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Practicing Agroecology: Management Principles Drawn From Small Farming in Misiones (Argentina)

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In face of sustainability challenges, agronomical research has focused on the design of new production systems, whereas ethnographic studies have put forward the traditional small production systems. A gap remains between such agroecological design and the practices of farms. Our objectives are to draw principles for agroecological management from the in-depth study of practices in ecologically based farms in Argentina. We extracted three principles: 1) adjustment and observation instead of control, 2) variable and flexible management in time and space, and 3) permanent at-home experimentation. After examining their generality, we discuss the paths to take these systems as models for the ecologization of conventional systems.

KEYWORDS agroecological management, diversity, practices, empirical knowledge, Argentina, small-scale farming

1. CLOSING THE GAP BETWEEN AGROECOLOGICAL RULES AND LOCAL PRACTICES: A CHALLENGE FOR AGROECOLOGY

In face of agricultural sustainability challenges, agronomical research has largely focused its efforts on defining agroecological rules that new production systems and practices could respect to be more sustainable. To a large

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extent, these rules are grounded on ecological concepts mainly related to the functional role of biodiversity, thus, stating that ecosystem maintenance guarantees the sustainability of productive systems. Nevertheless, agricultural systems and ecological processes may be connected in many different ways, thus contributing to the debate on the diversity of agroecological models. According to the degree of this connection, Wilson (2008) has distinguished weak ecologization of agriculture to qualify agricultural models which try to reduce negative impacts of agricultural practices on environment from strong ecologization defined as a way to take advantage of ecological processes within the productive process. Horlings and Marsden (2011) enlarged this view to weak ecological modernization, which may decrease environmental effects to a certain extent and strong ecological modernization including social, cultural, spatial, and political aspects.

On the other hand, ethnographic-based studies of small farmers' practices and knowledge in developing countries have shown the sustainability of the so-called "traditional" production systems (e.g., Izquierdo et al. 2003; Abbona et al. 2007) and put them forward as a resource (Gliessman 1992), as agroecological models (Lopez-Perez et al. 2002) and as an "ingenious agricultural heritage" (Koohafkan and Altieri 2010) to guide the transition toward more sustainable production systems. As a result, some authors like Altieri and Toledo (2011) consider that "modern farming systems will necessarily have to be rooted in the ecological rationale of indigenous agriculture and that promising agricultural pathways, modeled after traditional farming systems, can help in the design of a biodiverse, sustainable, resilient and efficient agriculture" (53). Nevertheless, these authors are not really explicit about how such sustainable agriculture can be "modeled after traditional farming systems" and there is a strong debate among scientists working on Indigenous Knowledge Systems (IKS) about whether this local knowledge is "site-specific" (McCorkle 1989) or generalizable to other contexts (Gladwin 1989).

As a result, a gap remains between the general rules used for agroecological design and these specific sustainable systems. Several authors have pointed out the necessity to bridge the design of sustainable systems from agroecological rules and the analysis of "traditional systems" showing a very low degree of artificialization (Toledo et al. 2003; Altieri 2009; Malézieux 2012). For instance, Altieri (2009) has widely described such systems by their viability and their ability to take advantage of biodiversity for production, thus, putting emphasis on the role of planned and associated biodiversity in agroecological rules as the cornerstone of agroecosystem redesign. In such studies, "ecologically based farming systems" (Altieri et al. 1983; Altieri 2000) are used as good examples of sustainable systems respecting agroecological rules, but no lessons are really drawn from their situated functioning. While agroecology severely questions the applicability of scientific knowledge assumed to be universal across local situations and calls for a relocalization process of knowledge production (Warner 2008), the question remains on how to produce generic knowledge from agroecological practices and knowledge emerging in particular action situations (Lyon et al. 2011). Agroecology is now facing "a greater conundrum of how to relate the general knowledge of science to the place-specific, experience-based knowledge of . . . farmers" (1).

Our objective was then to draw principles for agroecological management from the in-depth study of farming practices and knowledge in the case of agricultural systems showing exemplary features of ecologically based systems. Beyond the observed practices, which may appear very idiosyncratic or context-dependent, we argue that they exemplify management principles which are more generic.

