# On-farm management of crop diversity: an introductory bibliography

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Front cover photo: Farmer displaying her seed at the 1998 Maragwa Seed Show, Kenya. ITDG/Patrick Mulvany.

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# PREFACE AND ACKNOWLEDGEMENTS

Over the last decade, the need to develop practical strategies for supporting farming communities in conserving and using crop biological diversity sustainably has become widely recognised as important for ensuring food and livelihood security, especially in agriculturally marginal areas of the world.

This literature review was carried out by the Overseas Development Institute (ODI) and ITDG as part of the preparations for a joint project which aims to contribute to overall understanding of on-farm conservation and use of crop diversity by:

- exploring the community dynamics (as well as scientific aspects) of crop diversity conservation and use, and the implications of this for national and international action; and
- identifying and promoting strategies that will achieve sustainable use and conservation over the long-term, i.e. without requiring the continued intervention of outside agencies.

We gratefully acknowledge the funding provided for this project by the Environment Research Programme of the UK government's Department for International Development (DFID).

At the same time as carrying out the literature review, ODI prepared a paper on issues in agricultural biodiversity for the DFID project on `Linking Policy and Practice in Biodiversity'. We acknowledge the use of some of the background material for the issues paper in this literature review.

Joanne Long, at that time studying for the MPhil in Environment and Development at the University of Cambridge, UK, carried out the initial review under the supervision of Elizabeth Cromwell, Research Fellow at ODI, and Patrick Mulvany, Food Security Policy Adviser at ITDG. Additional material was later added by Kate Gold, Researcher, ITDG. Sincere thanks are due to Chris Wood, Brenda Walker, Zoe Wangler and Ann Watts at ITDG and to Mel Woodland at ODI for getting the text into shape and producing the final document.

The idea for the literature review came about during the preparation for the ITDG/ODI project, when we saw just how much literature exists, both published and unpublished, that discusses issues central to on-farm crop diversity conservation but which has not been collated and reviewed in one single location up to now.

The review is NOT a complete summary of all the literature that has been produced on crop diversity and on-farm conservation. Instead, it focuses on a selection of the most significant books and papers from the last decade that relate to a few central issues for the ITDG/ODI project: participatory techniques for researching on-farm crop diversity and indigenous knowledge; ideas on different models of on-farm crop diversity conservation; and the application of the principles and findings of conservation biology to crop diversity conservation. Inevitably we may have overlooked some relevant literature, and for this we apologise in advance.

Any views expressed in this literature review are those of the authors and do not necessarily reflect those of ODI, ITDG, or DFID.

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# PART 1 Crop Diversity

## 1.1 What is crop diversity?

Biological diversity or biodiversity refers to all forms of life - plants, animals and microorganisms – and the ecosystems in which they exist and interact. Agricultural biodiversity is a broad term that includes all the components of biological diversity of relevance to food and agriculture. Crop diversity refers to the biological diversity found in crops used for food and agriculture. It includes the knowledge of farmers and other users and is sometimes also referred to as `plant genetic resources for food and agriculture. Genetic diversity simply means all the variety of genes that exist in a particular variety or species.

Biological diversity exists at three levels in the farming system: at the ecosystem level, at the species level, and at the variety level. In practical terms this simply refers to the diversity of agricultural systems (agroecosystems), the diversity in the number of crop species grown in a particular agroecosystem, and finally, the diversity of different varieties of these crops. As far as crop diversity is concerned, genetic diversity within species is often more important than the diversity between species

A variety is an identifiably distinct type within a crop species. 'Modern varieties' (sometimes called 'high-yielding varieties' or (HYVs)) are the products of formal, institutional and scientific plant breeding, typically having a high degree of genetic uniformity, whereas landraces (sometimes called 'farmers' varieties', 'local varieties' or 'traditional varieties') are varieties which have been bred and selected by farmers, and tend to contain high levels of genetic diversity.

An important point to remember is that crop diversity is to a greater or lesser extent created and maintained with active human intervention. This means:

- agricultural ecosystems are `disturbed' environments, usually managed by farmers in order to maintain early stages of ecological succession; many aspects of crop diversity would not survive without this human interference;
- agricultural ecosystems rely to a large extent on `alien' species: the majority of economically important crop species have been introduced into many countries beyond their original area of origin. This means there is a very great interdependence between countries for the genetic resources on which our food systems are based.
- much crop diversity is held *ex-situ* (off-farm) in gene banks and other reserves, and not on-farm in the farming system.

## 1.2 Why Is Crop Diversity Important?

Biological diversity is essential to life, by providing the raw material for evolution and underpinning ecological stability. This also applies to crop diversity. Without it, crop improvement is impossible. It can be regarded as part of natural capital - a resource stock that can be drawn upon in order to contribute to strengthening people's livelihoods. Crop diversity must be conserved and well-managed in order to achieve a sustainable planet, but also to provide a positive development path for some of the poorest people on the planet. Over the last 20 or 30 years, plant breeders have been trying to produce higher yielding varieties of crops. As a result, for many crops we now rely heavily on a few `modern' varieties. Each of these modern varieties is very uniform and often contains less genetic diversity than farmers' varieties.

Why does this reduction in crop diversity matter? Uniform modern varieties do not resist diseases in the same way that landraces do (see Thrupp, 1998 for a table of crop failures due to genetic uniformity). Modern varieties need good land and a lot of fertiliser in order to yield well: they are not so much use for poorer farmers on less fertile land. Other reasons for maintaining crop diversity are in order to provide different dishes to eat, to ensure a harvest at different times of year, and also simply as a safe-guard for the future.

Concern about how quickly biodiversity was being lost was highlighted at the 1992 United Nations Conference on Environment and Development (UNCED). This produced the Convention on Biological Diversity (CBD), an intergovernmental convention ratified by 176 countries which entered into force on 29 December 1993 and in which the world's governments promise to try to conserve biological diversity, to make sure that it is used in a sustainable way, and that the benefits of using biological diversity are shared fairly amongst everyone. At first, the CBD had a conservation agenda and focused on wild ecosystems. Later, Decision II/15 of the Conference of Parties (COP) to the CBD recognised the specific nature of agricultural biodiversity and Decision III/11 in 1996 established a programme of work on Agricultural Biological Diversity.

