Agricultural Biodiversity at the Landscape Level

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Introduction

In the ELCI papers and discussions, two quite different meanings have been given to the 'landscape level'. On the one hand it has been interpreted as the summation over an area of the characteristics of agrobiodiversity. On the other hand, it has also been treated as only the essentially-unmanaged biodiversity of areas outside the farming landscape. The former meaning is more relevant to agrobiodiversity, but both have to be taken into account. Before going on to Principles, some discussion of the nature and properties of agrobiodiversity at the landscape level is therefore necessary.

Definitions and Properties

The landscape level means areas that combine several land-use types, over tracts of land that might be an administrative area, a community territory, a watershed or an arbitrarily determined area several square kilometres in extent. A more technical, and useful, definition of a 'landscape' is a 'heterogenous land area composed of a cluster of interacting ecosystems that is repeated in similar form' (Forman 1995: 13). Where the whole area is farmed, and there is functional (organizational) unity over such an area, meaning that the whole is worked by the same people, it might all be regarded as one agroecoystem.[1] More commonly several ecosystems are involved, so that landscape-level diversity includes diversity between agroecosystems as well as within them. The ambit includes not only the fields, pastures and agroforests, but also all areas of managed or unmanaged fallow and wild land within, among and around the agroecosystems.

At landscape or ecosystem level we need to take account of elements other the plants, animals, pollinators, pests and soil biota. Whole ecosystems are involved. Shifting or stable land-use or successional 'stages', as they are often described, now become primary elements, and they and the farmer-determined 'field types' into which they can be divided, are commonly used to provide the basis for sampling to yield detail on the content of biodiversity (e.g. Zarin, Guo and Enu-Kwesi 1999). The variation in the biophysical landscape that is being managed also becomes central to interpretation of the interactions between genetic resources, the abiotic and biotic environments and management practices (Almekinders, Fresco and Struik 1995). The biophysical landscape here includes soils, water and microclimate, all of which can vary within one field, but vary substantially more at landscape level.

Both biophysical diversity and the crops and livestock reared on it are subject to varying degrees of management. In large farms such as those of some Northern countries, and plantations in the South, management is generally uniform. In small farms, however, it is much more common to adopt different management methods on different micro-environments.

[1] The most widely-embracing definition of agroecosystems is that of Aarnink et al. 1999, which defines them as all and any ecosystems with human management. By this definition they would occupy the greater part of the whole biosphere.

No agricultural system can be understood independently from the manner in which management is organized and the forces that interact to shape this organization. Management involves farmers and their families, community leaders and others, and in modern times also officials of government and agriculture departments. What are sometimes called the socio-economic aspects of a farming system are better embraced by the term 'organizational diversity' proposed by PLEC (The United Nations University Project on People, Land Management and Environmental Change). Organizational diversity operates at landscape level to shape the agro-ecosystems. The layout of farms, the rotation of their land-use stages and field types, are all determined by those who manage the farms and the biological landscape within which farms operate. This is dynamic. Farmers are quick to respond to signals which demand variation in their strategies of resource mobilization.

Agrobiodiversity, the management of crops and the land, the biophysical diversity which is managed, and the varied forms of organization are all brought together as the constituent elements in the PLEC concept of 'agrodiversity' (Brookfield 2001). Although agrodiversity can be understood at the field level, it is especially at landscape level that its elements come together and determine the biodiversity of whole agroecosystems.

One aspect is of particular importance: the differential ability of farmers to manage their resources effectively. Farmers differ both in the amount of land and resources that they can use, and in their skills of management. The result is a patchwork of different outcomes for biodiversity, so that it is essential to take account of inequalities. This important aspect can only be viewed at landscape level.

Principles

Although with some differences of opinion, the following principles emerged from the meeting: Each is to some degree expanded.

1. At landscape level, it is more important to maintain diversity of land use across the whole area than to manage biodiversity within individual land uses.

In modern agriculture it is more common to minimize diversity of land use than to sustain it, by applying uniform systems of management which seek to override biophysical variations over large areas. Such uniform systems are very destructive of biodiversity, as well as being very costly. Shifting cultivation in which fire is the principal means of preparing the site for cropping is also a uniform system of management, though (in the long term) less destructive of biodiversity because of the importance of the fallow period. Diversity of land use can be attained by a variety of more benign methods. They include crop rotations, adapting choice of crops and cultural methods to soil and soil moisture conditions, interplanting crops in a mixture (polyculture), or planting crops among useful trees either conserved in land preparation or deliberately planted (agroforestry). There are also various mixed farming systems in which arable, trees and livestock are integrated. The values of maintaining landscape level diversity in any of these ways include maximizing the use of land, managing pests and diseases, sustaining habitats for pollinators and other useful biota, and enhancing biodiversity in the soil, as well as sustaining both floral and faunal diversity.

