PARTICIPATORY SOIL IMPROVEMENT: A CUBAN CASE STUDY IN FERTILITY MANAGEMENT

Lisa Kissing✉, A. Pimentel and María Valido

ABSTRACT. The degrading quality of soils worldwide and an uncertain supply of petroleum-based fertilizers are a threat to global food security. Although research has developed low-input technical solutions to improve the soil resource, such technologies are rarely adopted by small farmers in the global south. With the goal of increasing farmer adoption of soil building practices, a case study in the community of San Andrés, Cuba, tested a participatory methodology to explore local knowledge, identify research technologies to meet community needs, and catalyze farmer innovation on the selected technologies. Through qualitative research, this study explored the corpus, praxis, and kosmos that the community held to conceptualize, manage, and make decisions about their soils. Analysis of ethnopedology indicated that although individuals recognized the degrading quality of their soils, and shared a wider goal of long-term land improvement, existing nutrient management strategies were inadequate to satisfy crop needs. Results suggested that introducing new technologies to the community could accelerate the formation of a more appropriate praxis. To satisfy nutrient management needs, green manures and compost were identified as the best suited technologies to existing production systems. Then, a "soil fertility fair" joined researchers and community members, to experiment with green manures and compost, and evaluate the most feasible types to local conditions. The paper considers the fair as a gateway to sustainable soil management through farmer innovation. To help guide the future design of participatory soil improvement, the paper expounds lessons learned from a research experience with ethnopedology and soil fairs.

Key words: soil improvement, community involvement, soil fertility, green manures, compost

RESUMEN. La degradación mundial de la calidad del suelo y el agotamiento de las reservas de fertilizantes hechos a base de petróleo amenazan la seguridad alimentaria global. A pesar de que la investigación científica ha desarrollado soluciones técnicas para el mejoramiento del suelo con bajos insumos, los agricultores que producen a pequeña escala no adoptan dichas prácticas frecuentemente. Con la meta de aumentar la implementación de prácticas que mejoran el suelo, un estudio de caso en la comunidad de San Andrés, Cuba, probó una metodología participativa para explorar el conocimiento local, identificar las tecnológicas que podían satisfacer las necesidades de la comunidad, e impulsar la innovación campesina con las tecnologías seleccionadas. A través de una investigación cualitativa, el estudio exploró el corpus, la praxis, y el kosmos que la comunidad tiene para conceptualizar, manejar y tomar decisiones sobre sus suelos. El análisis de etnopedología indicó que aunque los productores reconocen que la calidad de sus suelos está empeorando y que comparten una meta general sobre el mejoramiento de sus tierras a largo plazo, las estrategias existentes del manejo de la fertilidad son inadecuadas para satisfacer la demanda de los cultivos. Los resultados sugieren que la introducción de nuevas tecnologías a la comunidad podría acelerar la formación de una praxis más adecuada. Para satisfacer las necesidades de manejo de nutrientes, se seleccionaron abonos verdes y compost como las tecnologías más adecuadas para los sistemas de producción existentes. Es por ello que la "feria de fertilidad del suelo" reunió a investigadores y miembros de la comunidad, para experimentar con diferentes tipos de abonos verdes y compost, así como evaluar su comportamiento en contextos locales. El trabajo considera que la feria es una puerta de entrada al manejo sostenible del suelo por medio de la innovación campesina. Para guiar el futuro diseño del mejoramiento participativo del suelo, el trabajo expone las lecciones aprendidas de una experiencia que integró la etnopedología y las ferias del suelo.

Palabras clave: mejora de suelos, participación comunitaria, fertilidad del suelo, abonos verdes, compost

INTRODUCTION

Soils worldwide demonstrate increasing degradation in the form of erosion, acidification, salinity, and compaction (1). Moreover, the supply of chemical fertilizers used during the last 50 years to increase soil fertility is threatened by diminishing petroleum resources. To feed a growing population in a modern paradigm of degradation and scarcity, institutional research strives to develop low-input methods to enhance soil resources. Resulting technologies, however, are rarely adopted by small farmers in the global south (2). Along with the difficulty of subsidence and tenant farmers to invest in the long-term benefits of soil improvement, the failure of soil development projects can be attributed to a lack of participatory design (3).

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In contrast to the one-size-fits-all technology packages promoted by the Green Revolution, low-input technologies require site-specific design and sensitive management by those in the field (4). To effectively diffuse such practices, participatory methodologies have evolved to incorporate land users in the process of technology development and adaptation. Although disciplines such as participatory plant breeding (5) and integrated pest management (6) have successfully integrated such methodologies, there are few examples of participatory projects in soil management. This paper proposes a methodology to improve the adoption of low-input soil improvement practices using two basic components of participatory development: the exploration of local knowledge systems and the enrichment of farmer innovation.