## 1.3 Valuing Crop Diversity

There are a series of articles in the literature which discuss the valuing of biological diversity from an economics perspective. These include Swanson (1997) and various articles referred to within it; Hanemann (1988), which gives an overview of economists' approaches to biological diversity; Randall (1988) which discusses the welfare change measurement approach to resource allocation; and Ehrenfield (1988) which is a philosophical overview of the implications of putting a value on diversity. Norton (1988) suggests putting a value on diversity is analogous to a guessing game. Cox (1993) discusses common property resources and different ways of valuing ecological resources as well as briefly discussing benefit: cost analysis. Primack (1993) looks at various abstract terms, such as `direct values', non-consumptive use values and common property resources and gives case studies showing how these relate to concrete situations.

Brush and Meng (1998) stress the need for conservation programmes to address the value of landraces to farmers, and discuss the “unique and separate set of problems” faced in attempting to value crop genetic resources, including their wide distribution, their status as public goods, their daily use by individual farm households, and their association with less developed agriculture. Using economic and ethnobotanical approaches, they show that wheat landraces in Turkey have a private value to farmers and a social value as sources of crop genetic resources. Another article to specifically address crop diversity is Smale and Bellon, (1999). They argue that although there are ethical difficulties involved, it is necessary to value crop genetic resources in order to identify least-cost conservation strategies. It also helps us to understand the ways in which farmers manage crop diversity. Drawing on various theories they present an economic framework to analyse farmers’ incentives to maintain diversity. In economic terms, varieties have both ‘private’ (i.e. grain, fodder) and ‘public’ (i.e. contribution to genetic diversity) characteristics.

Also of interest are publications arising from the Hidden Harvest project (IIED, 1995, 1997) which explored methodological alternatives for understanding the value of wild resources at the local level. The methodology involved seeking local level perspectives on economic questions about resource values and incentives. Campbell *et al* (1997) used PRA techniques to rank non-market values of woodland resources in Zimbabwe.

Finally, there is a large literature on environmental economics, which covers the valuation of diversity as a component of the environment (Pearce, 1993; Pearce and Moran, 1994; Pearce and Turner, 1990).

## 1.4 What is on-farm conservation?

Scientists have tended to conserve crop diversity mainly by collecting samples from farmers’ fields and storing them `*ex-situ’* (off-site) in gene banks. However, in recent years there has been increasing recognition of the need to complement this with `*in-situ’* (on-site) conservation.

Maxted *et al.* (1997a) define *in-situ* conservation as:

> “….the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations in their natural surroundings and in the case of domesticated or cultivated species in the surroundings where they have developed their distinctive properties”

They distinguish between two forms of *in-situ* conservation: ‘genetic reserve conservation’; and ‘on-farm conservation’ and expand on these concepts in Maxted *et al* (1997b). ‘On-farm conservation’ is considered to be ‘the sustainable management of genetic diversity of locally developed traditional crop varieties with associated wild and weedy species or forms by farmers within traditional agricultural, horticultural or agri-silvicultural cultivation systems’. The key feature of on-farm conservation is the traditional knowledge and practical skills of the farmers; thus it is sometimes referred to as on-farm management (Engels & Wood, 1999).

## 1.5 Approaches to on-farm conservation[1]

Although an early paper by Iltis (1974) proposed a original model of *in-situ* conservation which required no change in farming system nor introduction of foreign material, most authors recognise that for socio-economic reasons such 'freezing' of the genetic landscape is not possible, nor necessary (Louette and Smale, 1996). This paper and Louette (1994) are based around the idea that in-situ conservation means preserving in their original agroecosystem varieties cultivated by farmers using their own selection methods and criteria. The origins and dynamics of the crop diversity that can be observed on traditional farms are analysed. In fact, it is this very dynamism that is the main advantage of on-farm conservation as opposed to *ex-situ* methods (Maxted *et al*, 1997a).

Altieri and Merrick (1987) is one of the key early papers and is widely referred to. They outline the differences between *in-situ* and *ex-situ* methods of conservation, emphasising the dynamic conservation inherent in the former, drawing heavily on Prescott-Allen *et al.* (1982). They suggest that *in-situ* conservation is best done through the maintenance of farming systems.

Brush (1995b) (a reprint of his classic 1988 paper) clearly sets out the agenda for *in-situ* conservation in contrast to ex-situ methods, with a diagram outlining the operation of the traditional agroecological system. This is accompanied by a response by Altieri to Brush's ideas

Oldfield and Alcorn (1987) describe *in-situ* conservation as conserving a process of evolution and adaptation of crops to their environments. Brush and Meng (1998) note that the goal of in situ conservation is not to preserve a given number of alleles or genotypes (i.e. diversity *per se*) but to maintain an agricultural system which generates crop diversity in a similar way to traditional systems. This is supported by IPGRI (1996) where it is suggested that the main contribution of *in-situ* conservation is the maintenance of evolutionary processes rather than the material itself. However, Lande and Barrowclough (1990) remind us that a prerequisite for these processes is the existence of genetic variation.

Damania (1996) sees *in-situ* conservation as the conserving of diversity together with the dynamic environment. This draws on Chang (1994) who maintains such a strategy provides a broad genetic base and maintains population structures, stability of numbers and opportunities for future adaptive expansion. Brush (1991) states that *in-situ* conservation refers to the maintenance of four types of genetic resources in natural settings: wild crop relatives; weedy crop relatives; perennial species; and landraces of ancestral crop species.

This links to the idea of *in-situ* conservation as the maintenance of suitable conditions for introgression to take place. Engels and Wood (1999), acknowledge the potential for enhancement of on-farm populations but note the lack of methods for sampling or evaluating this in the field. Wood and Lenné (1993) discuss *in-situ* conservation in terms of maintaining *potential* diversity through maintaining the conditions for introgression to take place at the crop-weed-wild interface and question the claims of Altieri and Merrick (1987), Nabhan (1985) and Johns and Keen (1986) regarding the significance of natural gene exchange among crops.

[1] It is important to note that some of the earlier literature reviewed in this section uses the broader term *in-situ*.

That introgression may not always be positive is discussed by Wood and Lenné (1999a), who cite the possibility of aggressive weeds evolving, and the potential escape of genes from genetically engineered crops into the wild-weedy flora.

Some authors compare *ex-situ* and *in-situ* conservation. For example, Soleri and Smith (1995) compare populations of hopi maize conserved *in-situ* and *ex-situ*. Pistorius (1997) compares *in-situ* and *ex-situ* conservation by outlining the arguments in favour of each. Dempsey (1996, Appendix B) also contains a comparison of *in-situ* and ex-situ conservation.

