increase profit. These models were normative in nature; the modelers anticipated telling farmers what they "ought to do" when the solutions to the models differed from what the farmers "were" doing, which was usually the case.

As it concerns household livelihood decision-making, linear programming is a basic tool for economic analysis of small farm livelihood systems (Hildebrand and Sullivan 2002). In livelihood systems LP models, the optimal solution often involves a combination of goals such as maximizing cash available for discretionary spending after meeting other household goals which may include food security, education expenses, etc. (Bernet et al. 2001, Hazell and Norton 1986, Pannel 1997). By producing an LP model that represents a real-world livelihood system, it is then possible to run relatively inexpensive assessments of both policy scenarios and project ideas generated by extension agencies, infrastructure managers and policy-makers (Bernet et al. 2001, p.184). In this way researchers and extension agents can test production alternatives in the virtual livelihood system of the linear programming model. This provides an estimate of how the real world might respond—as seen through a change in resource allocation decisions (livelihood strategies) (Hazell and Norton 1986, Pannel 1997). This is done by adding alternatives to existing activities to assess the likely reaction of farmers when presented with new technologies, markets or shocks (Mudhara 2002). Thangata (2002), working in Malawi, studied labor scarcity with regards to improved fallow adoption. The novel element of his work was the incorporation of the effects of HIV/AIDS on labor availability and agroforestry adoption.

3. Ethnographic Linear Programming

3.1 Introduction

Because a livelihood system is the composite of all activities available to households in the system from which to choose to secure their livelihoods, it is the livelihood system that forms the basic matrix of the ELP. This facilitates data gathering because the basic matrix is common to all the households in the system.

3.2 Basic matrix

*3.2.1 All available on-farm and off-farm **production** activities*

Crop and livestock production activities conducted on the farm are included in this category as are activities off the farm such as hiring out labor, working for another entity, production of remittances, etc.

*3.2.2 All common **reproduction** activities*

Reproduction activities are those that contribute to the maintenance of the household and its members.

3.2.3 All available resources (land, labor, water, bush, cash) and constraints to be met (food, cash, other household goals)

Most limited resource farm households face similar kinds of constraints (land area, household labor availability, hired labor availability, consumption requirements, cash needs, markets, water availability if they have irrigation), but the degree that these constraints are binding on household options vary with the specific circumstances of each household. Some (water, markets, hired labor, and sometimes land) are exogenous to the household and are fixed in quantity, quality and/or capacity. Others are endogenous to the household (household labor, consumption requirements, cash needs, and sometimes land) and vary over time with household composition.

The main goal of most limited resource farm households is to meet minimum household consumption requirements (including food, clothing and shelter) in an endeavor to reproduce the family unit. Sometimes education for the children is included. Beyond the necessities of life, the farmers may wish to maximize discretionary cash for purchase of items that are desirable but not necessities. Other goals of a household to be maximized or minimized for various reasons may be: minimize male labor, maximize the production of a particular crop, etc. These goals can be included in the model as fixed minimum or maximum constraints or one at a time can be incorporated in the objective function to be minimized or maximized.

Seasonality or periodicity is important in small farm livelihood systems. Labor and cash resources should be considered at least by semester. Smaller divisions such as month or week may be necessary in some cases. Labor and cash need to be disaggregated at least into two semesters and for different types of labor. Expenses usually are incurred at the beginning of the respective period, and income is generated at the end of the period.

*3.2.4 Common coefficients used in the matrix (amount of resources used or product derived from each **production and reproduction** activity)*

Input and output coefficients (a_{ij}s) for each of the production and reproduction activities will generally be quite similar within a given livelihood system and usually can be obtained using focus groups or in-depth interviews of farmers. Information is needed on inputs required, source, cost if any, and time of acquisition. In ELP we use coefficients consistently reported by farmers. The amount of time required to prepare, plant or weed an acre or hectare of a crop or care for animals and who in the household is involved (is it a man's job, a woman's job, a child's job) will be similar, particularly in households with similar household composition. Time and other resources required for reproduction activities such as food preparation, washing clothes, tending children, etc. are also similar. However, the same operation in production activities may be different for different kinds of soils, types of households, ethnic groups, etc., and should be recognized. Also, coefficients for reproduction activities often vary with household composition and must be modified for each household. ELP is flexible enough to account for variation in individual farmer practices by incorporating them as separate activities. For example, if different kinds of soil are managed differently and produce different yields, each should be a separate activity.