2. MATERIAL AND METHODS

Our strategy was then to describe farming practices and knowledge within small family farms considered as typically organized on an ecological basis, that is, with a high level of agrobiodiversity and no chemical inputs. Within a joint Argentinian–French cooperation program, our study was undertaken in the Misiones region (located in the northeastern corner of Argentina), which is characterized by a subtropical climate and an ecosystem characterized by hot summers and without a dry season, making Misiones one of the most humid provinces in Argentina (average annual precipitations from 1600 to 2000 mm). The natural vegetation is the original and typical *Selva Misionera*, the ecosystem of greatest biodiversity and ecological complexity of the country. Its topography is strongly undulating with altitudes reaching up to 800 m, with red and clay soils that are fragile and very eroded. Part of this forest has been transformed to implant ranching and crops such as yerba mate, tea, citrus, tobacco, and sugar cane. Misiones' region nowadays shows a very polarized productive matrix with, on one hand, an economy based on small-scale farming producing a wide range of plant and animal products for family needs and for local markets and, on the other hand, large estates with mainly forestry industry.

The study used a case-based method (Mitchell 1983; Eisenhardt 1989), in which we selected a sample of 6 family farms (see Table 1) according to structural criteria such as the farmland size (from 4 to 42 ha), the family composition (from a couple to a complex family with three generations living in the same house), and their level of capitalization (farmers who do not own the land to farmers investing in the purchase of new land)

These farms also show a high diversity of products (see Table 2)—and as a consequence, a high number of different crops—associated with livestock. Such diversity can first be explained by the aim, shared among all producers, to produce a healthy and diverse food for the family while

TABLE 1 Sample of family farms

Farm	Dn	De	Da	Fr	Li	Ro-ML
Farmland size (ha)	4	7	42	7	5	32
Family composition	A couple	A couple with 2 children	A woman with his son and his family	A couple with a son and his family	A couple with 9 children	A couple with their 3 adult children, each with their family
Level of capitalization	Farmland with authorization of use or lease agreement	Farmland with authorization of use	Farmland with title of property	Farmland with lease agreement	Farmland with title of property	No deed of property

TABLE 2 Number of species cultivated in each farm studied

Farm	Dn	De	Da	Fr	Li	Ro-ML
Number of species	33	45	45	24	30	25

selling the excess of food when there is some. Feeding animals is also a need that they integrate into their food balance. Nevertheless, some producers also cultivate to make an income, in order to pay for school for children or land taxes. When the objective is to supply local markets, products diversity is strongly linked to consumers' tastes and demands. Some producers also take into account their mission to manage a natural heritage and its diversity.

Data were collected in 2012 and 2013 with a comprehensive procedure. Data collection was based on at least two semistructured interviews (along with walking around farm fields) touching upon the following topics: farm history and family, objectives, products (diversity and use), technical practices, knowledge sources, and networks. All interviews were recorded, transcribed, and structured in a database using NVivo computer-aided qualitative data analysis software. This information was then coded and inductively analyzed using a strategy close to the "grounded theory" consisting of making a "systematic comparison of small units of data and gradual construction of a system of categories" (Langley 1999: 700). Farming practices were first analyzed with a within-case approach (Miles and Huberman 1994) to abstract the "realized strategy" of each farmer, that is, the combination of practices implemented (Mintzberg and Waters 1985; Girard and Hubert 1997). In a second step, we compared the practices with a cross-farm analysis (Miles and Huberman 1994): Within an inductive approach and an abstraction process that is deeply rooted in what farmers currently do, and not in a priori literature-driven categories, we thus characterized management principles that were common among all studied farms.

3. RESULTS

3.1. Practicing Agroecology by Managing Diversity in Time and Space

3.1.1. Which species diversity?

These farming systems show a high diversity determined by their food needs and their autonomy objective as well as their permanent adaptive attitude taking advantage of opportunities emerging along the way. As a result, all farms show a high diversity in cultivated species (from 24 to 45 different species and up to five varieties by species), accompanied by a diversity of uses of each product as shown in Table 2.