The role of farmers is emphasised in many articles. For example, Shiva *et al* (1995) suggest that 'conservation of agricultural biodiversity is impossible without the participation of the communities who have evolved and protected the plants and animals that form the basis of sustainable agriculture' - the farmer is thus at the centre of conservation. This is inherent in many of the definitions of *in-situ* conservation and the assumptions made about it. These assumptions are examined closely by Wood and Lenné (1997).

Milner-Gulland *et al.* (1996) look at the connection between household decisions and agroecology, while Altieri *et al*. (1987) describes the continuum from traditional agriculture to natural ecosystems, stressing the importance of *in-situ* conservation involving elements of rural development, self sufficiency and indigenous knowledge. Altieri (1987) stresses ethnobotanical knowledge as a part of the social structure which needs conserving, and King and Eyzaguirre (1999) point out that because domesticated crops are shaped by indigenous knowledge and their uses within indigenous systems, the preservation of cultural systems is as important as the conservation of biological resources.

There are also a series of case studies of *in-situ* conservation in Zimbabwe which link traditional management, household security and crop diversity – for example, van der Mheen-Sluijer (1996), CTDT (1996), Musa (1996) and Rusike *et al.* (1996). Vega *et al* (1997), in a study of Cuban agroecosystems, suggest that conservation *in-situ* does not mean a return to traditional systems but rather that we can learn from the equilibrium between production and conservation observed in such systems. Maikhuri *et al* (1997) suggest that integrating traditional practices is a more efficient strategy than replacing them and call for multidisciplinary research efforts to evolve farming systems which can provide food and economic security and at the same time conserve traditional crop wealth. Olasantan (1999) makes a similar call.

Many authors identify the strong links between crop diversity and social, economic and cultural factors and point out that on-farm conservation consists of a range of interlinked elements which together support diversity as part of a dynamic system. Bellon (1996c), for example, is a good explanation of the multidisciplinary links involved and suggests that agroecological heterogeneity, socio-economic factors and the availability of family labour have a significant impact on the levels of crop intraspecific diversity maintained. Hodgkin *et al*., (1993) recognise that crop diversity conservation choices made by farmers may not always coincide with those that conservationists would favour to maintain the long term adaptiveness of landraces.

Adding value to traditional crops is discussed by Maikhuri *et al*, (1996) in an article on sustainable development in the central Himalayas. Brush and Meng (1998) wonder how long farmers will continue to "subsidise" on-farm conservation of crop genetic resources if methods to increase the private value of landraces are not devised, while Piergiovanni and Laghetti (1999), describe a scheme to add value to Italian bean landraces by attributing origin and quality marks. Tesamma and Bechere (1998) outline an approach aimed at enhancing the yield of durum wheat landraces in Ethiopia and thereby promoting their continued and effective use by peasant farmers. Sharma and Sundriyal (1998) give an example of how farmers in Sikkim, India, have developed a cash crop – cardamom - from indigenous agricultural biodiversity, thus ensuring that farmers conserve and manage a large number of cardamom varieties on each farm.

Thrupp (1998) calls for the development of "an ecosystems approach, using agroecology as a guiding scientific paradigm, to support and validate the sustainable use and enhancement of agrobiodiversity at al levels". The ecosystem approach is reflected in the literature relating crop diversity to agroecosystem sustainability. Pimbert (1999) shows how high agricultural biodiversity sustains the following production functions: soil organic matter decomposition, nutrient cycling, pollination, pest control, yield functions, soil and water conservation, water cycling in both low external input and high input farming systems and outlines contrasting options to sustain agricultural biodiversity. His 'learning process approach' promotes the local adaptive management of agricultural diversity. Similarly Altieri (1999) suggests that internal regulatory functions in agroecosystems is "largely dependent on the level of plant and animal diversity present".

Edwards *et al* (1999b) and Wood and Lenné (1999b) draw on conservation biology to compare agroecosystems and natural ecosystems. Wood (1998) relates ecological concepts to agriculture and links this to the debate on biodiversity and stability. Wood and Lenné (1999b) find no definitive evidence either that species-diverse, complex communities are stable or that species-poor, simple communities are not stable.

Other aspects of conservation biology relevant to conserving crop diversity include:

| | |
|---|---|
| population size: | Menges (1995), Lesica and Allendorf (1995), Spellerberg (1996), Caughley and Gunn (1995), Given (1994), Frankel and Bennet (1970) |
| exotic species: | Temple (1995) |
| conservation genetics: | Cox (1993), Spellerberg (1996) |
| disturbance: | Hobbs and Huenneke (1992) |
| reserve design: | Hunter (1996), Spellerberg (1996) |
| island biogeography: | Louette and Smale (1996), Bellon and Taylor (1993) |

# PART 2. On-farm conservation

## 2.1 Farmers' Perspectives of Crop Diversity

Despite the growing interest in on-farm conservation of crop diversity there is as yet little published information specifically relating to farmers' management of agricultural biodiversity. However, the anthropological and ethnobotanical literature does contain case studies of farmer classification systems. These studies clearly illustrate how farmers use agromorphological characters in their management of crop diversity.

Wood and Lenné (1993) discuss varietal classification, suggesting that, "traditional landraces usually differ in agromorphological characters which are used by farmers as markers for taste, texture, yield, storage characters, resistance to environmental stresses, use and maturity time. Remarkable parallels exist across crops and cultures and continents". They then give evidence from a range of case studies, including ones relating to sweet potatoes (Amante and Bader (1991), Bourke (1982)), Andean potatoes (Brush *et al* (1981), beans in Malawi (Ferguson and Sprecher (1987), Martin and Adams (1987)), shifting cultivation in South-East Asia (Conklin (1957), Dove (1985)), traditional tropical agriculture (Clawson (1985), Thurston (1992)).

Jarvis and Hodgkin (1999) also review studies of farmer classification, recognising that most use an agromorphological definition. They give examples from around the world, including: rice in Nepal (Sthapit *et al*. (1996a)), millet in India (Weltzien *et al*. (1996)), sorghum in Ethiopia (Teshome, (1996)), potatoes in the Andes (Zimmerer and Douches (1991)) and maize in Mexico (Louette *et al*. (1997)).

There are some other case studies in the literature. Casas and Caballero (1996) investigate traditional classification of *Leucaena esculenta* in the Mixtec region of Mexico. They recommend a series of references: Berlin *et al.* (1974), Berlin (1992), Casas *et al.* (1987), and Casas *et al.* (1994).

