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PARTICIPATORY EVALUATION OF SUSTAINABLE LAND USE AND TECHNOLOGY ADOPTION IN TWO AGROECOSYSTEMS

[EVALUACIÓN PARTICIPATIVA DEL USO SOSTENIBLE DE LA TIERRA Y ADOPCIÓN DE TECNOLOGÍA EN DOS AGROECOSISTEMAS]

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SUMMARY

In order to identify the main agroecosystems, their limiting factors and adequate technological options, participatory approaches, such as community ranking, were used in a micro-hydrological basin in Central Oaxaca, Mexico. This area is characterized by small farm size (1-2 ha), low input agriculture and low standards of living. The results of a pretested survey were presented at community meetings and were subjected to discussion to rank the problems found in order of importance. Overall, the main production constraints were: low soil fertility, insect pests and plant diseases, lack of rain and soil erosion. After field evaluations of several sustainable technologies, the following was found: a) organic mulching can reduce soil erosion, weeds and conserve soil moisture, b) intercropped green manures with maize could be a mean to improve soil fertility while still allowing producing this staple crop, c) composting of crop residues with weeds and farmyard manure was also promoted amongst the peasants, but only a few of them adopted this practice due mostly to high labor requirements and d) even though it is an expensive technology, the use of floating row covers to produce tomatoes and hot peppers was quickly adopted by the peasants. It was concluded that the best way to convince the peasants to adopt a technological innovation is to show them that it works under their own circumstances.

Key words: participation; coal; oxen teams; maize; beans.

RESUMEN

Con el fin de identificar los principales agroecosistemas, los factores limitantes y opciones tecnológicas adecuadas, se utilizaron enfoques participativos, como jerarquización participativa, en una microcuenca hidrológica situada en el centro del estado de Oaxaca, México. Esta zona se caracteriza por el tamaño de las pequeñas explotaciones (1-2 ha), la agricultura de bajos insumos y los bajos estándares de vida. Los resultados de una encuesta preliminar se presentaron en las reuniones de la comunidad y fueron sometidos a discusión para clasificar los problemas en orden de importancia. En general, las principales limitantes de la producción fueron: baja fertilidad del suelo, plagas y enfermedades de las plantas, sequía, y erosión del suelo. Después de evaluaciones en el campo de varias tecnologías sostenibles, se encontró lo siguiente: a) la cobertura del suelo con residuos de maíz puede reducir la erosión del suelo, malezas y a conservar la humedad del suelo, b) la intercalación de abonos verdes con el maíz puede ser un medio para mejorar la fertilidad del suelo al tiempo que permite la producción de éste cultivo básico, c) el compostaje de los residuos de los cultivos, hierbas y estiércol también se promovió entre los agricultores, pero sólo unos pocos de ellos han adoptado esta práctica debido principalmente a las necesidades de mano de obra y d) a pesar de que es una tecnología cara, el uso de cubiertas flotantes en hileras para producir tomates y pimientos picantes, fue rápidamente adoptado por los agricultores. Se concluyó que la mejor manera de convencer a los agricultores a adoptar una innovación tecnológica es demostrarles que funciona bajo sus propias circunstancias.

Palabras clave: participación; carbón; yuntas; maíz; frijol.

INTRODUCTION

An agroecosystem can be defined as a spatially and functionally coherent entity of agricultural activity, and includes the living and nonliving components, as well as their interactions (Gliessman, 2000). However, an agroecosystem not only affects the site of agricultural activity, but also the region where is located. Water is one of the main production factors in most agroecosystems and moves from the micro catchment level to the hydrological basin level; therefore, the micro-hydrological basin is the minimum study area to be used. This leads to the concept of hierarchical systems, where each level is represented by a set of functional subsystems and where the products of one can be the inputs of other subsystems (Hart, 1984).

Many traditional agroecosystems are considered sustainable, but there are not many scientific evaluations to support this affirmation (Brunett *et al.*, 2005); some are considered sustainable because they have passed the test of time. A sustainable use implies that the resources will be managed in such a way that they can still provide goods to future generations and a sustained yield is achieved (Gliessman, 2000). Furthermore, the system's production has to be distributed as equitably as possible in order to guarantee a sustainable development.

As previously mentioned, the identification of the main crop-production constraints in the agroecosystem is one of the critical steps for agroecosystem's improvement. An approach for production system`s diagnosis is the so called "farmer first" approach, a form of Participatory Rural Appraisal (Chambers, 1994). While many considered farmer first thinking as a step in the right direction, some argued that the approach failed to consider the socio-cultural and political economic dimensions of knowledge creation, innovation, transmission and use within rural societies and scientific organizations. Guijt and Cornwall (1995), found that the methodology was not applied correctly in many cases, the main issue was that the people did not actually participate in priority setting or in the subsequent actions to be taken.