For several decades, participatory development has recognized the value of local knowledge systems. Borne from years of intimate interaction between humans and their natural environments, knowledge systems are unique to each group and place, and heterogeneous according to the experience of each individual (7). Moreover, systems are dynamic, responding to constantly changing natural and societal contexts. Toledo has established a methodology for studying local knowledge systems according to three main components: *corpus* (cognitive understandings of the environment), *praxis* (the application of understanding through environmental management) and *kosmos* (the broader belief systems of a people) (7). Studying local knowledge can contribute to development projects by accurately assessing local needs and identifying technologies that are appropriate to sociocultural conditions (8). To apply such concepts in soil management, ethnopedology has begun to explore the diverse sets of understanding that human groups hold as a result of living and working daily with the soil. Previous research in ethnopedology has focused on gathering ethnographic data of knowledge systems (9) and comparing local and scientific knowledge of soils (10, 11, 12, 13). Few studies, however, have integrated both local and scientific knowledge in order to collectively engage researchers and communities in lasting soil improvement (14).

In addition to exploring local knowledge systems, participatory projects have incorporated farmer experimentation and innovation. Land managers are continually experimenting through curiosity, adaptation, problem solving, and peer pressure to find the practices they prefer most (15). By tapping into existing forms of farmer innovation, scientifically developed technologies can be appropriately adapted, adopted, or dropped by a community. Rather than enduring the difficult process of transforming farmer mindsets to accept a new form of management (16), or changing the political, social, and cultural barriers to improvement (17), farmer experimentation allows farmers to adapt and adopt practices best suited to their own knowledge systems and contexts.

Soil improvement projects using farmer innovation share a common recipe for success. Projects have begun with a careful selection of technologies best suited to available materials and existing forms of production (3, 18). After initial assessment, the power of the innovation process was handed to those in the field, consciously avoiding the patronization of “gift” giving and doing things for local people (3, 19). After starting with small groups, and only expanding after established success (19), leading farmers served as agents to introduce innovations to other communities using their shared language and culture. Researchers took only a background role, serving as initiators of pilot groups, facilitators of the process, and gophers between the community and research institutions (3, 20).

Cuba is an ideal location to study methods of participatory soil improvement due to its exaggerated soil degradation, resource scarcity, and advanced scientific research in low-input agriculture. Since 1990, when the island lost more than 80 % of its fertilizer and pesticide supply, Cuba has suffered an inadequate source of chemical fertilizers to maintain crop yields and soil fertility (21). Agricultural institutions such as the National Institute for Agricultural Sciences (*INCA*) have been internationally recognized for their work to resolve these problems through organic nutrient technologies, including biofertilizers, green manures, and compost (22). Despite such research, few rural farms regularly use organic fertility technologies. Although national agricultural institutions have traditionally followed a transfer-of-technology diffusion paradigm, innovative projects using participatory methodologies are beginning to take shape across the country (23). By paralleling global problems of land degradation, resource scarcity, and transitioning mechanisms of technology diffusion, lessons learned from this research in Cuba may be useful for application in other parts of the world. This paper presents a case study from Pinar del Río, Cuba, which implemented a participatory methodology for low-input soil improvement through the evaluation of local soil knowledge, the pairing of local needs with research technologies, and the encouragement of farmer innovation.

OBJECTIVES

- Elaborate and evaluate the soil knowledge of a small community
- Identify appropriate technologies to improve soil management
- Induce farmer innovation in proposed technologies through a soil fair

STUDY AREA AND METHODS

Study area. San Andrés is located in the mountainous zone of Cuban agriculture. One square kilometer generally contains concave, converse, and flat topographical features. Soils of the area are primarily ferrasols, derived from quartz parent material, under the dominant native plant species of *Pinus caribaea.* The current climate is sub-humid tropical with annual rainfall varying from 1400-1600 mm and an average temperature of 20-25°C.

The basic unit of production is a family, with an average of three to five members managing 3.5-13 ha of land. Most farming families are gathered into groups of cooperative production through a Credit and Service Cooperative (*CCS*), an Agricultural Production Cooperative (*CPA*), or a Basic Unit of Cooperative Production (*UBPC*). A small minority of farms remain private. Tobacco is the prime crop of the region, accompanied by tubers, grains, swine, and poultry. These agricultural products are marketed to *ACOPIO*, the state procurement and distribution system, or consumed within the home. As part of a cooperative, farmers secure their land rights by meeting quotas to *ACOPIO*. Families that have tobacco contracts with *ACOPIO* receive a technology package including fertilizer. Without a tobacco contract, fertilizers are difficult to obtain.