Richards (1995a) briefly covers the geographical etymology of rice varieties in Sierra Leone in his review of farmer sociology. Altieri and Merrick (1987) suggest Davis and Bye (1982) as a useful case study from Central America. From Sperling and Loevinsohnn (1996), there are several useful papers on understanding farmer seed and variety classification systems.

Benz *et al.* (1990) gives a series of individual accounts from Mexico concerning the understanding of *zea diploperennis*. Shigeta (1990) is a study of folk *in-situ* conservation but includes a section on diversity and genetic identity of *ensete* landraces listing vernacular names and their characteristics. Bellon and Brush (1994) is a case study of maize in Mexico, which deals with varieties and traditional classification and farmer perceptions. Peroni *et al* (1999) examined local classification systems for cassava and related this to morphological characteristics evaluated in the field.

Also of relevance are studies focusing on farmers' use of wild species. Evans (1996) looks at intrinsically wild food and discusses courses of action to help conserve wild food species. Ingram *et al.* (1984) discuss strategies for the conservation of wild (undomesticated) relatives of crops. The Hidden Harvest project considered the role of wild species in the agriculture of a community in Zimbabwe, and the community perception of the sustainability of this resource, (IIED, 1995, 1997). Casas and Caballero (1996) is a study of the manipulation of wild plants by farmers in a situation where wild resources of species are so readily available that cultivation is not necessary. This study hints at a continuum between domesticated and non-domesticated species, suggesting that manipulation can alter the genetic diversity of wild species.

The flow and exchange of genes between crop species and related weedy species is widely discussed in the literature. Wood and Lenné (1993) discuss the crop-weed-wild interface. They say, "*it is widely believed that farmers play an active role in fostering sympatric populations of wild and weedy relatives to facilitate gene exchange for the benefit of crops, especially for maize and potatoes......but in only one locality in Mexico is there full confirmation that teosinte is knowingly planted or desired by native cultivators*". The case in question is documented by Wilkes (1977) but as is pointed out by Wood and Lenné, (1997), there is no proof that desirable traits have been passed from teosinte to maize by this practise.

Jarvis and Hodgkin (1996) review the connection between wild relatives and crop cultivators, including evidence that farmers assist introgression, although they admit that knowledge is limited as to whether farmers actively encourage intercrossing. They discuss evidence for a range of crops (sorghum, maize, pearl, millet, potato, beans, carrots and cabbages), acknowledging the burgeoning literature on farmer selection but noting the absence of material on the role of wild relatives in this activity. A few useful studies are listed including Benz *et al*. (1990), which looks at the active encouragement of introgression by farmers, suggesting that the 'process of promoting hybridisation between maize and milpilla [a wild relative] is a practice widespread in Mexico'.

Serratos et al. (1997) discuss the geneflow between maize landraces, improved maize varieties and teosinte in Mexico, and admit that 'further research is needed in this area'. Senghor (1999) describes farmer knowledge and management of cultivated and wild rice, including natural hybrids, and explains how such forms contribute to the expansion and preservation of genetic diversity. Longley (1999) discusses the potential for gene exchange between semi-weed and cultivated rice and say that if this happens it is an "unconscious" result of farmer practices rather than a deliberate strategy.

## 2.2 How do farmers' decisions affect crop diversity?

Cox and Wood (1999) consider that farmers' decisions, influenced by economic, social, cultural, natural and historical factors, are the principal determinants of crop diversity. Population structure and natural selection from the surrounding environment are also important and may themselves be influenced by farmers (Jarvis *et al*, 1998).

Jarvis and Hodgkin (1999) summarise five aspects (see below for more detail), of farmer decision-making that affect crop diversity: what agromorphological characteristics to select for; what farming practices to use; where to plant; size of population to plant; and seed sources, but conclude that, in the most part, the link between the effect of farmer management decisions and the amount of genetic variation within the crop population has not been studied in detail. They outline the multidisciplinary global IPGRI project which aims to address this (see also IPGRI, 1996, and Jarvis and Hodgkin (eds.), 1998).

### 2.2.1 Agromorphological characteristics

Apart from the considerable literature on farmer classification systems (see Section2.1) there are few studies directly linking farmers decisions on agromorphological characteristics to crop diversity.

Louette and Smale (1996) report on a study of maize management by small farmers in Mexico, and show how the morphophenological diversity of local materials is enhanced by introductions of improved cultivars and also landraces from other regions. (The diversity is assessed through factor and cluster analysis.) This ties in aspects of farmers' decisions over both selection and seed source, illustrating the variation of diversity over time.

Teshome *et al* (1999) show that sorghum landrace diversity in Ethiopia was significantly related to a number of farmer selection criteria. Sandoval (1991) discusses farmer decision-making, highlighting how it is necessarily based on phenotypic criteria such as morphology and taste. A study by van Oosterhout (1993) concerned agromorphological characteristics of Sorghum varieties in Zimbabwe.

Eyzaguirre and Iwanaga (1996a) recognise that agromorphological diversity relating to use (e.g. flavour) and preferences (eg. colour), is an important farmer strategy for maintaining and managing diversity. They link this to participatory plant breeding and suggest that considering the criteria farmers use in selection may provide an alternative way to look at breeding aims.

Soleri *et al* (1999) is an account of research into farmers' maize seed selection processes in Oaxaca, Mexico. Farmers' selection criteria could be divided into three categories: those relating to seed viability (e.g. rejection of pest and disease damaged cobs); those relating to cob and kernel size (e.g. ear length and weight); and those relating to defined varietal characteristics (e.g. grain type, colour etc.). Criteria in the third category varied between households and communities, but the first two categories were unchanging and of primary importance. When selected and randomly chosen samples were sown in the field and the population means for a number of agromorphological characteristics compared, the effect of selection was found to be negligible.

There are several case studies documenting the role of indigenous farmer experimentation in relation to crop diversity: Bhutan *et al* (1999) and Fujisaka (1999) list farmers reasons for planting selected rice varieties, reflecting different agro ecosystems and the multiple uses of rice. A long-term study of farmer maintenance of root crop genetic diversity in the Philippines suggests that the most important criteria for evaluating introduced varieties is survivability, only later do agromorphological criteria come into play (Prain and Piniero, 1999).

Yamaguchi and Okamoto (1997) analyse relationships between crop diversity and human activities in relation to traditional practices of landrace maintenance of Japanese radish.