Therefore, when applied in a simplistic, populist manner, participatory strategies encounter the same sorts of problems as other interventionist approaches. No matter how firm the commitment, the concept of powerful outsiders helping powerless insiders is always present (Scoones *et al.*, 2007). Since embracing participatory methods from the late 1980s, scientists and a variety of public and private agencies have encountered both successes and failures. However, recent evidence shows that participatory methods can generate quantitative data which are useful to determine local priorities and potential for innovation (Mayoux and Chambers, 2005).

Ashley *et al.* (1989) and Pretty (1997), have proposed that the peasants themselves evaluated the technology and decide which was the most suitable. Thus, a menu of sustainable technologies could be subject to validation in the farmer´s fields.

Many of the technological innovations generated to increase the well being of peasant peasants and for conservation of their production resources have been frequently not adopted in Mexico. Some examples in Oaxaca are fertilization of rain-fed maize (Ruiz, 1987), the introduction of improved varieties in low rainfall areas (Ruiz, 1990) and the construction of bench terraces with heavy machinery. These technologies were not adopted because: a) they did not address the most limiting factor and/or b) the peasants did not receive proper training on the new technology or b) the new technologies did not fit well within the farmer's agroecosystem.

However, there are a few successful cases. One of these is credited to Bunch and Lopez (1995), who found that contour grass barriers, use of organic fertilization and crop rotation were successfully introduced in the San Martin Jilotepeque area in the Guatemalan highlands. Contour ditches and side-dressing of nitrogen fertilizer in maize were used as starting technologies to motivate people. This is an example of how technology that addresses the main limiting factors and fits into the agroecosystem is readily adopted. The agriculture practiced in San Martin Jilotepeque is considered traditional and for self-consumption.

The State of Oaxaca, where this study was carried out, is characterized by peasant agriculture, low use of modern technologies and low general development. In this state, there are 7210 human settings, but about 80 % of them have less than 500 inhabitants (INEGI, 2009). These peasants carry out a variety of activities, including the cultivation of staple crops (*Zea mayz, Phaseolus vulgaris* and *Cucurbita pepo*), forest exploitation, small cattle rising and non-agricultural activities. The Central Region is crossed from N to S by The Atoyac River, which flows mostly during summer and fall. The SW basin of the river is represented mostly by the San Bernardo River and The Valientes River, forming the SW micro-hydrological basin of the Atoyac River (SWAR). This area covers some 70, 000 ha, and includes about 7,000 ha of temperate forests.

According to Valdés-Rodríguez *et al.* (2011), to facilitate the process of technology adoption, the UNDP has developed a methodology that allows for the design and evaluation of sustainable livelihoods through five steps, which include a participatory appraisal to determine the adaptive strategies of the people and a study of the potential of technology and science to complement indigenous knowledge. This study included these parts of the UNDP approach.

Using field surveys and Participatory Rural Appraisal (PRA) methodologies, this study was carried out in the SWAR with the following objectives: the characterization of the main agroecosystems (AE) present, the identification of their production constraints, and the evaluation and promotion of sustainable production practices (Pretty, 1995) for AE's improvement.

MATERIALS AND METHODS

Considering several criteria; including population size land tenure conflicts and road accessibility, two communities out of twelve present in the SW microhydrological basin of The Atoyac River were selected. These were San Lucas Tlanichico and Magdalena Mixtepec.

To give an idea of the environmental conditions in the study area, some agroecological parameters of these communities are presented in Table 1.

A pretested survey was applied to 10 % of the homesteads (N = 290), and the results were used to identify the main agricultural activities, local technology, and production problems. In most cases, the informers were the peasants, which were located at work in nearby fields. According to their registered frequency, the production problems were ranked. Afterwards, these problems, and others not perceived during the survey were ranked again during at least two community meetings per site. After the results of the survey were presented, the peasants were invited to propose other problems and to participate in the ranking process; every farmer was allowed to vote only once. These meetings were promoted one day in advance and lasted about 90 minutes per session. Even though everybody in the community was invited, women participation was low.

In order to tackle some of the main production constraints, field experiments on recognized sustainable technologies were carried out in both localities. The feasibility of intercropping green manures (soybeans, chickpeas and wheat) with maize was evaluated, as well as the use of maize stubble for mulching rain-fed peanuts. Composting of crop residues with farmyard manure was also promoted, and the use of floating row covers (Agribon e™, PGI-Bonlam México, SA de CV) was evaluated in tomatoes and hot peppers. These experiments were established in randomized block designs with 6 replicates and the data were subjected to analysis of variance and Tukey's test for comparison of means.