2. In this context, conservation and management of biodiversity will be optimized by varying the intensity of agriculture across the landscape.

Although ecological notions of succession to stable climax vegetation, which were first proposed in 1916, are still discussed in an influential modern book (Whittaker 1970), they have been largely displaced by an emphasis on disturbance, universal and relatively frequent, as creating new conditions within which succession takes place. Such successions can follow different paths, and rarely go so far as an ultimate climax before a new disturbance intervenes (Connell and Slatyer 1977). Connell (1978) proposed that species diversity ('alpha', 'beta' or 'gamma' diversity depending on scale) would be greatest where disturbances were at 'intermediate' levels in terms of frequency, nature or intensity. Whereas local climaxes may evolve in the absence of disturbance, such are commonly poor in species richness, just as are areas that have been heavily disturbed and are newly colonized. Biodiversity is therefore least both in recently-disturbed areas and in areas that have experienced no severe disturbances in a long time. It is now recognized that disturbance is necessary for the maintenance of high species diversity. All agriculture is a disturbance, but the disturbance may be of several types and orders of intensity. If the intensity of agricultural disturbance is varied through time, for example by deep ploughing or hot fire at one stage, and only shallow ploughing or patchy, cool fire at another, the conditions proposed by Connell would obtained. The implication is that for production of rich biodiversity, management practices should be varied between fields and through time. This is a common outcome of rotational practices.

3. Farm resource management practices should be modified so as to enhance habitat qualities in and around farmlands. In particular, it is advantageous to mimic natural habitats by integrating productive perennial plants.

Fundamentally, this principle is an advocacy of agroforestry in one or other of its many forms. The purpose is to retain diversity in the environment. However, natural habitats can also be mimicked in other ways. Distinctively, Wood (1998) has argued that monoculture, with its selective high primary productivity, mimics the first stage of natural regrowth after disturbance, and that pure stands of wild seed-producing grasses can endure indefinitely in many environments. That is to say that low plant species diversity is not necessarily harmful at all, provided it is supplemented by high species diversity in the soil, on field edges and in adjacent areas. This minority view cannot be disregarded, and such conditions may be part of a wider agrobiodiversity.

4. Areas within the whole landscape should be preserved in the sense that interference with biodiversity within them is carefully controlled, not that they should be reserved from all forms of human use.

This principle was argued at the meeting, especially among those who regard the 'landscape' as being composed largely of non-agricultural elements, that is of wild biodiversity. It was disputed by others who saw such reservation as licence to dispossess farmers of access to important parts of their resources. A compromise was reached, noting the widespread existence of small areas within agricultural landscapes that are reserved for religious reasons, to protect watersheds, or because they contain trees bearing fruit of high value. Other areas may harbour wildlife that is useful to people, provided the rate of hunting is managed. Total exclusion is therefore not supported, but good management may involve the allocation of some areas for little or no agricultural use. Participatory decision-making is of great importance in achieving any such compromise.

5. NBSAP planning needs to take account of the fact that ecological and socio-economic differences will make it easier for some farmers to manage biodiversity than others, and that these differences may be widening. Instruments for conservation need to be sensitive to these conditions.

Farmers managing good soils, and disposing of adequate resources of labour and other inputs, have an easier time in developing effective management of their soils than do poor farmers working only poorer soils. Increasing population density and evolving commercialization of production have the effects that resources become concentrated in the hands of a minority of more affluent farmers. In some areas, for example a high-density area of western Kenya, there is now a marked differentiation between a minority of affluent farmers who are able to invest in the good management of their soils and biodiversity and a majority now reduced to working very small farms. The latter cannot produce much of their own food, and depend so heavily on external employment that they are scarcely able to farm at all (Crowley and Carter 2000). No single strategy applicable to all farmers can be effective in the face of such differentiation.