Any particular product may be the basis for family food, or a condiment used in a high variety of cooking processes, or the active principle of a home-made natural medicine, or the specific product asked for by clients at the local market, while not forgetting the use of wood in buildings. There are crops that are grown in all the farms such as maize, manioc, pumpkin, certain vegetables, citrus fruits, and bananas, although in variable amounts for each. Other crops can be found only on some farms according to the preferences of each family as well as local market demands. The main difference found among the studied farms was in the forestry component (natural or planted) since only two of the farms plant trees to obtain wood for commercial purpose. This can be explained by the available space, their attitude toward long-term thinking and tenure security. All producers told us that as far as they could remember, there has always been diversity on their farms as a permanent feature strongly linked to their way of life.

The diversity of cultivated varieties can also be seen as the result of an opportunist strategy in seed origins. Even if the basic principle is to keep home-produced seeds, allowing producers to choose the variety they like without purchasing them, most of them take advantage of free exchanges to enlarge their panel of cultivated varieties and to test new ones. Purchasing seeds from the local store is generally seen as the last solution, whereas, on the contrary, some of the producers even take advantage of spontaneous seedlings, with specific management practices (e.g., replanting spontaneous seedlings in more favorable places). In some farms, this system goes with a timing of planting/harvest dates so as to have the greatest diversity of products to be sold on the local market at each moment of the year or to have a longer harvesting period.

3.1.2. Cultivating different species in the same place at the same time

Far from being specialized agricultural systems relying on single-crop farming, all producers cultivate many different species in the same place at the same time. Table 3 illustrates the species combinations practiced by one producer, each species interacting with up to 14 species.

Producers justify this practice of mixing crops with different arguments. The main argument is the maximum use of space in their relatively small farmland, which encourages them to plant, for example, pumpkin on the edge of plot of corn to save space. Another organizational argument is for limiting the workload by taking advantage of a synergy between two technical operations. For example, one of the producers takes advantage of the uprooting of garlic to plant his peanut in the resulting clean area. Nevertheless, some arguments put forward by producers are related to ecological processes. In particular, some of them rely on a specific knowledge of soils, using their experience based on results obtained in previous years and

TABLE 3 Example of combinations of species (X) carried out by a producer in Misiones

	Cedar	Lemon	Corn	Manioc	Pineappple	Watermelon	Pumpkin	Banana	Bean	Stevia (sweetleaf)	Sugar cane	Cucumber	Melon	Native trees	Onion	Lemon verbena	Number of combinations in which the specie participates
Lemon	X		X	X	X	X	X	X	X	X	X			X	X	X	14
Cedar		X	x	X	X	X	X	X	X		X			x	X	X	12
Watermelon	X	X	X	X	X		X		X			X	X	X	X		11
Manioc	X	X	X		X	X	X		X	X				X	X		10
Corn	X	X		X	X	X	X	X						X		X	9
Pineapple	X	X	X	X		X	X		X	X				X			9
Native trees	X	X	X	X	X	X		X									7
Pumpkin	X	X	X	X	X	X			X								7
Bean	X	X		X	X	X	X										6
Onion	X	X		X		X		X									5
Banana	X	X	X											X	X		5
Stevia (sweetleaf)		X		X	X												3
Lemon verbena	X	X	X														3
Sugar cane	X	X															2
Cucumber						X							X				2
Melon						X						X					2