Evaluation of ethnopedology. To evaluate the *corpus, praxis, and kosmos* of local soil knowledge systems (7), the study used a triangulation of three qualitative research methods: structured interviews, participatory transects, and life histories (24). The three methods took place during household visits to a sample of farms. Purpositive sampling identified 10 representative farms of the region to participate in the study, including a diversity of sizes and production systems (Table I). To gather a diversity of household interactions with outside knowledge, the sample population included households with and without connection to nearby research institutions. These included a farm diversification project that has operated for seven years in the community, the Program for Local Agricultural Innovation (*PIAL*), and a regional agricultural university, the Agronomy Faculty of the Countryside: San Andrés (*FAMSA*). The members of each household were presented with a clear purpose of the study, and asked if they were willing to participate in a visit. Assenting households then provided verbal consent before commencing with the visit. Each visit was conducted in the presence of an agronomy student from Pinar del Río capable of clarifying misunderstandings between local vocabulary and the foreign researcher's word choice. In an attempt to gather the heterogeneity of knowledge in the community, all individuals present at the time of the visit were incorporated into the study, gathering the perspectives of wives, elders, youth, children, extended family and visiting neighbors along with those of the male heads of households. As a result, while only 10 farms participated, methods captured the responses of more than 30 individuals.

The first method used during a visit was the structured interview. In the comfort of their home, individuals answered seven questions concerning particular types of soil management practices that were typical to the region (Table II). As a method, structured interviews were chosen for uniformity and consistency. The interviews, which varied in length from 10 to 30 minutes, were digitally recorded and transcribed. Gathered data included specific soil management practices on each farm, in addition to household opinion on the effectiveness of each practice. Additionally, data included fallow times in cropping patterns and underutilized nutrient sources in agroecosystems. Transcriptions were coded for aspects of *praxis* including (a) the main practices used to improve soils, and (b) the limitations of each practice.

Table II. Structured interview questions

1. How do you work (till) your land?
2. Do you apply any organic material from outside the farm?
3. Do you have live or dead fence barriers?
4. Are you familiar with legumes? If yes, which ones? Have you or do you use legumes in crop rotation?
5. Do you practice compost? If yes, could you explain how? What materials do you use?
6. Do you "fill" your soils?
7. Do you leave your land to "rest"? Do animals graze it? Which crops require more rest?

Second, participatory transects took place during household visits. The participating family was encouraged to lead the researcher through their farm. The researcher then guided a discussion of land and soil characteristics according to Table III, while also observing in-field

Table I. Basic characteristics of farms included in the study

#	Location	Size	Driving production unit	Association with research institutions
1	Puerto Escondido	6.5 ha	tobacco, swine	PIAL participant of 5 years
2	San Andrés	6.5 ha	mixed home consumption	PIAL participant of 7 years
3	Cayo Hueso	6.5 ha	honey, vegetables	not associated
4	Canalete	13 ha	tobacco, tubers	contact with FAMSA
5	Canalete	3.25 ha	tobacco	PIAL participant of 7 years
6	Canalete	10.25 ha	tobacco	contact with FAMSA
7	Puerto Escondido	6.5 ha	tobacco, tubers	not associated
8	Puerto Escondido	10.25 ha	swine	PIAL participant of 1 year
9	Puerto Escondido	6.5 ha	tubers and citrus	not associated
10	Puerto Escondido	13 ha	fruits and vegetables	PIAL participant of 7 years

management practices on each farm. The method was chosen because previous research in Cuba found farmers more at ease to answer detailed questions while moving through their own land (25). In addition, participatory transects increase accuracy by pairing discussion with observation of actual farm management. Transects varied in length from 20 to 60 minutes. Content was recorded through detailed field notes and photography. Collected data included the terminology farmers use to describe their soils, the indicators they process to evaluate soil quality, and how they design their farming system based on these soil properties and indicators. Data also recorded present fallow times in cropping patterns and underutilized nutrient sources in the agroecosystem. Detailed field notes and photography were coded for the *corpus* of soil management, identifying (a) the terminology farmers use to describe their soils, (b) the indicators they process to evaluate soil quality, and (c) how they feel their soils have changed through time.

Table III. Participatory Transect questions

1. What are your soils like?
2. How do your soils change? How have they changed through time?
3. What soils are best for which crops?
4. Which weeds grow in what areas of your land? How have they changed through time?

Field notes and photography gathered during participatory transects were combined with transcriptions from structured interviews to evaluate *praxis.* A radial or “amoeba” graph quantified the use of 11 practices recognized by the researcher to sustain short-term and long-term integrity of the soil resource (Figure 1). If interviews or participatory transects indicated that a household used a certain practice on a significant quantity of its land during the past year, the household was given a “1” for that management practice. When poorly or infrequently implemented, a household was given a “0.5”. If non-existent within the past year, the household received a “0” for the practice. If every household practiced all of the soil improvement methods, each radial arm of the graph would extend to the 100 % point, creating a full circle. A more likely result reflects an asymmetrical polygon with arms extended at various lengths. Arms reaching furthest to the 100 % line represent management practices that are most fully developed in the community, while the smallest arms suggest areas to improve.