### 2.2.2 Farming practices

Jarvis and Hodgkin (1999) list those farming practices that may affect diversity: land preparation, planting, thinning, weeding, fertiliser application, pest control, irrigation, harvesting, and post-harvest processing and recommend Snaydon (1984) for a discussion of how they affect diversity.

Wood and Lenné (1999a) discuss the origins of agricultural biodiversity and list deliberate human management factors that may have an impact on diversity. Sometimes these impacts are rather complex, for example weeding may:

- reduce potential for introgression
- reduce alternative hosts for pests and diseases attacking the crop.
- reduce competition and thus allow the crop to grow in a wider range of ecogeographical niches.

Polaszek *et al* (1999) cite several papers referring to cropping practices – multilines, varietal mixtures, intercropping and multiple cropping – that increase crop diversity. They also argue that the use of modern, disease resistant varieties, or varietal mixtures as part of a pest management strategy need not necessarily reduce local crop diversity.

Edwards *et al* (1999a) consider the impact of agricultural intensification on biodiversity. Intensification driven by local land shortages will have a local impact on biodiversity while intensification driven by market opportunities and specialisation of production systems will have a much wider impact on crop diversity.

Other relevant case studies of the effect of farming practices on crop diversity include the effect of different types of fertiliser (Silvertown et al. (1994); and a comparison of irrigated and rainfed farming in Morocco (Sadiki, 1990).

### 2.2.3 Where to plant

Farmer's decisions on where to plant may affect crop diversity in several ways. Choosing a particular site will expose the population to natural selection processes that may result in selection for tolerance to a particular stress related to that micro-environment. The spatial distribution and isolation of a population will also be affected by where it is planted in relation to other crops/varieties.

Jarvis and Hodgkin (1999) list a series of studies concerning how plant populations adapt to their environments and the amount of genetic variation over time due to environmental factors: Merrell (1981); Allard (1988, 1990); Fowler (1990); Le Boulc'h *et al*. (1994); Goldringer et al. (1994); Via (1994); and Anikster *et al*. (1997)

Huenneke (1991) covers how the pattern and extent of genetic variation are related to ecological range and performance and how genetic variation within a population is related to that population's chances of persistence and ecological success.

Bennett (1970) discusses adaptation in wild and cultivated crop populations. Richards (1987) considers strategies of diversified crop production, spreading risks across slopes in different agroecological zones. Demissie and Bjornstad (1996, 1997) study the influence of agroecological variation on selection in barleys in Ethiopia.

Almekinders and Louwaars (1999) describe the use of local varieties for variable environments, saying that farmers use genetic variation in crops to match variation in soil conditions between and within fields. They illustrate this with a case study of Mende rice farmers in Sierra Leone. For a fuller description see Longley and Richards (1993).

Bhuktan *et al* (1999) describe how rice varieties are rotated spatially, with the specific aim of reducing early varietal degradation.

Bellon and Taylor (1993) is a case study of the link between folk soil taxonomy (i.e. perceived agroecological conditions) and uptake of new technology (i.e. new varieties). Similarly, Bellon and Brush (1994) look into interactions between farmer's management and maize germplasm. Both investigate what influences a farmer to plant in a particular habitat.

### 2.2.4 Population size

Farmers' decisions regarding population size are closely linked to crop diversity. Several principles of conservation biology are relevant here, including genetic drift; population genetics; minimum viable populations; inbreeding and the impact of stochastic events. Jarvis and Hodgkin (1999) recommend Shaffer (1990); Lande and Barrowclough (1990); Barrett and Kohn (1991); Frankel *et al.* (1995); Menges (1991); Caballero (1994a) and Slatin (1987).

There are also a series of studies concerning the significance of population size: Frankel *et al.* (1995); Menges (1995); Lesica and Allendorf (1995); Huenneke *et al.* (1992); Schaal and Leverich (1992); Trenbath (1992); Caughley and Gunn (1995) and Given (1994).

### 2.2.5 Seed sources

Almekinders and Louwaars (1999) observe that while small-scale farmers usually prefer to use their own seed there are a variety of reasons why they may use seed from other sources (and therefore, intentionally or not, influence crop diversity):

- To obtain seed of new varieties
- Loss (poor harvest, stored seed lost to pests or diseases, seed eaten or sold) of harvested seed.
- To replace diseased or genetically degenerated seed.
- Own seed not of good quality e.g. difficulty of avoiding seed-transmitted diseases.
- Farmer seed production not feasible e.g. hybrids, some vegetables
- Difficulty of maintaining seed viability from harvest until planting
- Specialisation e.g. use of mechanised planters (requiring graded seed) or production for particular markets (requiring uniform, pure seed).

Schneider (1999) examines varietal diversity of sweet potato and notes that as well as intentional selection for distinctive properties, there is also unintentional selection because a preferred variety is not available.

Bellon (1996a) reviews farmer decision making with respect to diversity and describes a series of processes involved in farmer diversity management. These are the decisions made by farmers concerning seed flows; variety exchange; variety adaption and seed selection and storage. Variety selection has a direct impact on diversity in an individual farmer's field. He suggests that 'seed flows are important to understanding the diversity present in a location because they are the basis for incorporating new varieties and obtaining materials that are lost but desirable'. This is based on a series of studies that have documented the flow of seed among small farmers: Cromwell (1990); Dennis (1987); Louette (1994); and Sperling and Loevinsohn (1993). He also comments on the importance of markets in pooling together varieties from different regions (see also Quiros *et al.* (1992). Van Oosterhout (1996) documents seed flows with a series of maps

Jarvis and Hodgkin (1999) focus on aspects of seed saving and storage systems, migration (i.e. seed flows) and bottlenecks. Migrations and bottlenecks are perceived to add and subtract to the seed diversity over time. Useful studies of these dynamics are Louette and Smale (1996); Louette *et al* (1997); and Levin (1984). Zimmerer (1998) highlights the importance of seed procurement networks in maintaining the diversity of Andean potatoes.

Seed flows are linked to population size for each cultivar. Cromwell (1996) and Friis-Hansen (1996) both cover this area. Storage systems are also considered important (see Kashyap and Duhan, 1994).

David *et al.* (1997) investigate the success of a range of bean seed marketing channels in Uganda and highlight some of the dynamics surrounding seed availability in communities. A range of other literature including material on this topic is suggested, including Sperling (1994).