thus putting a specific crop in a specific place based on "what is the best use of use the soil" ("*a que sirve la tierra*" (De)). In this case, the combination of crops in the same place is mostly the consequence of a precision reasoning process on the individual location of each crop. However, most producers also take into account potential biological interactions between crops when trying to avoid negative combinations: They cultivate together only species that they know "do no harm to each other" ("*Ese no se hace nada*" (Fr)), arguing that some species combinations are negative and, thus, prohibited. Producers have various explanations for these negative combinations. For pumpkin or cucumber with corn, they related it to spatial extension of these species: looking at the way these *Cucurbitaceae* spread out on the ground, producers consider that they can be cultivated on the edge of an area of corn, but not in the middle. As a result, some species such as cucumber or melon can be only be cultivated alone, whereas other ones can be combined with more than 10 other species without problem (Table 3). For some other negative combinations, they only notice the negative effects of combining two species when they do not give fruits or when they do not have roots ("*si otra cosa plantas en el medio de mandioca, no crece, no tiene raices*" (De)). When investigating their underlying spontaneous theories of these negative combinations, we found that most of them relate to issues of shade and light and qualify crops and their relations according to the pair of *caliente-frio* (hot/cold) opposites, however with very different meanings. For some producers, this qualification concerns one crop and its relation to others: This is the case of a producer who considers that corn is *caliente* (hot) and cannot be cultivated with any other species. As a result, she cultivates corn at a low density, referring to the positive effect of wind cooling the crop between the rows. For other producers, the opposite *caliente/frio* qualifies the relation itself, and not the species. For example, the producer whose practices are described in Table 3 qualifies manioc as *caliente* for other plants (watermelon, bean), whereas watermelon is qualified as *frio* (cold) for manioc. For him, it may be different according to the variety, with the example of large leaves of a manioc variety creating more shade ("*Hay mandioca, grande la hoja, grueso, a éste no le viene porque le "sombra" demasiado [. . .] Porque tiene grueso las hojas y más sombra tiene, le calienta y no crece éste*" (De)). One then explains that the distance between rows has to be calibrated to provide the mixed crops (in this case, corn, watermelon, and bean) the right balance between light and shade according to the different stages of crop development. He even identifies a sensitive stage when seedlings should not be too much in the shade of the corn. Another producer sums up that "shade is good and bad" in order to put forward the necessary balance between them. All his cultivation reasoning is based on a permanent reference to the shade or the light as a criterion for the choice of the location of a crop, of a tree to grow, or of crops to be combined. The ability of a plant to give shade to others is thus part of his assessment of its interest, in order to associate it with other crops. The *caliente/frio* opposite can also be seen from the positive side by some producers as an argument to combine crops. This light–shade opposite is often related by producers to the issue of humidity (or in contrast to drought) produced by a crop: shade is related to terms like maintain, and its opposite "light" with expressions such as "drinks the water," "dries the soil," or "burns the fruits" ("*chupa el agua*," "*reseca la tierra*," "*la fruta quema*"). As a consequence, the spatial combination of species has to be organized in time to take into account the development stages of each crop. Avoiding a negative combination may thus be solved by "planting in time" ("*Ahi puede plantar con mani rama. El mani. No hace dano. Solo que tiene a plantar a tiempo*" (Dn)) For example, garlic and peanuts planted together is possible at a stage (garlic "which has a head"), which indicates the time for the planting of peanuts because at this point, one is not detrimental to the other.

Beside these positive species interactions referring to trophic resources (light, water), the only biological regulation of crop pests explicitly expressed by producers is about bean and tobacco: one producer cultivates tobacco in the middle of beans which plays, according to this producer, the role of repellent for a pest of tobacco. He, thus, takes advantage of this biological regulation between species. This example shows the type of knowledge that one producer may have of the biological processes he manages, which should be put in relation to his experience as leader and trainer of exchange groups of producers. Nevertheless, his discourse contrasts with the other producers who manage combinations with the very general principle of avoiding negative combinations.

3.1.3. Combining crops and livestock at the plant and animal scale

There is a strong relation between animal feeding and crops since most of the animal food is produced on the farm (specific crops or byproducts of crops for family food), at least for local breeds. As a result, all parts of cultivated plants (leaves, stems, etc.) are used to feed the animals within a more general philosophy of "nothing is lost when there are animals," especially with unsold products. Taken as a whole, producers' practices make the most of the diversity of resources produced on farm for animal feeding: their use is decided according to the crop state, the current yield of other crops, and the family needs, thus, giving the system a great temporal flexibility. In this totally intentional interweaving of crops and livestock, they favor microlevel reasoning, at the plant and animal scale. For example, they permanently give a dual-purpose to corn (food/grain), with a practice of planting 4–5 seeds per hole for maize. From the classical agronomic viewpoint, such practice can be seen as a source of competition between plants detrimental to crop yield. In doing so, if more than one seeds succeeds, producers obtain clumps of 4–5 seedlings of corn. The smallest plants will be thinned out gradually when there is a need of them to feed the pigs or kept as stockpiled food for later uses, using a strategy of animal food insurance "for periods of lack of fodder." This multiple seedling practice is described as traditional by the producers themselves and seems to come from the former generations of producers. Some producers explain it by the use of the sowing tool (*taca-taca*), whereas it can also be a response to the variable germination percentage of seeds produced on-farm.