Third, life histories opened perspective on how participants live, understand, and react to the world. The ten households selected for farm visits discussed topics such as family histories, farm histories, daily life, educational background, and future visions (Table IV). This method, more than any, gave a voice to the local people, removing control and bias from the researcher in the gathered data. Varying in length from 30 to 60 minutes, life histories were digitally recorded and transcribed.

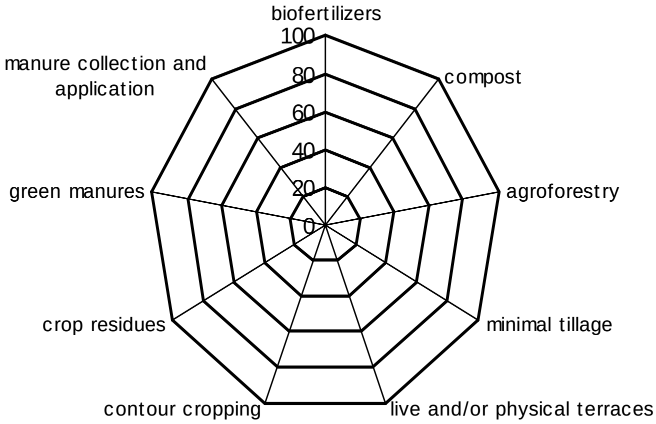

Figure 1. Radial or “amoeba” graph measuring percentage of total farms implementing certain soil management practices

Table IV. Life histories

1. What is the history of your farm?
2. How did you meet as a couple?
3. What is a normal day like on the farm [for women and men]?
4. How have you learned how to farm?
5. What do you lack?
6. What goals do you have for the future of your farm?

Data collected included the history of soil management on the farm, where farmers “learned” about management practices (e.g. generation to generation, practical innovation, or an outside development project), and the role that each gender and generation plays in the daily management of the farm. Additionally, the method revealed sociopolitical and personal influences affecting household decision making of agricultural management. The data was coded for aspects of *kosmos* including (a) sociopolitical factors influencing management, (b) barriers to improvement, and (c) family goals for the farm’s future. The data was also coded for two additional aspects of *praxis* including (c) where and when farmers “learned” how to manage their farm the way that they do, and (d) how land management has changed through history.

Identification of appropriate technologies. Once ethnopedology evaluated the knowledge and needs of soil management in San Andrés, the researcher identified appropriate technological solutions to introduce through farmer experimentation. Solutions were considered that could be inserted within current management practices, and could utilize available resources. Through data gathered in participatory transects and structural interviews, the study sought niches for incorporating nitrogen-dense legume biomass and underused organic materials of high nutrient quality, following the recommendation of Palm *et al.* (26). Transcriptions of life histories were coded to discern the division of labor between sexes and generations present in the community. Results then matched the appropriate groups to lead experimentation on the proposed technologies.

Structuring local innovation. The "biodiversity fair" was the chosen tool to induce farmer experimentation and innovation on selected research technologies. Biodiversity fairs are a Cuban creation that test a variety of institutionally-bred crop cultivars on a local farm, provide a space for community members to evaluate the cultivars according to the preferences of both men and women, and supply seed of the preferred varieties for continued experimentation on participants' farms. Additionally, the fair celebrates the Cuban culture of *fiesta* to draw entire families for a day of discussion, eating, music, and dance. In this case, the fair was structured to introduce soil fertility technologies, rather than crop cultivar varieties. The development of the fair followed the guidelines of de la Fé *et al.* (27). The objectives of the fair were not defined until the needs of the community were evaluated through ethnopedological analysis and appropriate technologies were selected as possible solutions.

After indentifying green manures and compost as applicable solutions, the study sought local leaders to establish experimental plots of the technologies. Fourty-one days prior to the fair, 14 varieties of green manures were established on a local leader's land (Table V). Varieties were replicated twice, producing a total of 28 experimental plots. The leader farmer and his family maintained the plots according to typical soil preparation and irrigation techniques of the community. Eight of the tested varieties were locally-collected legumes, while six were improved varieties commonly used worldwide as green manures, which demonstrated good growth in Cuban climate (28, 29).