David (1997) has a similar useful focus, being an attempt to understand local seed systems as a basis for designing improved delivery systems and investigating alternative modes for distributing new bean varieties. The table 'Use of diverse seed distribution channels in selected countries', is a good summary of the geographical variation (on a per country basis) in different seed distribution channels. David and Sperling (1999) challenge commonly held assumptions about small farmers seed purchasing and diffusion behaviour, and produce recommendations for farmer-oriented distribution systems for seed of new bean varieties.

Longley and Richards (1999) review the significance of farmer seed systems in enabling small farmers to retain or obtain seeds within their communities during disaster (drought, war) situations.

Kamau (1997) is a case study identifying the constraints to farmers' use of certified bean seed in Kenya. Farmers' seed source preferences are tabulated. Friis-Hansen (1999) covers community seed exchange, seed selection, and seed treatment and storage with examples from a Tanzanian case study. Mpande and Mushita (1996), ENDA *et al.* (1996), Almekinders *et al.* (1994) and Musa (1999) are further studies from the literature of local seed systems.

Cromwell *et al* (1993) identified four main groups of farmers with regard to seed sourcing behaviour:

- Seed secure farmers, who can fulfil their own seed needs
- Farmers who source seed off-farm from time to time out of choice

- Farmers who source seed off-farm from time to time out of necessity
- Farmers who are seed insecure and consistently need to source seed off-farm

Wright and Turner (1999) refer to these groups and discuss the implications for genetic diversity; for instance, that seed secure farmers will tend to maintain their own varieties and have a limited influx of new varieties, but may manage a wider range of varieties than other farmers, while seed-insecure farmers may use a wide range of varieties, but may not necessarily continue to use them from one year to the next.

## 2.3 What factors influence farmers decisions?

Farmers' decisions are constrained and influenced, directly or indirectly, by external factors. Jarvis and Hodgkin (1999) summarise the interactions involved in farmers' decisions:

> ‘Farmers make decisions in the process of planting, managing, harvesting and processing their crops that affect the genetic diversity of crop populations...each of these decisions, which can affect the genetic diversity of cultivars, is linked to a complex set of environmental and socio-economic influences on the farmer’..

and list a series of studies which link environmental and socio-economic factors to farmer maintenance of local crop cultivars: Glass and Thurston (1978), Clawson (1985), Richards (1986), Brush (1991), Brush (1995a), Brush *et al.* (1992), and Cromwell and van Oosterhout (1999).

Van Oosterhout (1995) discusses the historical influences on diversity in Zimbabwe, looking at climate, politics and science. Cuanalo de la C. and Arias (1998) put forward an equation to describe the social, economic, environmental, and technical factors that influence farmers’ decision-making in Yucatan, Mexico. They suggest that one or other of the factors could be isolated in order to deduce the impact of that particular influence.

Hodgkin (1995) classifies factors that influence farmers to maintain diversity into:

- Economic (e.g. less risk of crop failure but low yields)
- Ecological (e.g. use of microniches)
- Political (e.g. national agricultural policies, donor policies)
- Social (e.g. recognition of traditional knowledge)
- Cultural (e.g. value systems)

Agricultural biodiversity is discussed in depth by Thrupp (1996). The conditions which maintain high diversity are outlined and a range of influences described. Issues such as the impact of the ‘green revolution’ and impacts of ‘unsuitable agriculture’ are discussed and several case study examples and references are included. Political elements are covered in a synopsis of institutions and initiatives affecting diversity. Jarvis and Hodgkin (1999) suggest other useful references on this issue, including Leskien and Flitner (1997); and Qualset *et al*. (1997).

CTDT (1996) is a case study of socio-economic and technical factors determining community biodiversity development and management in Zimbabwe. It focuses on availability of seeds, access to seeds, seed production, seed selection and seed storage and treatment and links this information to socio-economic data.

Eyzaguirre and Iwanaga (1996a) discuss the influence of poverty, which they suggest increases resource degradation through creating bottlenecks in populations as seed sources are consumed or sold to feed the family. There is also documentation of evidence to show the negative effects of depopulation: Tiffen *et al.* (1994) for Kenya; and Zimmerer (1991) for Peru.

Bellon (1996b) is an empirical investigation of the integration of farmers into markets, technological change and the impact on crop infra-specific diversity. Similarly, Zimmerer (1992) looks at how changes in land use and labour shortages affect crop diversity in the Andes.

Influencing factors can be equated to farmer knowledge. Richards (1995b) deals with the sociology of farmer knowledge. Considering links between farmer ideas about variability and underlying plant genetic resource distributions, he suggests that farmer knowledge consists of two hybrids - one described as 'sociotechnical', and the other of local and exotic knowledge. These ideas are illustrated by a case study from Sierra Leone and a series of historical/ anthropological examples. Useful references from this study are Latour (1993) and Richards and Diemer (1996).

## 2.4 What other factors influence crop diversity?

Although many argue that modern varieties have been responsible for the erosion of traditional varieties, others would say that they are an important and essential component of crop diversity. Witcombe (1999a) addresses the question of whether plant breeding leads to a loss of genetic diversity, stressing that this can only be judged using objective methods. He concludes that in areas that already grow modern varieties, plant breeding does not necessarily have a negative impact on genetic diversity, but that in areas not currently growing modern varieties genetic improvement will often reduce biodiversity. The possible effects of new technologies, such as transgenic crops and marker-assisted selection, on crop diversity are discussed, and it is suggested that the use of participatory plant breeding will limit the rate of loss (of genetic diversity) and put a ceiling on its reduction.

Also of possible use are Rejesus *et al.* (1996) which covers breeders' perspectives on diversity, and Hamrick and Godt (1990).

There is some literature that links ecological concepts such as succession and disturbance to agricultural biodiversity. Hobbs and Huenneke, (1992) look at disturbance, diversity and invasion, and the maintenance of diversity through maintaining a disturbance regime.

## 2.5 What are the dynamics of crop diversity at the community level?

In general, there are two approaches to the study of farmers and crop diversity. What might be called the 'biological' perspective, focussing on varieties and environmental issues, tends to regard the farming community as an entity, whereas the more 'sociological' studies, although documenting the dynamics and disparities within the farm community, have not always understood or been aware of the genetic dimension. Schneider (1999) gives a good illustration of this in his case study of sweet potato. Participatory rural appraisal (PRA) (see Section 3.3) can be seen as one way of approaching this problem, accessing information on community dynamics through, for example, resource mapping. Longley (1999) writes of the need to "incorporate the technical knowledge of individual farmers within an analysis of the wider social and cultural aspects of the community".