3.1.4. Diversity as a result of a localized socio-cognitive activity

Far from the idea of an isolated practice, organizing the diversity within a farm revealed itself as a sociocognitive activity that is largely embedded in social networks of producers. For example, the high diversity in cultivated varieties results from individual or family choices. Criteria used are their own taste or their customers' preferences, the specific growth properties, harvesting facilities, or their cooking or animal feeding properties. More often, choosing a variety to cultivate is the result of complex tradeoffs between these targeted properties and the opportunity to find the seeds. As a result, most producers show opportunistic practices regarding seeds and their origin. Following an economy principle, all producers mainly keep their own seeds, which are thus qualified as homemade (*casero*). This principle can be replaced by exchanges of seeds or plants with family members, neighbors, local advisors, and other producers met at seed festivals, as well as the national extension project (Program Prohuerta; see http://inta.gob.ar/documentos/prohuerta) on vegetable gardens that supplies producers with varieties which are not necessarily local. As a consequence, seeds used may not only be "local," but are surely the outcome of localized exchanges between producers and their acquaintances. In most cases, the management of genetic material is limited to the storage of seeds, whereas one producer chooses the location of corn crops to avoid combinations in lineages. As a result, most producers have an approximate knowledge ("*No se de clases de variedades*" (Ro)) of the genetic material they grow: The most important aspect for them is that it will be possible to collect seeds from the production. Their knowledge of local seeds is often focused on behavior or properties of varieties.

Facing such a diversity of varieties and crops, all producers put forward their need of technical knowledge (which here refers to the knowledge and know how regarding the production process, and not the standardized knowledge which can be brought by technical advisors) to organize and steer their production. For all producers who were born on farms (i.e., all producers of our sample except one), they acquired this knowledge since childhood from their parents and transmitted it to their children, thus, giving to their practices the legitimacy of an inheritance as well as permanency. Their very frequent use of "always" highlights the validity of their practices, reifying them in a "style of planting" that has never failed and making useless any question about why doing so. The one who was not born on a farm learned from her husband, observing him (*"yo miro a mi marido y me enseña muchas cosas"* (Li)), but also following technical training courses and participating in producers groups, thus, placing her activity in many networks. This search for new knowledge within networks of producers is common to all the producers studied, whether they are born or not on a farm. The most cited source of knowledge refers to exchanges between producers and the experience that each producer can take to his or her farm ("*voy llevando la experiencia de otros*" (De), "*llevamos la experiencia de los productores*" (Dn), "*visitamos chacras, sí, así vamos aprendiendo cosas que vemos y probamos en nuestra chacra, y así*" (Ro)), some of them becoming themselves a source of knowledge for others by their activist involvement in extension groups. Nevertheless, the local nature of small producers' knowledge should be qualified in light of the many different sources of knowledge which they use to perform their activities, even remote ones such as the Paraguayan television. One producer refers also to the bible to explain his way of cultivating, as the higher principle which guides his life, and in particular his relationship to nature. Others draw from their knowledge of a previous work experience (e.g., grafting in a citrus company).

3.2. Agroecological Management Principles

From these practices in ecologically based farming systems, we have extracted three agroecological management principles. The expression "management principle" refers to the common coherence of the spatial and temporal organization of the practices carried out and their underlying logic, following Mintzberg and Waters (1985) and Girard and Hubert (1997).

3.2.1. Adjustment and observation instead of control

The first one is to favor adaptive management by relying on frequent observations of a crop's state and dynamic, with few intentions of predicting, planning, or rigorous control of productive processes. Contrasting with the classical planning and prediction paradigm that guides the management of crops in an industrialized agriculture, these producers clearly show a preference for adjustment: As external interviewers, we found it very difficult to formalize the calendar of cropping activities, as if each action is decided along the way. Beyond this apparent improvisation, what seems to be a management principle for them is the idea of taking advantage of circumstances, as shown by the many occurrences of the word *aprovechar* (to take advantage or grab the moment) in the interviews. This idea goes with a certain position regarding risks, as shown again by the practice of planting 4–5 seeds per hole for maize. Far from the classical agronomical strategy of risk reduction by controlling processes, such multiple-seed planting plays the role of a risk insurance policy for maize production, since producers explicitly hope that at least one seed will yield a producing plant. At the individual scale, these adjustments strongly rely on observation and remembered skills, as shown by a producer who goes back frequently to past results and observation to justify a decision. This producer seems to have a really good memory of past years and is able to reconstruct crop sequences from many years on her farm. Observation is, thus, incorporated into daily routines for many producers for whom walking around on their farm and observing what is going on is seen as a daily and enjoyable activity. By contrast with the importance of observation in their management, their knowledge may seem tentative since they cultivate many varieties for which they do not know specific names. Rather than the scientific identification of a variety or a population, what is important to them is the cropping or cooking properties of their varieties; as a consequence, they have very precise expectations about each variety regarding its role in the cropping, farming or even family system.