Table V. Classification and origin of 14 varieties of green manures in the soil fertility fair

Legume variety	Seed type
Abrus precatorius L.	Locally-collected
Calopogonium caeruleum (Benth.) C. Wright	Locally-collected
Canavalia ekmanii Urb.	Locally-collected
Canavalia ensiformis (L.) DC.	Improved variety
Clitoria L. "moñuda"	Locally-collected
Clitoria ternatea L.	Locally-collected
Clitoria ternatea L.	Improved variety
Crotalaria juncea L.	Improved variety
Galactica jussiaeana Kunth	Locally-collected
Macroptilium atropurpureum (DC.) Urb.	Locally-collected
Mucuna pruriens L.	Improved variety
Phaseolus lunatus L.	Locally-collected
Vigna unguiculata L.-black I94	Improved variety
Vigna unguiculata L.-brown I93	Improved variety

The researcher then assisted the "leader" families in hosting a soil fertility fair, which demonstrated the first results of experimentation to the community. Invitations were hand distributed to households in the community, including those that did and did not participate in the "household visits" of ethnopedological evaluation. During the fair, the host family members shared their thoughts on the process and results of experimentation. Participants then walked with the family to the experimental plots, in order to evaluate the established varieties through informal farmer to farmer discussions. Finally, the researcher regrouped with the participants to discuss their perceptions of the trial and select the most preferred varieties. After the fair, the experimental plots served as a local seed bank. The preferred seed varieties were distributed to fair participants, well timed for appropriate establishment of green manures on nearby farms during the rainy season (28). Such distribution expanded the process of experimentation and innovation to surrounding farmsteads.

RESULTS AND DISCUSSION

Ethnopedology

Corpus: In Pinar del Río, individuals understand their soils according to specific indicators of color, texture, water holding capacity, the type of crops a soil can support, and which type of weeds grow on such soil. Interviewees detailed the loss of soil quality through these indicators. Farmers have noticed a reddening of soil color, hardening of texture, drying of soil, the inability to grow nutrient demanding crops, and the increased prevalence of "bitter" and "bad" weed species which animals do not eat. As a result of such erosion and degradation, one farmer lamented, "These lands aren't the same anymore; they have gone degrading before us". Another confirmed, "Practically, we don't have soils now". As a result of the cognitive understanding that the quality of their land has degraded, the interviewed households have taken action to ameliorate such degradation.

The corpus described by this case study is unique, yet shares common features with previous research. Among the taxonomic criteria described by 62 different ethnicities worldwide, 100 % of studied groups used color, 98 % texture, and 55 % soil moisture to describe their soils (10). Therefore, three of five indicators used to conceptualize soils in San Andrés strongly correspond to global norms. On the other hand, previous research has placed less emphasis on the two additional indicators used by the people of San Andrés: nutrient demanding crops and weed species supported by a particular soil type. The conceptualization of the soil resource described by this case study concurs with research in Ethiopia, which concluded that farmers rarely distinguish between the physical properties of soils and their impacts on production (12).

Praxis: Table VI describes the six most common management practices that the people of San Andrés use to improve their soils: terracing, contour cropping, soil filling, natural fallow, capitalizing on carry-over fertilizer effects, and expansion into virgin lands. The rightmost column of Table VI explains the limitations that participants encountered with such practices.

Tabla VI. Praxis of soil management

Practice	Description	Origin of practice	Familiar to household	Practiced by household	Limitations of practice
"Soil filling"	Farmers collect rich topsoil that has eroded and accumulated in depressions as a nutrient source added to furrows before planting.	Recent innovation	100 %	90 %	Unsustainable, labor intensive
Contour cropping	Farmers till and plant along the natural contour of a slope to avoid erosion.	Researcher-led improvement project in 2001	100 %	80 %	Takes time to impact fertility
Live and dead terracing	Farmers plant large grasses or pineapple (live) or build up soil (dead) in lines along the contour. Terraces will naturally develop to minimize erosion.	Researcher-led improvement project in 2001	80 %	60 %	Takes time to impact fertility
Natural fallow	After nutrient demanding crops, farmers leave areas bare "to recover". Present weed species will colonize the parcel. Livestock then graze the fallowed areas.	Passed down from previous generations	80 %	40 %-all farms larger than 6 ha	Low quality fallows, little nutrient benefit to livestock or soils
Carry-over fertilizer effects	To take advantage of fertilizer residues that are supplied by the state during tobacco production, nutrient demanding crops like corn are planted directly after tobacco.	Recent innovation	70 %	50 %-all households with tobacco contracts	Small fertility benefit to a single crop
Expansion into virgin lands	Farmers till under virgin soils to plant nutrient demanding crops that will not grow on degraded soils, such as cocoyam.	Passed down from previous generations	70 %	50% - all farms that border protected forest islands	Unsustainable, ecologically destructive, illegal

To evaluate the ability of local praxis to sustain the soil resource in the long term, a radial or "amoeba" graph evaluated local management. Figure 2 shows the percentage of all farms adequately implementing eleven predefined soil management practices. The amoeba graph is divided into two types of practices: 1) those that promote physical conservation in the lower half and 2) those that promote biological activity, and consequently soil fertility in the short term, in the upper half.