6. It is important to expect change to occur. Conservation of a constant state is not a realistic goal.

All ecosystems are dynamic and, since they are rarely changing toward a steady state, their dynamics depend on the disturbance regime, both natural and anthropogenic. The landscape is a set of patches, none of which is in equilibrium; most change processes are, in fact, non-equilibrial. The nature and content of all patches changes through time, and the manner in which one patch changes has effects elsewhere in the system. Fallow areas are a particularly dynamic set of patches, and many of them are managed in ways that range from simple encouragement of preferred plants to planting of additional crops, usually tree crops, intended to occupy the land for periods of years. Management of the fallow for productive purposes may continue more than ten years in an area of Peru (Denevan and Padoch 1987). A distinction may be drawn among such plants from those which accelerate the regeneration of soil fertility, or fallow-improvement plants, and those which are encouraged or planted to provide income or material services, or fallow-enhancement plants (Cairns and Garrity 1999). Some managed plants in the fallow fall into both categories.

Practices in Relation to Each Principle

Principles 1 and 2 (Maintenance of diversity across the landscape)

There are few national agricultural or land-use policies which strongly incorporate these principles, and where they exist they are little implemented. Most national policies encourage mono-cropping rather than diversity. Although subsidies for use of agro-chemicals have now been removed in many countries, encouragement of organic methods of soil-fertility management is more on paper than in practice.

Voluntary efforts by farmers in the ‘Landcare’ movements of Australia, New Zealand and, more recently, South Africa, do often incorporate the maintenance of diversity as a tool in the control of land degradation. In these, the farmers of an area come together to map their own soil resources, and areas suffering problems such as erosion or salinization. In Australia many Landcare groups consist of neighbouring farmers working together to solve common problems, such as weeds, soil salinity, or feral animals. Tree planting, revegetation and property planning are common activities of Landcare groups.

Landcare groups also work on complex projects involving geographic information systems, developing new machinery for soil conservation or revegetation works, community education and community development. Many groups are working together to tackle problems at the catchment and regional level. In Australia, Landcare began as a formal movement in the 1980's and has developed to involve more than 3,000 Landcare groups around the country.

Such movements have not yet been organized nationally in most developing countries, but there are numerous NGOs and community groups networked through the Dutch-based Centre for Information on Low External Input and Sustainable Agriculture (ILEIA). This organization, founded in 1984, was a response to concern that ‘mainstream’ agricultural development was by-passing the small farmers of the South. ILEIA started to identify promising technologies involving only marginal external inputs, and building on local knowledge and traditional technologies, involving the farmers themselves in development. It produces the quarterly *LEISA Magazine* , in which a large number of local initiatives is given publicity. While management of biodiversity is not the primary aim, promotion of biodiverse agriculture is a central part of ILEIA’s activities.

The United Nations University Project on People, Land Management and Environmental Change (PLEC), since 1998 supported by the Global Environmental Facility, is another networking organization that brings together the efforts of more than 200 scientists and almost 3,000 farmers in twelve developing countries[2]. PLEC is specifically devoted to developing sustainable and participatory approaches to conservation, especially of biodiversity, within small farmers' agricultural systems.

Working since 1997 in almost 30 'demonstration sites', it shows how agrodiversity not only supports global objectives toward conserving biodiversity, but also supports human needs and development. From some of its areas has come the important finding that sound management of biodiversity, both agrobiodiversity and managed forest biodiversity, can be profitable to farmers. PLEC works with the most skilled, or 'expert' farmers, in devising ways of using natural resources that combine superior production with enhancement of biological diversity. Successful farmers in turn train other farmers. Work is at different levels of farm intensification. As one example among many, PLEC scientists in northern Ghana are working with local farmers to conserve *Oryza glaberrima*, the indigenous African rice. Farmers have traditionally relied on a diversity of varieties of this rice for food and livelihood security in face of difficult water availability and ecological change. The local group of PLEC scientists, and their farmer collaborators, are experimenting with ten varieties.

An important PLEC innovation has been the formation of farmers' associations, both to manage demonstration activities and to form bridges between farmers, scientists and the authorities. These associations have been formed in most PLEC areas, and are working effectively in coordinating conservation with development at the local level. The project supports them in a number of ways, principally with material assistance rather than money. Several of the associations have organized income-earning activities among their members, especially in creating value from biodiversity. With these sources of income, they are able to plan and conduct new activities. By degrees, they are also becoming associated with other projects and with NGOs, thus facilitating the mobilization of support. The backing of the scientists has been very important in their formation, but increasingly the more successful of these associations are taking charge of their own affairs. They need support over a longer period than PLEC, with its limited-term GEF funding, is able to provide.