Shiva *et al* (1995) contains a useful series of case studies from `local experts' in India. Van der Mheen-Sluijer (1996) suggests that farmers who turn up a good variety through on-farm selection tend to become guardians of that variety. Often richer farmers become guardians. Age is also an important factor. Steinberg (1998) found that the five most diverse Mopan Mayan kitchen gardens were all tended by individuals older than 50.

The literature on local seed systems contains information on community dynamics. David (1997) discusses access to seeds from different delivery channels by different categories of farmers in Uganda, and it is suggested that this is affected by gender but not wealth. Almekinders and Louwaars (1999) also discuss traditional seed exchange and the fact that access is not always equitable, for example that poor households are often not part of the social network of those farmers that possess a surplus of produce that may be used as seed. Shrestha (1998) describes the traditional seed supply systems in Nepal, with particular emphasis on the role of women.

van Oosterhout (1996) writing on the coping strategies of small farmers, covers community dynamics and seed networks. The literature on community seed banks (for example, Lewis and Mulvany, 1997) also touches on community dynamics and who guards the village diversity.

Bunning and Hill (1996) present a gender perspective on farmers' rights and illustrate with several case studies the different roles and responsibilities of women with respect to crop diversity, emphasising their particular role in the conservation, development and utilisation of less common crops and varieties, and in the management of high-diversity home gardens. Howard-Borjas (1999) examines the role of women in plant genetic resources management and concludes that integration of gender perspectives in plant genetic resource management programmes is necessary if such initiatives are not to fail. Tsegaye (1997) looks at crop diversity in Ethiopia and the role that women play in the development and conservation of crop genetic resources while Tapia and de la Torre (1998) examine the role of Andean women farmers.

Lewinger Moock and Rhoades (1992) contain case studies on biological and cultural diversity and farmer knowledge.

The participatory plant breeding literature contains surprisingly little on community dynamics. Almekinders and Louwaars (1999) recognise that different groups of farmers have different specialised knowledge or preferences and include case studies by Zimmerer (1989) and Ashby *et al* (1989) illustrating gender and wealth differences with respect to farmer choice of varieties.

# Part 3. Techniques for studying on-farm crop diversity

This section looks at some of the techniques used to study on-farm crop diversity. Firstly, we examine ways to measure crop diversity in the field; secondly, how to document indigenous knowledge about crop diversity; and, finally, how participatory techniques are being used in the study of on-farm crop diversity.

## 3.1 Measuring crop diversity in the field

Much of the literature considers diversity in a broad sense relating to the number of different crops grown by the farmer. There is much less information about practical techniques for measuring genetic diversity within crop species. See, however, Hawksworth (1995) for a series of papers which do detail a range of methods for measuring biodiversity in the field, including the use of morphological differences between different varieties of a particular crop species.

Tripp (1996) states that 'the most common means of assessing the status of farm level crop diversity is by counting named varieties'. However, counting varieties does not take account of the genetic variation existing within such varieties, especially in open-pollinated species. On the other hand, a high number of varieties may mask an overall genetic uniformity (Cox *et al*, 1986). They show that while the overall number of wheat varieties grown in the USA increased during the 1970's genetic diversity decreased because large areas were sown to related varieties.

Jarvis and Hodgkin (1999) compare the 'hard' scientific analysis of genetic diversity not directly perceptible to the human eye with the 'softer' science of measuring agro-morphological differences. Both types of measurement are incorporated in IPGRI projects around the world. For example, Pham *et al* (1998) take both an agro-morphological approach and a genetic approach in the Philippines, although no details of methodology are given.

Cox and Wood (1999) compare pedigree-based, phenotype based or genetic-marker based methods of measuring genetic diversity and conclude that all have problems. Phenotype-based methods, although applicable in the field, suffer from genotype x phenotype interactions and the fact that similar phenotypes may be expressed by different genotypes.

Yang and Smale (1996) illustrate some of the difficulties of using agromorphological characteristics to measure crop diversity. They explains how:

- many economically important, observable plant traits (e.g. yield, grain quality) are controlled by more than one gene. Different gene interactions may produce morphologically similar and/or comparably-yielding plants.
- environmental variation leads to genetically identical plants appearing different and expressing different sets of genes. Conversely two diverse plants may appear similar in an inhibiting environment.

Meng *et al* (1999) measured crop genetic diversity of wheat in China using an ecological index of spatial diversity constructed from variety area shares and wheat morphology groups.

There are some examples of methodologies for measuring crop diversity in research projects.  For example, Zimmerer (1991) gives an example of measuring diversity in the field as a case study. Guarino (1995a) is particularly useful, discussing GIS and remote sensing, ethnobotanical collections and participatory methods of measuring diversity in crop species.

Brown and Marshall (1995) and Allard (1970) discuss sampling strategies, but not specific measurement techniques.

## 3.2 Documenting indigenous knowledge

Previously disregarded by scientists, indigenous knowledge is now seen as a valuable resource, and the literature on gathering and documenting indigenous knowledge continues to grow. IIRR (1996) is a useful training manual on integrating IK into development work. Part 1 of the manual is an overview of IK-related issues, while Part 2 is a description of more than 30 methods for recording and assessing IK, including field observation, in-depth interviews, interviewing, participant observation, participative technology analysis, surveys, working with groups (brainstorming, five questions, games, role play, group discussions), strengths and weaknesses, SWOT analysis, village reflections, village workshop, use of diagrams (flowchart, historical comparison, illustrations and diagrams, mapping, matrix, modelling bioresource flows, seasonal pattern charts, taxonomies etc.). Use of the methods is illustrated in mini-case studies, including one on local vegetable varieties for home gardening programmes.

Casas and Caballero  (1996) carried out fieldwork involving the documentation of ethnobotanical information and detailed information on management through in-depth open-ended interviews and also used a process of more structured interviewing where dried specimens of different species were shown to informants who were then asked for the corresponding plant name. The characteristics analysed are listed.  Interviews were also used by Benz *et al.* (1990) in combination with on the ground reconnaissance and repeat interviews to corroborate information.

Shiva *et al.* (1995) presents rather anecdotal profiles of a series of individuals, from three different areas, who are ‘seed keepers’. Also useful is the example of a seed register documenting indigenous resources and indigenous knowledge.