Data should be obtained separately for each perennial crop or crop association the household pursues and on a per unit of land area basis or per plant basis, if appropriate (for instance, in the case of some trees). Numbers needed are the same as for annual crops. Additionally, number of years before the crop produces is important information.

The same data needed for annual crops are required for each kind of animal activity the household pursues and on a per animal (or herd, flock, etc.) basis. Additionally, data for death loss, birth rate, weaning rate, etc., must be gathered.

All data elicited for other activities (annual and perennial crops, animals) should also be gathered with regard to forest, bush or body of water. These might include extraction of firewood, medicinal plants, or food stuffs in time of shortage, etc. Ownership (community, ejido, tribe, other) should be explored, as well as traditional or locally accepted standards for use of these resources.

Particular attention must be paid to seasonality of strategies within each livelihood system. Researchers can expect fluctuation of everything from consumption to labor availability throughout the year. In addition to understanding what fluctuates, the temporal dimension of these changes must be recognized; for example a hungry season, months when school is in session, time when men migrate to find work, etc. This seasonality can and must be incorporated into to the model to ensure adequate simulation. Essentially all aspects of the model are subject to seasonal fluctuation. Recognizing and accommodating this in the model is crucial to ensuring adequate simulation of livelihood systems.

Yields that are dependable or can be "counted on": implicit risk.
It is necessary to know and include in the model the amount produced of each usable product, when it is available, how it is used, and who has control of and access to each usable product to determine 'whose' account receives benefits.

One of the most difficult things to ascertain, yet crucial for simulating livelihood systems, is the 'dependable' yield, or yield that farmers 'count on' for their basic food crops. It is conventional to ascertain and use "usual" or "average" yields when analyzing farm systems. Even though this seems logical, it is not the measure of productivity that will provide good descriptions of these households, nor the one used by farmers. Farmers cannot depend on "average" yields; they know that often yields will be below "average." For basic food crops, they calculate area to be planted based on a yield level that will occur with greater frequency. They may, for example, want to plant a large enough area so that they can feed the household 90% of the time, or nine years out of ten. The yield level that meets this criterion will be much lower than average yields widely accepted in economic analyses. This dependable lower yield level is what farmers can "*count on*" most of the time (Figure 1). Because this is the yield level farmers use for planning how much land to plant to their basic food crops, this is the level that must be used in the ethnographic linear program model. Allan (1965) recognized this situation in what he termed the production of a 'normal surplus' of food in the average year.

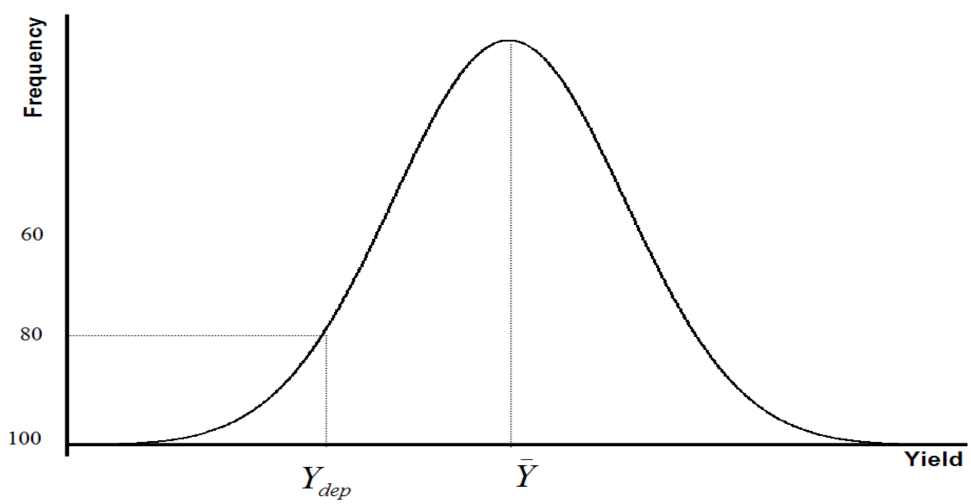

Figure 1. Dependable (Y_{dep}) versus average yield.