PLEC produces a twice-yearly periodical, including numerous articles by its members, called *PLEC News and Views*; 18 issues have now appeared since 1993. One of the project's main objectives is to influence agricultural and conservationist policy in appreciating the value of indigenous land-use systems which have withstood all the tests of population growth, economic and environmental change.

Principle 3 (Enhancement of habitat qualities: agroforestry)

[2] The countries are Brazil, China, Ghana, Guinea, Jamaica, Kenya, Mexico, Papua New Guinea, Peru, Tanzania, Thailand and Uganda.

Agroforestry is a very ancient practice in many regions, where crops are planted, and livestock grazed, among trees which are conserved when the farm site is prepared, or are planted among the crops and pastures. Practices range from maintenance of only scattered trees to the planting of specific cash crops under a partial forest cover. Tea has been planted under forest in southern China for at least three centuries, and interplanting of a range of crops among coppiced or pollarded *Alnus nepalensis* has similar antiquity both in Yunnan and in the Nagaland region of northeastern India. *Alnus nepalensis* is long-lived, and litters profusely so that in addition to fixing nitrogen through a symbiotic fungus, it also supplies other nutrients to the soil.

More recently the aromatic and medicinal plants *Amomum villosum* and *Amomum* tsao-ko have been planted commercially under quite dense forest in Yunnan, with some resulting problems for forest regrowth (Guan et al., 2002, forthcoming). A study of agroforestry systems in four areas of Yunnan, carried out in the early 1990s, identified 82 forms and 220 associations among the agroforestry patterns mainly of minority peoples (Guo and Padoch 1995). In the same general region of southwestern China, a similarly-long history has also been established for the practice of planting a range of cereal, tuberous, cash, medicinal and oil-bearing crops among young Chinese fir (*Cunninghamia lanceolata*), itself of high value for its wood. This system was later imported into Burma by the British, and it formed the basis of the well established *taunggya* or (in Indonesia) *tumpangsari* system under which farmers are permitted to take a few years of crops between young teak (*Tectona grandis*), planted commercially after clear-felling of the natural forest (Menzies 1988; Tapp and Menzies 1997; Peluso 1992).

Some of the Alder systems in China involve planting of crops in rows between rows of Alder. This is an indigenously-developed practice (Guo, Xia and Padoch 1997). Agroforestry through alley-cropping has been widely promoted since the early 1980s, when this system, using exotic nitrogen-fixing trees, was first developed by the International Institute for Tropical Agriculture in Nigeria. It has since been promoted so widely that, in many circles, the term 'agroforestry' has been taken to mean only alley-cropping.

But, even from the beginning, farmers were often reluctant. They found the method not only burdensome in its labour demands, but also restrictive of yields because of competition between the tree rows and the crops (Carter 1995). In the 1990s, the International Centre for Research in Agroforestry (ICRAF), which had become the leading agency in the advocacy of alley-cropping as a means of stabilizing shifting cultivation, began to recognize these problems and to look at other and older forms of agroforestry, especially were soil-improving species were involved. This led to the re-evaluation of sequential – as opposed to simultaneous -- planting of nutrient-scavenging or nitrogen-fixing trees during fallow periods after and before the crop, on the same land (Sanchez 1995). Being not unrelated to the long-derided 'shifting cultivation', sequential or relay agroforestry followed ancient practices of farmers. The major change in approach was disarmingly explained by ICRAF's then Director-general, Sanchez (1999: 5): 'Competition for light, water and nutrients between the improved fallow and the crop is minimized by relay intercropping or sequential agroforestry systems. Sequential improved tree fallow systems are more robust than simultaneous agroforestry systems, such as alley cropping.'

Other forms of agfroforestry are more strictly tree-based. They are particularly characteristic of Southeast Asia. The richest in species composition are the village forests of Java, exclusively composed of useful species derived from the original forest they replaced, both by natural selection and planting. In examples studied in the 1980s, over 250 species were represented, growing in a multi-layered structure at mean densities of around 800 individuals per hectare. These forests are designed 'to provide all the products necessary for daily life, except for the staple food [rice]' (Michon and Mary 1994). Tree-based agroforests are also common in Sumatra and Kalimantan, where they meet commercial as well as domestic needs (Padoch and Peters 1993). They are developed and sustained by a combination of deliberate planting, casual planting and volunteer growth spared in successive weedings. They contain durian, langsat, rambutan, mangosteen, rubber, ilipe nut, sugar palm and constructional wood trees, to name only the principal plants. To a casual observer they look wholly natural, but are the product of 300 years of management, which still continues.