RESULTS AND DISCUSSION

Agroecosystems present

In Magdalena Mixtepec, all the peasants surveyed planted staple crops (maize, beans and squash) and also exploited the forest to get firewood and to make charcoal. About 86 % were producing passion fruit *Pasiflora edulis* and 50 % of then had some peach trees *Prunus persica* at home. About 15 % of the peasants produce horticultural crops and 40 % of them declared to have goats and sheep. This agroecosystem (AE) was called Staple crops-Firewood and charcoal-Passion fruit (S-F-P) and was present in at least eight communities of the SWAR.

In the S-F-P agroecosystem only 27 % of the peasants applyied farmyard manure to their land. The main reason was the scarcity of the product, as there are not many oxen teams due to the steep slopes of the land. The scarce manure produced is kept in the open. Most peasants have practiced slash and burn agriculture in communal lands. About 60 % of the peasants recognized to have some degree of soil erosion for using this practice. A few peasants have built stone faced terraces, which can be considered as a local technology. This practice was more common in land under irrigation.

From the standpoint of income, the decreasing order of importance of the different sub agroecosystems is: charcoal and firewood, staple crops and passion fruit production. This means that there is a year round extraction of wood, which has resulted in more time to reach the areas where it is possible to find *Quercus* sp. to make charcoal. Also, some peasants practice clandestine logging, as it is not permitted to cut whole pine trees, except for construction purposes. However, once in a while, the community may decide to sell a few hundred trees to local logging companies.

In San Lucas Tlanichico, all the surveyed peasants planted peanuts and staple crops, and 80 % have an oxen team for their draught-power requirements. About 50 % of them was selling minor cattle (poultry, pigs and goats) occasionally. This FS was named the Peanuts and staple crops - Oxen teams - Minor cattle agroeco system (P-O-M). This AE is common in at least six communities of light textured soils of the SWAR.

Table 1. Agroecological parameters of the communities selected.

Community name	Altitude (m)	Mean yearly Temp. (° C)	Yearly rainfall (mm)	Slope (%)	Soil Units*
Magdalena	2100	19.5	670	15-100	Cambisol
San Lucas	1585	21.0	930	2-15	Regosol

* Soil classification, FAO (1998).

In the P-O-M agroecosystem most peasants used sustainable practices such as application of farmyard manure and crop residues, and crop rotation. Most of the manure comes from oxen teams and crop residues of peanuts or beans are either brought back to the field or fed to cattle. Some peasants, however, burn these residues in the field. The most common crop rotation is maize-peanuts-maize, as they know that continuous maize shows decreased yields after two years. Terracing on gently slopes has been promoted over the years by means of mechanic plowing or by the use of wooden plows drawn by oxen teams.

The decreasing order of importance of the different subsystems is: Oxen teams, peanuts and staple crops, and minor cattle. Peanuts represent the cash crop, as most is sold to local dealers. The oxen teams are sold every 2-3 years to the butcher as they become badly tempered.

In both localities it was common that during the dry months (December to March), the peasants look for work in Oaxaca city or they even emigrate to the USA.

Validation of Problems and ranking

Discussions and voting about the main problems during community meetings showed that in the S-F-P agroecosystem the most important problems were: insect pests, low soil fertility, drought and diseases affecting horticultural crops. According to the survey, the second most important problem was soil erosion. Even though they admitted that the land yields scarcely after three years of maize cultivation, they did not recognized soil erosion as a problem. During the field visits, however, it was evident that the soil was being washed away. After talking with individual peasants latter, it was clear that some were concerned about soil losses and showed interest on the evaluation of a planting method where the slashed vegetation were left unburned.

In the P-O-M agroecosystem there was a closer agreement between the results of the survey and the ranking carried out at the community meeting. The top three problems were drought, insect pests and cattle diseases. Again, the research team was concerned about soil erosion, but the peasants ranked it fifth, while poor soils and crop disease where both ranked in the fourth place. The reason for a closer match in rankings may be that the community surveyed for this system is more open and developed than the one surveyed in the other AE.

Evaluation and promotion of sustainable technologies

Several demonstrations about composting of crop residues and manure were carried out with peasants in both AE. In some cases, weeds and forest litter were also used. After the demonstrations, however, only one farmer in each community had the initiative to make his own compost. The compost produced was used mostly to fertilize their backyard garden, where they produce a variety of crops. Some of the reasons for the low impact of this technology include the scarcity of crop residues, high labor requirements for cutting crop residues for better decomposition, and relative availability of inorganic fertilizers.