3.2.2. Variable temporal and spatial units within a flexible management concept

In the same vein, the second principle is to organize production in time and space in a very flexible way. Their taking-advantage-of-circumstances strategy pushes them to give up the ex ante planning of stable temporal and spatial objects: their management relies on various spatial units which additionally vary over time, providing flexibility to management styles. In particular, with the high degree of diversity and the complex combination of various crops in the same area (see section 3.1.2.), purely agronomical plots do not exist anymore in these farms. On the contrary, their practices open the continual (re)-definition of situated boundaries of cultivated units, whether it be "patch," "line" or even "plant." In the same way, the classical agronomic concept of planned crop sequence is of limited use in their management since they do not seek high predictability of cropping yields, showing a somewhat fatalistic attitude toward hazards related to their religious beliefs. As a consequence, at each moment of the year, there are very few fixed boundaries or deadlines to conform with. Many decision possibilities stay open all along the year in terms of planting, thinning, and harvesting.

3.2.3. Permanent on-farm experimentation and specification of technical options

A third principle is to permanently experiment to check and specify technical options regarding their specific farm, putting learning-by-doing processes at the heart of their knowledge system, whereas generic knowledge is often largely mistrusted. Whatever its origin, the knowledge which is used is almost always tested to see if it works at home." They perform many on-farm experiments, a practice which appears frequently and spontaneously in their discourse, with a high frequency of words such as "testing," "searching" or "studying," just as if they were researchers! The (quasi) mandatory nature of this on-farm validation can be linked to the mistrust that the producers express regarding general rules which are considered as not necessarily valid. Most producers insisted repeatedly that practicing and observing what is really happening on the farm are the only ways to learn ("*hay que practicar*" (De). For example, a producer's wife explained that one time, they were expecting good results for pineapple because the soil was "new" (general rule) and that was not been the case. She carried on her example by saying that on the contrary, when they tried to grow pineapple on a place looking like a pasture with a hard soil, they had good results. They concluded that it was worth not following the general rule and trying to plant, enabling them to identify the favorable context (here the degree of sunlight) for a specific crop. Some farmers are conscious that the knowledge they produce can be controversial regarding legitimate technical knowledge, but they strongly affirm the value of their own experience. Experiments can also be performed at the collective scale, that is, during exchanges between producers, which highlight the diversity of their worldviews. These exchanges mix discussions between producers and collective real tests of practices to see what works.