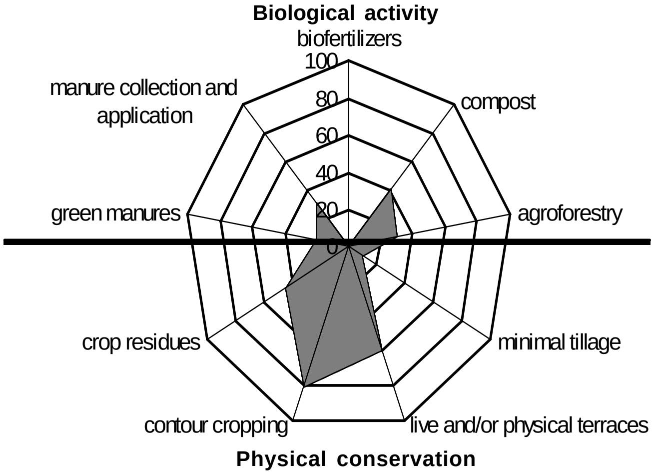

Figure 2. Radial or "amoeba" graph showing the percentage of total farms using certain soil management practices

In terms of physical conservation on the lower half of Figure 2, 80 % of visited farms practiced contour cropping and 60 % had established live or dead terraces (another 20 % were familiar with terracing and considering implementation). In terms of soil fertility on the upper half of Figure 2, four of ten visited farmsteads maintained a compost system, two of which were poorly put into practice. Only two of ten households, those families most connected with national and international researchers through *PIAL*, were familiar with and planning to implement green manures, cowpea (*Vigna unguiculata* L.) in association with corn (*Zea mays* L.), during the rainy season. An extensive temporal or spatial incorporation of legumes was not present on any parcels during the researcher's visits. The technology of biofertilizers, although well-developed and produced by Cuba's *INCA*, was not used by any participating farmsteads. Results of the amoeba graph show that physical conservation of soil, in the form of contour cropping and terracing, are common in San Andrés, while practices that increase biological activity are infrequently implemented, such as compost, biofertilizers, and green manures.

Through life histories, families explained the development of soil knowledge praxis. Interviewees described how their ancestors were relatively recent settlers to the fertile lands of Pinar del Río. Former generations broke virgin ground and mined native soil fertility for 50-200 years, until The Revolution, when the state began to distribute synthetic fertilizers. After 1990, many farmers described that, "It was very difficult" being cut off from synthetic fertilizers and simultaneously realizing that the native fertility of their soils had largely eroded from damaging industrial practices. Lacking alternatives after 1990, the families of San Andrés had merely seventeen years to innovate and develop a new local knowledge set to manage soil fertility without chemical fertilizers. "We have barely just started to experiment" one farmer explained. "Little by little" was a common mantra about adopting new practices to suit their lands. Seventeen years of largely isolated innovation has failed to develop a praxis that can satisfy current or future nutrient needs in food production. In contrast, less than seven years after their introduction by outside researchers, soil conservation practices have been quickly and widely integrated within local praxis (practiced by 60-80 % of households) (Table VI and Figure 2). Ethnopedology, therefore, indicated that introducing new techniques from outside the community has accelerated the development of more appropriate praxis.

The praxis of San Andrés confirmed that management systems are constantly evolving to fit changing environmental and sociopolitical conditions (7). This study evaluated how quickly local knowledge systems could adapt to the dramatic shift in agricultural contexts from industrial (pre 1990) to petroleum scarce (1991) production. Results indicate after 17 years, land managers were unable to adapt their knowledge system to satisfy corpping needs within the new agricultural context. The study echoed Paneque and Calaña (30), who stated that there is currently little «culture» of organic nutrient management in Cuba as a result of an agricultural history of recent settlement on fertile lands followed by ample and cheap chemical fertilizers. These results parallel those of Obeteur *et al*. that small farmer knowledge around natural resources and management decision making cannot evolve quickly enough to confront new paradigms such as increasing population pressure on the land, unpredictability of global markets, and climate change (31). Idealizing local knowledge and leaving land-managers to develop their own solutions is rarely the quickest path toward sustainability (2, 14). Rather, the results of San Andrés suggest the need to update traditional knowledge systems with new technology and modern needs, a conclusion also found in research with farmer groups in Greece (32).

Kosmos: Frequently, producers have a conceptual understanding of soil degradation, but fail to address it, or are familiar with soil improvement practices, but do not choose to use them on their land. The difference between the "Familiar to household" and "Practiced by household" in the description of praxis demonstrates the discrepancy between knowledge and practice in San Andrés (Table VI). Kosmos explores the larger concepts that influence land-user decision making around soil management. Resource and time constraints, economic conditions, and family goals were the three main contexts influencing land-user decision in soil management.

Life histories revealed that socio-economic indicators such as the availability of material resources and leisure time play powerful roles in farmer decision making concerning agricultural management. One farmer responded to the question "What do you lack?" with "We lack everything". Electricity did not reach 40 % of the households studied. Without time-saving technologies like gas stoves or refrigerators, women in particular lacked the time and energy to maximize the nutrient potentials of their small poultry, home gardens, and kitchen waste. Men, on the other hand, pined for basic working tools like machetes and irrigation systems. The labor demands of maintaining a farm without basic resources lead one farmer to concede, "There is no time" for more integrated soil management.