Principle 4 (Reservation of protected areas in non-agricultural land)

This principle is associated with the long-established practice of reserving areas from interference, something very difficult to achieve in closely-occupied agricultural areas, although it has been done with mainly small tracts of land where the biota seems to merit conservation. Conflicts with the users of adjacent land very commonly arise, and have led to new approaches to the management of protected areas that usually include 'buffer zones' in which some human activity is permitted. Three of PLEC's four demonstration sites in China are adjacent to protected areas, and in one a community lost access to almost half of what its people regarded as their territory for agroforestry, gathering and hunting when the protected area was designated. In another, the intensification of productive agroforestry in the adjacent areas, to generate good incomes without encroachment on the forest, has been a major focus of work with the people (Dao, Du, Guo, Liang and Li 2001). Only 19 of 131 countries in Asia, Africa and Latin America have designated substantial areas as 'protected' (Schelhas and Greenberg 1996), but smaller protected areas are more widespread.

Many small areas are designated by the agricultural people themselves to reserve land and forest for the gathering of fuelwood, medicinal and other useful plants, or for religious reasons as the abode of the dead. The village of Missidè Héïré, in the Fouta Djallon of Guinea, reserves 3.1 ha of forest and 15.6 ha of woody savanna immediately adjacent to its 27.2 ha of intensively-cultivated infields for these purposes, and also for protection from seasonal fire arising in the surrounding out-fields and fallow areas, which belong not to its own people, but to others (Boiro et al. 2002, forthcoming). In Ghana, cemetery areas are often reserved under forest, which also serve as a resource for produce collection and for the small wildlife which live within them, and are harvested by trapping. In northern Thailand, quite large upper-catchment areas are conserved from agriculture for watershed protection. In northern Tanzania, an individual farmer has created a woodlot in which rare species are conserved and has himself developed a set of 'bye-laws' to restrict, but not wholly prevent, access by others (Kaihura 2002, forthcoming). For such restrictions to work, community agreement, or the support of village authorities, is essential. Often, but not always, this is forthcoming. Such purely local arrangements are common, and they represent an important means of conserving diversity in the landscape. To the authorities, they may be invisible, and it is important to recognize that such conservationist arrangements do occur at local level, without external imposition.

Principle 5 (Differentials among farmers: land tenure)

The arrangements for tenure of land in different areas around the developing world defy generalization. There remain areas in which individuals as such get their land only from a group territory, and farm different plots at different times. Once there are permanent improvements of any kind in land, such as the planting of trees, individual rights are usually established. It is for this reason that migrants renting land as tenants are often forbidden to plant trees. Some tenancies are informal, but where land is short the conditions are often quite onerous, requiring that a significant share of the main crop be paid to the owners of the land. Although some writers distinguish between tenure arrangements under varying conditions of population density, no general rule can be applied; other conditions intervene. Different tenure arrangements can sometimes be found within the territory of a single group, and the history of settlement, agriculture and society can have a major effect on what happens even today.

An important distinction can, however, be drawn between countries and regions in which the state claims title to land, and allocates it to individuals on a legal basis, and those in which private arrangements continue to hold sway. One important aspect of colonial rule was the assumption by the state of title to all land not in current use, and sometimes to land in use as well. This has continued beyond the end of colonialism in many areas, among which the shifting-cultivation areas of Indonesia are a striking example (Brookfield, Potter and Byron 1995). Re-allocations took place, forcing people to occupy new areas, and to surrender large tracts of land to settlers, or companies.

Modern political changes in many countries have had a major impact on tenurial arrangements. In China, where all land management was collectivized in the 1950s, an individual household responsibility system restored private management in the early 1980s, but without formal surrender of title by the state. Even so, renting of land by individuals from other individuals became common in China by the 1990s. In other regions the state has intervened in different ways, creating individual titles where none existed before. This has been done, for example, in Kenya in response to a widely-held belief that only with individual title could farmers get access to credit, and be assured that improvements they made would continue to be their property. One consequence has been the great inequality in land holding and management in an area of western Kenya mentioned under C5 above.