It is more difficult to obtain an estimate of dependable yield than of average yield. One way found to be useful is first to find out how much of the basic food crop (or crops) the household needs for a year's supply (for an annual crop) and then ask about how much land is usually planted to this crop. Another would be to ask about how much land is planted to the crop and then ask about how much product they need from this land most of the time.

Prices

Prices of products sold are often taken from local markets, or worse, national data. For farm products purchased at the farm gate, the price paid to the farmers at that point (if commonly used by farmers in the livelihood system) must be used. If farmers take the products to a road or waterway where buses, trucks or boats pass by then the price paid the farmers at that point, or the charge for taking the farmer and his/her produce to a market must be taken into account. The time required for marketing farm produce must also be considered. This is not charged as a cash cost but rather as time used by the relevant person or persons in the selling activity. Sometimes farmers are not paid at the time of transaction, but must wait days or weeks to be paid. This affects seasonality of cash flow so must be taken into consideration in the model. The additional labor for returning to the source of the cash must also be considered.

Local market prices of items purchased by farmers are probably relevant, but cost of getting some of these items to the farm must also be considered.

Credit

Costs of credit are complex. Farmers often pay very high interest for credit supplied by local money lenders simply because of convenience or lack of other real alternatives. Transaction costs for formal credit often include the labor costs of multiple visits to the lending agency, first for purposes of formalizing the loan application, and second, to return for the money if the application is approved. If a formal credit scheme is to be considered, these costs must be taken into account as they can require cash (for bus fare, for example) as well as lost time away from the farm.

Units

In talking with limited resource farmers, care must be taken to assure that all units are completely understood. Local usage of weights (quintal, kg, lb., ton) or volume (bushel, fanega, almudes, latas) must be conversed with the farmers in their own language. Conversions can later be used (or not) to scientific notation units to be acceptable to professional journals.

Labor

Labor required during each period, disaggregated by gender (usually sufficient: male and female children, male and female adolescents, male and female adults), in terms of who performs which activities. It is important to obtain data that reflect each step (land preparation, seeding, weeding, harvest, etc.) in each activity. These data must account for alternative types of households, such as female-headed or multi-generational, as well as any activities undertaken by hired or exchange labor.

The concept of the eight-hour working day is uniquely Western and Northern. Local peoples have different ways of describing and understanding the length of a working day. It may vary depending on effort (toil) expended, length of walk to reach working place, opportunities for gathering fruits vegetables, firewood or water on the way home, etc. A day could be 4 to 10 hours long. This must be taken into account. A day's work may vary depending on whether a person is working his or her own land rather than as a laborer for another farmer. Food may or may not be included when wages are paid. Boys and girls begin working in the fields or with livestock at different ages in different cultures. Time spent on farm tasks usually varies when school is in session and when not (seasonality). Likewise, children help with household chores. The age at which this begins, as well as time spent daily is important to know. Observations, focus groups, informal interviews, and participatory tools including games, are useful for obtaining as well as understanding these data.

Land area

The amount of land a farmer owns as well as how much he or she farms is important to know. Land in use may vary from one season or one year to another. Differential time required for different tasks (on one or various fields) should be explored and incorporated into the model. It is also quite common for farmers to rent fields, and this is relatively easy to incorporate into models. Local rates, as well as if payment will be made in cash or kind should be known. Time required to travel to distant fields must also be accounted for.

The above provides the information for the basic input/output matrix of the livelihood system, which will be common to households sharing the same livelihood system.

3.3 Household-specific information

Constraints such as land area, labor availability, consumption requirements, cash needs, and goals such as to meet food needs for the household, maximize discretionary cash, minimize male labor, maximize production of a basic food crop are highly diverse from farm to farm even in a relatively homogeneous area and depend to a large extent on household composition. So after the information for the basic matrix is collected, it is necessary to begin being specific.