With limited time and physical energy, households prioritize their agricultural management according to basic economic need. Above all, households manage land holdings to meet the immediate needs of securing land rights and feeding their families. As members of a *CCS*, 90 % of families in the study needed to fulfill quotas to *ACOPIO* in order to secure their land rights. Most households do not use non-food legumes in rotation because they need what little land remains apart from production for *ACOPIO* to grow food for family consumption. Those that held tobacco contracts with *ACOPIO*, 50 % of families included in the study, confront particular constraints in agricultural flexibility. Fulfilling tobacco contracts on soils poorly suited for the crop requires a significant sacrifice of land and time in the cropping cycle. Additionally, the arduous task of hand-processing tobacco commits many families to a way of life that sucks time and energy from other agricultural work.

The access to economic benefits for soil building practices also influences agricultural management. Although the preferred pricing of organic and biodynamic markets is available to farmers in other parts of the world who take the time and effort to manage soil resources ecologically, such markets are inaccessible to farmers in Cuba's controlled economy. However, the Ministry of Science, Technology and Environment (*CITMA*) has recently instituted farmer payments as a means of rewarding farmers that protect their soils. This study revealed, however, that few families in San Andrés are aware of this new economic opportunity. While 60 % of farms included in the study demonstrated significant soil conservation efforts, only 20 % of households actually received payments, with another 10 % aware of the opportunity without submitting an application.

Despite many external factors discouraging individuals from choosing to improve their soils, families remain very interested in and committed to the idea of enhancing their land. Such commitment stems from an internal goal shared by many men and women farmers: "That my children will one day gain something from this land". Despite lack of resources, constricting markets, and insecure land tenure, 60 % of families have worked to install long-term soil conservation, with the hope that one day it will benefit their children; 90 % of participating families demonstrated sincere interest in further improving their soils through new fertility management techniques.

The importance of socioeconomic contexts in San Andrés parallel a study in West Africa, which found that sociocultural factors significantly affect farmer adoption or rejection of soil improvement technologies (18). Many of the barriers encountered in San Andrés were also described in previous studies, including few economic incentives for soil improvement (12), the lack of access to incentives such as niche organic markets (25), limited market access for soil enhancing crops (33), and added time and labor demand on the part of the land user (26). Despite such obstacles, the families of San Andrés shared long-term goals that encouraged investment in soils. With 90 % of families interested in improving soil fertility, this study found that Cuban farmers share a broad commitment to sustainable management. These results contrast with a study conducted in the Havana province, which found a more shallow interest in ecological management among Cuban farmers (25).

Identification of appropriate technologies. Once ethnopedology highlighted fertility management as a need, green manures and compost were identified as the technologies most appropriate to local conditions. While supplying significant nutrient inputs to the agroecosystem (26, 29), green manures and compost demand little time and labor from those managing the land, do not require additional resources that are difficult to obtain in the Cuban countryside, and do not depend on specialized markets that are underdeveloped in the area.

Temporal and spatial niches for legume incorporation were discovered in fallows given after cocoyam (*Xanthosoma sagittifolium* L.) and cassava (*Manihot esculenta* C.) for farms greater than six hectares, and intercropping with cocoyam (*Xanthosoma sagittifolium* L.), corn (*Zea mays* L.), and rice (*Oryza sativa* L.) for all farm sizes. The study discerned male heads of households, in charge of crop planning and planting on 90 % of farms evaluated, as the appropriate group to implement improved fallows and green manure intercropping.

Opportunities for improving nutrient cycling efficiency appeared in the following poorly utilized nutrient sources of agroecosystems:

- ⇨ Manure from oxen, swine, poultry, and goats
- ⇨ Plant residues of cassava, corn, beans and rice
- ⇨ Banana leaves, trunks and peels
- ⇨ Rice hulls, coffee hulls and grinds
- ⇨ Ash from wood cooking stoves
- ⇨ Kitchen scraps

In contrast to green manures, women emerged as promising initiators for compost and improved nutrient cycling. Women were the managers of home gardens, small animal production, and kitchen labor on 100 % of evaluated farms.