It is too often the case that land tenure conditions are imposed from above, without adequate knowledge of indigenous systems, in particular social systems under which people can use their personal networks to access additional land, obtain assistance where it is needed, and help one another. Sometimes indigenous systems of tenure are quite deliberately disregarded, and new conditions are imposed that reflect the views held at state level concerning what proper land arrangements should be. A more sensitive approach to indigenous land rights is only slowly taking shape, and being applied in the management of relations between the state and its rural citizens.

NBSAP planning, like national agricultural policies and national environmental policies, are also top-down arrangements, and it cannot be said that any of those so far prepared take adequate account of the variety of land tenure arrangements that exist. Nor do they take account of the consequences in terms of inequality that make imposition of any set of uniform strategies an impossible goal. It is therefore important that in the development of such policies, there be consultation at local level on the implementation of strategies, and that this consultation be fully participatory among the farming populations who will be expected to conserve agrobiodiversity.

Principle 6 (inevitability of change)

Farming systems, even those described as 'traditional', do not remain constant. Indeed, they can change very quickly, adapting to new circumstances, disasters and, in particular, opportunities. Although some farmers now regret the loss of formerly-widespread landraces, a great many eagerly adopted the products of modern plant breeding during the 'green revolution' years, and many continue to do so.

The market has increasingly become the dominant force in farmers' decision-making. Farmers such as the Kofyar in northern Nigeria have not only given up most aspects of an intensive subsistence-based system developed over centuries on the Jos plateau but, in moving onto the plains, they have also shifted to market production as their principal enterprise. Yam cultivation for the urban markets absorbed more than a third of their total labour inputs in the 1980s (Stone 1997). In the West Africa case study written for ELCI, Gyasi and Enu-Kwesi describe in some detail the shift in production patterns made by the enterprising and adaptable people of southeastern Ghana. Having been major innovators for the export market in the late 19th and early 20th centuries, they responded to disease problems and market instability by shifting their activities to production for the national urban market in the second half of the 20th century. They continue to respond to the signals from that market.

The dynamism of farmers' practices has a large literature, the modern beginning of which was Richards (1985). Recently, Brookfield (2001) has described and discussed over 20 modern case studies, from the literature and field work, in which a high degree of adaptability is demonstrated. Where the available literature allowed this, a small number of historical cases was also examined in this general review of the topic of agrodiversity.

A case of particular interest is Cuba. Collapse of the entire trading system with eastern Europe in 1989-90, coupled with continuing American embargo on trade with Cuba, deprived the country of support for a mainly monocropping system of industrial agriculture inherited from before the 1959 revolution, and greatly strengthened with Russian support between 1964 and 1985. It became necessary quickly to diversify cropping, replace agro-chemicals with organic fertilizers, bio-fertilizers and bio-pesticides, and replace machine power by animal power. Big state farms were broken up into cooperatives, and individual farming was restored. A particular difficulty affecting diversification, not yet resolved, was collapse of the centralized seed production, improvement and distribution system. Despite major efforts, yields remain low, but a substantial measure of diversity has been restored. It is well analyzed in the Case Study paper on Cuba and Brazil.

Conservation of agrobiodiversity *in situ*, on farm, has to take place within a highly dynamic context. Agroecosystems change constantly, and none is a museum. There is considerable debate about how to encourage or assist farmers to conserve agrobiodiversity, especially landrace germplasm. However, landraces among open-pollinated crop plants, and even among some clonally propagated plants, themselves are not constant. Taking the example of maize in a region of Mexico, Louette (1999) showed how every landrace is a metapopulation created by geneflow within the local region and by new seed brought in from other areas. She remarked that ‘a landrace is far from a stable, distinct and uniform unit. Its diversity is linked to the diversity of material sown in the area, and then related to to diversity of the introduced varieties’ (Louette 1999: 137). Therefore, it is more practical to treat *in situ* conservation on farm as having the object of enhancing the processes that create genetic diversity, rather than to protect any specific body of genetic material. Agrodiversity, and its continual adaptability, provides the context of process that create genetic diversity.

Tools for the Maintenance of Agrobiodiversity

Farmers’ associations

It is not easy to specify tools for agrobiodiversity maintenance at landscape level, as the main requirement is the formation of groups of farmers able and willing to cooperate in agroecosystem management in whole communities and over areas of sub-regional extent. Moreover, the necessary scientific support has to be provided where it is not already present. The Australian landcare model could be used in participation with NGOs or Universities, and the PLEC farmers’ association model can be employed if the necessary external support is forthcoming from agricultural and other research centres. The farmers’ association model (a variant of the Community-based organization, or CBO) is as close as it is possible to get in many developing countries to the landcare model, and it can be an important tool for conservation in harmony with the improvement of livelihood security.