Perhaps the most efficient means of constructing the ELP model after the basic input/output coefficients have been estimated is to select a willing household whose farming practices reflect those in the basic matrix and model that specific household. The process is to obtain information from the household members individually and as a group on all the relevant activities and constraints. This must be specific enough to identify 1) who eats how much of each kind of food; 2) who can use cash from various sources; 3) what are the necessary cash expenses for the household; 4) when during the year must cash expenses be made, and who is responsible for each; 5) what each member of the household does; and 6) how much time is spent doing it, on a monthly or other relevant periodic basis. *Some of the reproduction activities will take more or less time as household composition varies. These coefficients in the basic matrix are variable as household composition changes so they will need to be varied for different households.* It is important to note alternative types of households such as female-headed or multi-generational in terms of who performs which activities, when, and how. Seasonal cash accounting is critical and must include remittances from persons who work off the farm whether or not in residence. Frank discussions with the household members may be necessary to elicit goals of individuals within the household.

Given the wide availability of laptop computers, the complete descriptive model of a specific household can be constructed and modified as these discussions are going on. Often inconsistencies can be spotted when the model is infeasible or the solution is inconsistent with what is known or described.

Interviews reveal the amount of land available for each kind of use (upland, lowland, irrigated land, pasture, bush, fallow, orchard, forest, etc.), and who controls the land and who has access to it. Land tenure should be explored as it could have important credit and other implications.

When irrigation is an option, indications of the adequacy of water are necessary. Area of land irrigated in season is one indication and would probably provide the most usable coefficient for the matrix. But it is important to recognize that farmers probably are spreading the water to the maximum amount of land rather than applying it at a rate to maximize production per unit of land area.

Data should be obtained separately for each annual cropping activity or crop association the household pursues, based on their measurements, to be converted later if necessary.

3.4 Infeasibilities in the model

Infeasibilities (no solution possible) can be the result of several problems in model specification. Perhaps the most common are the overstatement of food and cash needs that reflect wants rather than needs. If the food and cash needs are set at unrealistic levels then infeasibilities can easily occur, or else the solution does not reflect the livelihood strategies of the household being modeled. When this occurs, limitations within the system such as minimum cash required and/or food consumption can be reduced iteratively to see which is more constraining. In the case of cash, once the model returns a feasible solution, it indicates that the particular household is living with less cash than reported. In the case of food, if the model gives an infeasible solution, it means that particular household is eating less than commonly understood or reported. Gough (2002) in a study conducted in Malawi, found that although many individual household models were infeasible with reported consumption levels, when the model was scaled up to the community level, there was enough food for all. These results may be a good indication of the existence of local safety nets, sharing, and long-term exchange at the village level.

3.5 Calibration and validation with other households in the livelihood system (using Visual Basic)

When the ELP model adequately describes the first household, the model can be run with data from another household as part of the process of simultaneous calibration and validation. Considerably less time will be required in interviewing subsequent households than was required for the first. Note that the term "adequately" is subjective. The model should reflect the correct strategies (that is, the correct activities of the modeled household). The magnitude of each activity should be relatively close to what the actual household does but it should not be expected that they would be exact. Exactly meeting the magnitude often means that an artificial constraint has been built into the model. If that was necessary for the model to describe the household then one or more constraints are usually missing or the magnitude of an input/output coefficient is incorrect. More discussions with the members of the household will be required.

The composition, requirements and constraints of this second household should be different from the first, but share the same livelihood system. If the first ELP adequately reflects the livelihood system being modeled, changes in the subject household should only require changing the household composition. This, of course would change household consumption requirements, cash needs and labor availability as well as the variable coefficients in some of the reproduction activities. Land area may need to be changed if the second household is larger and has more labor resources than the first. The solution to this ELP model should be close to what this second household actually does. This is normally a subjective call when working in the field.

A limited number of additional households of diverse compositions should also be modeled in this process of calibration and validation. The model can be considered validated when it adequately simulates or describes each of these diverse households. This type of participatory calibration and validation has been carried out by several researchers in Zimbabwe, Malawi and Ecuador with good results.