4. DISCUSSION AND CONCLUSION

Whereas ecologically based agricultural systems have been mainly described as alternatives to conventional approaches, some authors like Lyon et al. (2011) prefer to call them "farming without a recipe." Our results provide positive insights by scaling up ecologically based practices in three management principles. Drawn from idiosyncratic practices of small producers in Misiones, their generalizability has to be questioned. At a first level, some of the practices of Misiones farms, such as intercropping, strip cultivation, and patchy use of the farmland, have already been described for such "resource-poor farms" (Cáceres 2006a) and create a huge complexity of spatial management units and crop combinations (Toledo et al. 2003). The predominance of learning-by-doing processes in such systems has also been shown by other research (Cáceres 2007), especially within the milpa crop-growing system found throughout Mesoamerica which "includes a set of agronomic practices that have been proven through centuries of trial and error, empirical knowledge and intelligent observation" (Lambert and Arnason 1982). Moreover, avoiding negative combinations of crops is a practice that has been reported in Africa by Séhouéto (2006) and the opposites of *caliente/frio* as the conceptual basis for reasoning crop combinations seems also to be classic all over South America (Cerdán et al. 2012). Close to our European systems, the farmers' attitudes facing hazards in Misiones is not so far from the attitude called "diversifying to mitigate the effects of hazards" described by Girard and Hubert (1997: 64) in sheep farming systems of southern France. At a second level, the flexibility of decision making in Misiones with possibilities staying opened all through the year in terms of cropping operations can be seen as specific to the subtropical climate context where light, heat, and humidity are not constraining ecophysiological processes. Nevertheless, such flexible and complex management has already been described for market-gardens in France (Salmona 1994). While some agroecological principles may be inappropriate in new ecological settings (Abbona et al. 2007), they could perhaps be generalized in terms of the nature of uncertainties (Voß et al. 2007) that farmers are facing all over the world, more or less independently from their climate contexts. What remains to be investigated is the relevance of our management principles for other farming systems with various functional relationships between production and ecological processes, including more intensive farming. At a third level, the generalizability of our management principles should be discussed with regards to the socioeconomic context in which they appear. In particular, the process in which local knowledge is combined with other types of knowledge, including scientific, is probably specific to the technological context and the styles of articulation between extensionists and farmers (as shown by Cáceres 2006b). Our third principle of permanent on-farm experimentation and specification of technical options should then be discussed regarding the way scientific knowledge is localized within specific socioeconomic contexts and historical backgrounds (Landini 2010).

By describing the management principles underneath the high biodiversity of these systems, we have also contributed "to turn the 'problem' of diversity and context dependency of agricultural practices into a real ecological and social virtue" (Horlings and Marsden 2011). Moreover, far from taking local knowledge as the panacea for sustainable systems or as a green alternative to scientific knowledge (Murdoch and Clark 1994), our results put forward the need for further research on the link between action and knowledge processes and the possibility to generate technology "as a demand-driven process and spatially sensitive" (Horlings and Marsden 2011: 446, Table 1). Nevertheless, we did not analyze directly the process of ecologization, its driving forces and dynamic. Taking these agroecological principles as tools for the ecologization of conventional systems brings about at the same time the re-design of these systems (in the line of Ricci et al. 2011) and the change of management paradigms implemented by farmers. An open research question remains on how to guide such a paradigm change within the transition process.

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REFERENCES

Abbona, E. A., S. J. Sarandon, M. E. Marasas, and M. Astier. 2007. Ecological sustainability evaluation of traditional management in different vineyard systems in Berisso, Argentina. *Agriculture, Ecosystems and Environment* 119:335–345.

Altieri, M. A. 2000. Multifunctional dimensions of ecologically based agriculture in Latin America. *International Journal of Sustainable Development & World Ecology* 7(1):62–75.

Altieri, M. A. 2009. The ecological role of biodiversity in agroecosystem. *Agriculture, Ecosystems and Environment* 74:19–31.

Altieri, M. A., P. B. Martin, and W. J. Lewis. 1983. A quest for ecologically based pest management systems. *Environmental Management* 7(1):91–100.

Altieri, M. A., and V. M. Toledo. 2011. The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty and empowering peasants. *Journal of Peasant Studies* 38(3):587–612.

Cáceres D. M. 2006a. Agrobiodiversity and technology in resource-poor farms. *Interciencia* 31(6):403–410.

Cáceres D. M. 2006b. Dos estratégias de articulación entre técnicos y pequeños productores. Diferentes enfoques metodológicos y tecnológicos. *Cuadernos de Desarrollo Rural* 57:59–99.

Cáceres D. M. 2007. Tecnologías para campesinos: dos enfoques contrapuestos. *Comercio Exterior* 57(5):354–369.

Cerdán, C. R., M. C. Rebolledo, G. Soto, B. Rapidel, and F. L. Sinclair. 2012. Local knowledge of impacts of tree cover on ecosystem services in smallholder coffee production systems. *Agricultural Systems* 110:119–130.

Eisenhardt, K. M. 1989. Building theories from case study research. *Academy of Management Review*14(4):532–550.

Girard, N., and B. Hubert. 1997. A conceptual framework to identify a diversity of farmers' strategies and responses to uncertainty in sheep farming systems of southern France. In *Proceedings of the 4nd International Symposium on Livestock Farming Systems, Foulum (Denmark)*, 22–23 Aug. *1996*, 60–66 (EAAP Publication no.89). Wageningen, the Netherlands: Wageningen Pers.