Tools for monitoring

To link associations at local, landscape level with national NBSAP and agricultural planning requires, however, means of monitoring that can only be provided centrally, at government level. The tools are available, including Landsat TM and Spot imagery, in most countries air photographs, and increasingly capacity in the interpretation of such data and its input into Geographic Information Systems. With these tools, supplemented by work on the ground in participation with the farmers, it is possible accurately to delineate agroecosystems, and to monitor changes that take place at landscape level. The basic problem is while the materials, and the skills, may be available, it costs significant money to use them. Hitherto, they have been used only in localities which have been of interest to particular scientists, and where linkages between farmers and scientists have been established.

Promoting agroforestry

Among the principal tools for enhancement of landscape-level biodiversity is the practice of agroforestry in any of its several forms as outlined above. Whether for soil improvement or for income, it is a form of intensification. In western Yunnan in China, farmers’ income from interplanting maize and beans among chestnuts is 2.8 times that from planting maize and beans alone, or 2.1 times that from planting chestnuts alone. Farmers are therefore very ready to learn from the experts on planting and grafting methods, and on proper spacing and maintenance (Dao et al 2001). Since some trees combine well with crops, whereas other inhibit the growth of crops among them, a good deal of knowledge is required. Similarly, if sequential or relay methods of agroforestry are to be employed for soil improvement, a lot of experimental work has to be done to obtain the best combinations, and the right timing. Research and experiment in these areas are invaluable tools in enhancing diversity.

Capacity building

In all such improvements the building of capacity among the farmers is essential. This can be done simply by providing instruction, but it is much better done if the most effective methods are first learned by the most skilled and inquisitive among the farmers, and then passed on to others through farmer-to-farmer training, formally organized or only informal. Structured methods of achieving this, such as those developed by PLEC, are evaluated by farmers as a major improvement on standard agricultural extension methods. The teachers are on the spot, and the demonstration is locally available. Farmer-to-farmer training, mostly informal, is in fact the way in which most beneficial agricultural changes have come about over time, in most parts of the world. The difference now is that the specific objective of enhancing biodivdiversity can be incorporated, and its value developed and demonstrated as part of the process. This requires another form of capacity building, that of a new generation and type of agricultural extension worker who can himself or herself learn from farmers, as well as from books.

Indicators

Briefly, in conclusion, the principal indicators for the effectiveness of these tools are as follow:

1. Successful formation of farmers' groups (Landcare type, CBO type, PLEC type), each bringing together farmers over a few square kilometres, in representative areas of a country.
2. Linkage of these farmers' groups with scientists and their institutions, and with local authorities, but in such a way that the agenda of the group comes to be determined by the members.
3. As a more critical test, the continued operation of these groups, with national support and scientific guidance as still needed, five years after formation.
4. Monitoring of change in the representative areas where farmers' associations (CBOs) has been developed, using remote sensing and GIS methods, in association with participatory inquiry among the population, and support of this monitoring by national authorities.
5. Successful determination, though scientific research in collaboration with farmers, of appropriate forms of agroforestry, and the application of these methods in representative areas.
6. Successful adoption of agroforestry practices, and improvement of farmers' income as well as biological diversity, through using them.

7. Recognition of farmers' own practices for conservation of specific areas for non-agricultural use, including the preservation of wild species, and collection of this information at district or regional level.

8. Full participation with farmers associations and local community groups in the application of patch conservation to new areas, and administration of such conservation being in the hands of farmers' associations.

9. Successful meetings held with farmers' associations and other stakeholders on the implementation at local level of NBSAP and other conservationist planning, feeding back to revision of NBSAP policies to take account of the conditions of land tenure and resource ownership of different classes of farmers.

10. Policy and practice for *in situ* conservation on farm becomes fully aware of the inevitability of change, so it shifts from conservation of specific genetic resources to support for the local systems which create the conditions under which such resources are conserved and further developed.

11. Farmer-to-farmer training becomes the basis of conservation management with improvement of farmers' livelihoods.

12. A new generation of agricultural extension workers trained to work with the more expert farmers, and learn from them as well as from scientific research and its products.

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