Building an applied model is a continuing process, and the most successful models evolve through time to take into account new findings. There never is a definitive version, but rather at any moment in time the model represents a kind of orderly data bank that reflects both the strengths and limitations of the available quantitative information. Through validating the model, information is obtained about its structure and while judgments on the model's adequacy must be made, it also is important to continue to improve the model

In the case of data reconciliation, it may not be obvious which parameters are the causes of inaccuracy. Crop outputs that are higher than reality may be caused by (1) overestimates of yields or crop prices for products sold, (2) underestimates of input requirements, (3) underestimates of input prices, (4) yield and input errors for competing crops, or (5) overestimates of resource availability. The last factor, however, is likely to be the cause only if there is a systematic overstatement of production across all products. Each of these factors may be worth investigating.

Each adjustment and the reasons behind it must be documented. Arbitrary adjustments in parameter values, with the aim of improving the model's fit, should be strictly avoided. The initial version of the model has to be documented, and then each subsequent change should be recorded along with the reason for the change. It is far preferable to have an unsatisfactory fit, but a clear documentation of the model's development, than a better fit but arbitrary parameter values. Among other things, a model with arbitrary adjustments does not provide a basis for future work and extensions. This aspect of the work is stressed because it is an area where slips frequently occur with large models if only because the model builders are under time pressure. Rules for altering the model after the initial validation attempt should be (1) to change the model only if further investigation yields new information, and (2) to document all changes. If done in this spirit, the validation process can lead to a better model.

4 Testing alternatives in a livelihood system and aggregating with diversity

Once the model is calibrated, it can be used for hypothesis testing or pre-evaluation of potential technologies, activities, infrastructure or policies. The new option under consideration is *added* to the matrix so that the ELP solves for the desired objective function when the proposed new option is in competition with existing farm activities.

Governments often make policy decisions without taking into account how they may affect different sorts of farm households. For example, a decision could be made to import fertilizer, and credit for farmers could be tied to its use. However, the application of fertilizer would require additional days of labor. In this case, a column for the new activity is added to the matrix (fertilized maize, for example), without eliminating the type of maize production already present in the model. The model can then be solved for a number of households with different compositions to estimate the impact on different kinds of households. Aggregating on the basis of the relative frequency of these types of households in the livelihood system provides a much better estimate of potential effect than if only an "average" household were aggregated for this purpose.

5 Conclusions

Ethnographic linear programming, which combines methods from anthropology and economics, is a useful tool for agricultural researchers and technology developers, policy makers, and managers of infrastructure and natural resources. It can help them understand the varied responses of diverse households to past or potential future modifications. ELP is a dynamic, adaptive methodology that has evolved through an iterative trial and error process. It will continue to change but is sufficiently robust to be more broadly disseminated and used. The methodology is a working tool applicable before and during projects, rather than as an analysis tool for obtaining static results after the fact.

In its developing stages ELP has been used for a number of applications by researchers in the areas of rural development and natural resource management, and it is amenable to other uses. For example: Cabrera (1999) assessed the potential adoption of asparagus among small farmers in Perú; Kaya et al. (2000) assessed potential adoption of improved fallows in Mali; Litow (2000) assessed the potential impact of *milpa* production by small farmers on deforestation in the Maya Biosphere Reserve in Guatemala; Breuer (2000) assessed the potential for medicinal plant production in Paraguay; Bastidas (2001) assessed the impact on small farmers of potential changes in irrigation water availability in the Andes of Ecuador; Mudhara (2002) and Thangata (2002) assessed the potential for improved fallow adoption in Zimbabwe and agroforestry in Malawi, respectively; Breuer(2003) assessed sustainability, food security and improved worker livelihoods in an Ecuadorian agrosocioecosystem dominated by banana plantations; Pluke (2004) assessed the potential for improving Integrated Pest Management research based on improved understanding of the livelihood system of small farmers in Puerto Rico; and Bellow (2004) assessed the differential impact of fruit-tree agroforestry in two small farm communities in Guatemala.

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