Gladwin, C. H. 1989. Indigenous knowledge systems, the cognitive revolution, and agricultural decision making. *Agriculture and Human Values* 6(3):32–41.

Gliessman, S. R. 1992. Agroecology in the tropics: Achieving a balance between land use and preservation. *Environmental Management* 16(6):681–689.

Horlings, L. G., and T. K. Marsden. 2011. Towards the real green revolution? Exploring the conceptual dimensions of a new ecological modernization of agriculture that could "feed the world." *Global Enviromental Change* 21:441–452.

Izquierdo, I., F. Caravaca, M. M. Alguacil, and A. Roldán. 2003. Changes in physical and biological soil quality indicators in a tropical crop system (Havana, Cuba) in response to different agroecological management practices. *Environnemental Management* 32(5):639–645.

Koohafkan, P., and M. A. Altieri. 2010. *Globally important agricultural heritage systems: A legacy for the future*. Rome: UN-FAO.

Lambert, J. D. H., and J. T. Arnason. 1982. *Traditional milpa agriculture in Belize*. Ottawa, ON, Canada: Institute for International Development and Co-operation, University of Ottawa.

Landini, F. 2010. La dinámica de los saberes locales y el proceso de localización del saber científico. Algunos aportes desde un estudio de caso. *Cuadernos de Desarrollo Rural* 7(65):21–43.

Langley, A. 1999. Strategies for theorizing from process data. *Academy of Management Review* 24:691–710.

Lopez-Perez, J. A., A. Bello, A Garcia-Alvarez, and M. Arias. 2002. Mediterranean agrosystems as an agroecological model for nematode management. In *Proceedings 4th International Congress of Nematology*, eds. R. C. Cook and D. J. Hunt, vol. 2, 71–84. Leiden, The Netherlands: Brill Academic.

Lyon, A., M. M. Bell, C. Gratton, and R. Jackson, R. 2011. Farming without a recipe: Wisconsin graziers and new directions for agricultural science. *Journal of Rural Studies* 27:384–393.

Malézieux, E. 2012. Designing cropping systems from nature. *Agronomy for Sustainable Development* 32:15–29.

McCorkle, C. M. 1989. Toward a knowledge of local knowledge and its importance for agricultural RD&E. *Agriculture and Human Values* 6(3):4–12.

Miles, M. B., and A. M. Huberman. 1994. *Qualitative data analysis: An expanded sourcebook*. London: Sage.

Mintzberg, H., and J. A. Waters. 1985. Of strategies, deliberate and emergent. *Strategic Management Journal* 6:257–272.

Mitchell, J. C. 1983. Case and situation analysis. *The Sociological Review* 31(2):187–211.

Murdoch, J., and J. Clark. 1994. Sustainable knowledge. *Geoforum* 25(2):115–132.

Ricci, P., S. Bui, and C. Lamine. 2011. *Repenser la protection des cultures: innovations et transitions*. Paris: QUAE Editions.

Salmona, M. 1994. *Les paysans français. Le travail, les métiers, la transmission des savoirs*. Paris: Editions L'Harmattan.

Séhouéto, L. 2006. Savoirs agricoles localisés et production vivrière en Afrique subsaharienne. *Revue internationale des sciences sociales* 1(187):127–134.

Toledo, V. M., B. Ortiz-Espejel, L. Cortés, P. Moguel, and M. de Jesús Ordoñez. 2003. The multiple use of tropical forests by indigenous peoples in Mexico: A case of adaptive management. *Conservation Ecology* 7(3):1–17.

Voß, J.-P., J. Newig, B. Kastens, J. Monstadt, and B. Nölting. 2007. Steering for sustainable development—A typology of empirical contexts and theories based on ambivalence, uncertainty and distributed power. *Journal of Environmental Policy & Planning* 9:193–212.

Warner, K. D. 2008. Agroecology as participatory science: Emerging alternatives to technology transfer extension practice. *Science, Technology & Human Values* 33(6):754–777.

Wilson, G. A. 2008. From “weak” to “strong” multifunctionality: Conceptualizing farm-level multifunctional transitional pathways. *Journal of Rural Studies* 24: 367–383.