Structuring local innovation. Green manures and compost were introduced to the community of San Andrés through Cuba's first "Soil Fertility Fair". To host the first half of the fair, one family emerged as a leader in previously experimenting with green manures (Figure 3). In early May, forty individuals gathered near the experimental plots to discuss and evaluate 14 varieties of green manures. Participants included men, women, and children from San Andrés, along with researchers from a national institution (*INCA*) and a regional agricultural university (*FAMSA*). To begin the fair, the family who led experimentation discussed the results, lamenting that dry conditions prevented faster growth of the species, and consequently, participants were unable to view the prime development of the plants. The family did express the value of several species that grew well despite drought conditions. After viewing and discussing the varieties in the experimental plots, the participants identified four preferred varieties, which were selected on the basis of leaf biomass: the locally-collected species *Macroptilium atropurpureum* (DC.) Urb. and the internationally-bred cultivars *Canavalia ensiformis* (L.) DC., *Crotalaria juncea* L., and *Mucuna pruriens* L. Shortly after the fair, seed from *Canavalia ensiformis* L., *Crotalaria juncea* L., and *Mucuna pruriens* L. was collected and distributed to the participants. More time was necessary to propagate the species *Macroptilium atropurpureum* (DC.) Urb., due to the small amount of seeds initially collected.

Figure 3. A local family hosted the first half of the soil fertility fair

Of the four legumes preferred by fair participants, one was a locally-collected species. Evidence that this species could compete with internationally-bred cultivars suggests great potential for local legumes in Cuba. The promise of local species parallels an international call for germplasm collection of underutilized crop and forage legumes (34), along with the prioritization of Cuba as a global center of legume diversity (35).

The second half of the fair took place on the land of a leader who had experimented for 15 years with compost and manure management. Since the methods implemented by the leader were so advanced and diverse, the fair served to spotlight the farm's existing methods of nutrient management. This portion of the fair focused on female participation, given that the managers of many underutilized nutrient sources in agricultural systems were women. The farmer gave a brief introduction to his experience with compost and manure experimentation. Then, he led participants through the farm, highlighting the management details and benefits of vermiculture, composting with poultry manure, and gravity-distributed fertigation from aquaculture. Additionally, the researcher and leader farmer hoped to work with female participants to create three types of compost (bocashi, aerated compost, and vermicompost) using common underutilized nutrient sources. In practice, however, rain arrived before participants could learn hands-on how to make these types of compost.

The method of the biodiversity fair implemented in this study is designed only as a catalyst for local experimentation and innovation. Past the initial excitement generated by an intervention, one must look to previous literature to forecast the process of farmer innovation that may take place as a result of the soil fertility fair. Although there are few studies that have documented the impacts of farmer innovation in the long term (3), Bunch and López (19) have evaluated the impact of an innovation project in Honduras 40 years after the initial intervention. 80-90 successful innovations existed among the 12 villages that once participated in the project. Many technologies that the project initially introduced had disappeared or completely changed form after years of farmer innovation. As a result of altered environmental, political, cultural, and social conditions, the average half life of an innovation was only six years (19). Pretty and Singh conclude that the process of innovation itself needs to become sustainable, rather than the technologies themselves (3). Recent studies have focused on building learning loops between local institutions and innovating farmers to ensure sustainable soil management into the future (3, 18, 20).

Experiences from the soil fertility fair suggest several changes in the presented methodology when designing future participatory soil improvement projects. First, the nature of soil improvement requires a slight alteration of the biodiversity fair methodology. Biodiversity fairs are designed to encourage the adoption of improved crop varieties by gathering community members to directly evaluate growth characteristics and taste quality on a local farm. Results of soil fertility, however, are not present in the growth of green manure varieties or in the types of compost. Instead, participants should see the nutrient benefits that introduced technologies contribute to subsequent crops. To prove the effectiveness of fertility management practices, future soil fairs could establish plots using different types of green manures and compost, turn the amendments into the soil, and then plant a nutrient demanding crop, such as corn, on every plot. The varying effects of green manures and compost on corn quality would demonstrate more clearly the "results" and effectiveness of the introduced technologies. This recommendation adds considerable time in the development of a soil fair, comprising at minimum two cropping cycles.

CONCLUSIONS

To feed a global population on an increasingly degraded land base, methodologies should connect farmers and researchers in the development and installation of soil improvement technologies. Through local knowledge systems and farmer innovation, small farmers may be able to establish practices that sustain high crop yields, stabilize their agricultural ecosystems, and maintain the integrity of natural resources. Ethnopedology proved to be an effective means of expounding soil knowledge in a small community and identifying local needs and barriers to improvement. In an effort to reach sustainable soil management, this study enhanced the experiential knowledge of land users with low-input technologies suitable to local conditions. The introduction of green manures and compost through farmer experimentation allowed the community to evaluate the technologies according to their own needs. Then, the celebration of a soil fair created then a space for researchers and community members to come together, generating the excitement, knowledge, and resources necessary for continued innovation with the introduced technologies. To ensure the long-term adoption of soil improvement technologies, the initial efforts of a fair should be supported by continued connections between institutional researchers and farmer experimentation groups. Although San Andrés successfully hosted the country's first soil fair, further study is needed to determine how effectively the methodology will impact soil quality in the long-term.

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