Mulching peanuts with grinded maize stubble gave higher soil water contents, especially during a year with early season drought. This resulted in a higher number of pods per plant, seed weight, total plant weight and yield per plant (Table 2). In terms of kg/ha of shelled seed, the plot with mulch out-yielded the un-mulched one by 428 kg/ha.

Regarding the production of green manures in intercropped with maize, it was seen that dry matter yields were 30 % smaller than the observed when these were grown as monocrops. The legumes tested yielded more when intercropped at the time of maize planting, but wheat produced higher yields when intercropped during the first weeding in a shallow soil. This effect was attributed to cooler temperatures.

All these crops produced twice as much when planted during the first weeding than when planted during the second weeding, Showing a general trend of decreasing dry matter yields as planting was delayed (Table 3). Thus, early planting is advisable for maximum growth. The amount of nitrogen fixed ranged from 10.4-19.9 kg/ha and from 2.8-4.7 kg/ha of phosphorus.

Table 2. Peanut yield and yield components under mulching and without mulching in San Lucas Tlanichico, Oax.

Mulching ?	Pods/plant	Total dry weight (g)	Weight/seed (g)	Seed weight per plant (g)
No	18.7 b	13.1 b	0.78 b	19.8 b
Yes	23.5 a	20.0 a	0.96 a	25.9 a

* Different letters indicate significant differences according to Tukey's test ($\alpha = 0.05$).

Table 3. Dry matter yields (kg/ha) of intercropped green manure crops during three opportunities in a deep soil. San Lucas Tlanichico, Oax.

Green manure crop	Seeded at planting	Seeded 1st weeding	Seeded 2nd weeding
Wheat	1240 b	666 b	324 b
Chickpeas	1762 a	718 b	343 b
Soybeans	1294 b	1277 a	582 a

* Different letters indicate significant differences according to Tukey's test (α = 0.05).

Preliminary estimates of maize yields under intercropping showed that, at most, a decrease of 10 % in maize yields could be expected as a result of competition with green manure crops.

Bunch and Lopez (1993) consider that intercropping a multipurpose crop, instead of a green manure crop, is more likely to be accepted, as peasants rarely will turn them under. The planting of such crops should not represent any opportunity cost. All plantings were done immediately after normal operations such as seeding and mechanical weeding.

One of the concerns of peasants about the so called green manure crops was the availability of seed. Fortunately, there is a range of open pollinated varieties of leguminous and minor cereals.

Producing cash crops such as tomatoes and hot peppers is a good way to use scarce water and land, providing that the selling price is worth harvesting. Using floating row covers in these crops proved to be a safe way to counteract serious viral diseases transmitted by white flies, reducing insecticide use by half. This cloth, however, is expensive for the peasants. Even so, as the peasants saw that this was an effective technology, which reflected immediately in higher crop yields (Table 4), they started to implement it by themselves. At least 20 peasants in several communities have bought Agribon to produce tomatoes and hot peppers. Several short courses were implemented to train the peasants in using this technology.

Table 4. Tomato crop yields under Agribon protection and with and without insecticide in Magdalena Mixtepec, Oax.

Treatment	Infected plants (%)	Fruit size (g)	Fruit yield (ton ha^{-1})
Agribon	12.3 c*	53.6 a	43.5 a
With insecticide	38.7 b	28.4 b	14.9 b
Blank	54.5 a	25.0 b	6.8 c

* Different letters indicate significant differences according to Tukey's test (α = 0.05).

According to Bunch and Lopez (1995) what matters is the sustainability of increasing yields or the sustainability of the development process. They believe that the peasants will keep doing certain practices as long as they get increased yields, decreased costs or decreased risks. Therefore, technologies should be chosen for their ability to produce such effects in a relatively short time.

Why farmers adopt production technologies seems elementary and apparent; new production technologies are adopted when the techniques are perceived as being in farmers' best interests (Nowak, 1992). However, this is not a guarantee that the technology will be permanently adopted; other factors such as conflict, socio-cultural organization and empowerment can lead to a new survivorship strategy (Aguilar-Cordero, 2008).

CONCLUSIONS

In both agroecosystems it was possible to find indigenous technologies with a high degree of sustainability, such as stone faced terraces and crop rotation. Composting was not well accepted by the peasants mostly because of high labor demands. Since they prefer to apply manure directly to the fields, it is necessary to increase its quantity and quality. The use of multipurpose crops as green manures may not be possible due to cultural and practical reasons, such as not harvesting an immature crop and cutting it without damaging the maize crop. Thus, these crops must be grown to maturity to use the seed as human food and then use their residues as fodder. The peasants adopted technologies of immediate impact, such as floating row covers, in spite of their cost. Such technologies can be used as effective lures to hook the peasants to use other sustainable technologies.

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