Pham *et al.* (1998) use interviews with key informants and collections of samples of all the seeds held by these individuals. Bellon and Brush (1994) uses structured and semi-structured interviews to investigate the indigenous knowledge of the ‘keepers of maize in Mexico’ and like the above example from the Philippines also took samples of all declared varieties.

Bellon and Taylor (1993) investigated indigenous knowledge of soils through using a survey questionnaire eliciting data on: family demographics, landholdings, and farmer’s perceptions of soil types and maize variety characteristics. This was combined with soil samples.

Guarino (1995b) comprehensively outlines secondary sources on cultures and indigenous knowledge systems. Kibiro (1999) reminds us that the gathering and documentation of indigenous knowledge should benefit the communities from whom it was obtained, and not be used for commercial purposes.

## 3. 3 Participatory techniques

The last two decades has seen a growing movement towards the use of participatory methodologies in rural research and development. Various methodologies, each with their own tools and techniques, have been developed. Central to these approaches is the belief that local people are capable of critical reflection and analysis and that their knowledge is relevant and necessary.

Thrupp (1996) suggests that participatory approaches to agroecological research and development are essential to develop changes, highlighting that such approaches require deliberate measures, training and time to change the conventional approaches of agricultural research and development. Farrington (1998) contrasts the ‘functional’ participation of farmers in the work of public-sector organisations with the ‘empowering’ type of participation employed by many NGOs. Both such types of participation can be identified in the crop genetic resources literature.

There are many sources of information on participatory methodologies. Slocum *et al* (1995) contains an overview of participatory methodologies, together with details of more than 30 tools for field work, and van Weldhuizen *et al* (1997) is a trainers guide for participatory learning with farmers. In general, participatory techniques for plant genetic resources management may be separated into the use of PRA/RRA type approaches to investigate existing plant genetic resources management in a community/region and PPB processes to improve or develop crop diversity. In many cases however, these form a continuous process with the former being used in initial investigations and the latter being implemented following such research.

### 3.3.1 PRA/RRA

Much of the literature on on-farm conservation on crop diversity refers to participatory techniques, but in many cases little detail is given on methodologies. Jarvis and Hodgkin (1999) advocate ‘participatory and learning approaches’ by multidisciplinary teams to investigate farmer decision making and genetic diversity (but don’t elucidate on these approaches). Maxted *et al* (2000) put forward a model for participatory *in-situ* plant genetic resource conservation, but outline what you need to find out without discussing the nuts and bolts of how to do it. Hardon (1995), in discussing participatory processes, suggested that “a methodology for the collection of relevant information and its interpretation needs to be developed as well as methodology for the monitoring of continuing programmes”.

Guarino and Friis-Hansen (1995) discuss qualitative research methods and the emergence of PRA and rapid rural appraisal with respect to collecting plant genetic resources and documenting associated indigenous knowledge, and list information sources on RRA/PRA methodologies.

PRA emphasises multidisciplinarity of approach and the adaptation to particular local circumstances. Upadhyay (1998) illustrates the multidisciplinary aspects of PRA in the IPGRI *in-situ* crop conservation project. Flexibility is emphasised by Van der Mheen-Sluijer (1996) who suggests that, ideally, a set of data collection techniques, which are flexible enough to be adapted to each area's requirements but at the same time standard enough to provide the minimum data and allow for comparisons across districts should be identified for each project. Here a pattern for carrying out a participatory, action-oriented research process is outlined, giving the objective and procedure for each technique (various ranking and scoring activities) in clear detail.

The PRA 'toolbox' contains many different techniques or tools. Sandoval (1994) outlines the technique of 'Memory banking' as a method of using PRA to explore indigenous knowledge of plant genetic resources. Memory banking involves 3 phases:

1) (Over a month or more) establishing a rapport with the community to arrive at a working knowledge of the agricultural system and the different players involved, through a collection of contextual information, specimens of landraces and participant observation.

2) Reconstruction of local history

    **a)** interviews with so-called community gatekeepers

    **b)** life histories - open ended interviews with elderly, key informants (See Crapanzo 1984)

    **c)** drawings of different varieties from memory (cognitive mapping)

3) Triads tests to investigate the relationships between varieties (involves presenting 3 stimuli to participant and asking which does not belong and why). This is further elaborated on in Sandoval (1991), which also contains useful material on other methods, problems, ethics and useful organisations.

Ngoc De (1997) discussing data collection and analysis in Vietnam, outlines a range of PRA techniques used, including: community meetings, key informant panels, mapping, individual interviews along defined transects, direct observation and problem identification. The training manual for the project may be of use on elucidating techniques (Mekong Delta CBDC, 1995).

Pham *et al* (1998) in the Philippines used informants from the community who were identified through group discussions.

Subedi *et al.* (1998) use PRA/RRA as part of a PPB process to assess farmers' needs and requirements, describing these methods as 'quick and effective for situation analysis of the locality' but recognising that they 'may not reveal information on the extent of the diversity in landraces as well as cultivars, and their performance'. In particular, farm walks and focus group discussions are outlined. A method for selecting key informants, 'Rapid Farmers' Network Analysis' is also mentioned as a means to identify key individuals in a community.

Gröhn-Wittern and van Oosterhout (1996) document the PRA methods used in their research process, including selecting key informants, listing varieties, matrix ranking, drawing up cropping calendars, seed sourcing map, list of who grows what and group discussion. The paper goes on to show how the data gathered can be interpreted, analysed and presented.

One of the most detailed discussions of PRA techniques for investigating genetic resource management is the local resource evaluation exercise (wild food and tree-based resources) carried out as part of the IIED Hidden Harvest Project in Zimbabwe. An evaluation of the use of PRA for this process contains a useful methodological overview and process notes (method, results and analysis) for a range of techniques, including: resource maps, transect walks, ecological assessments, product flows (using resource maps), product and activity calendars, wealth-ranking, household surveys and consumption patterns, case studies, historical changes, resource tenure, valuation of marketed products, market analysis and role plays (IIED, 1995).

Finally, Mpande and Mushita (1996) present the holding of a seed fair as an alternative, participatory research method.

Other useful references on PRA include: Berg (1992), Briones *et al.* (1989), Chambers *et al.* (1989), Mooney (1992), Salazar (1992), Scoones and Thompson (1995), Witcombe (1996), Maurya *et al.* (1988), Sperling *et al.* (1993), Joshi and Witcombe (1995), Moahyi (1997), van der Heide *et al.* (1996).

### 3.3.2 Participatory plant breeding

Participatory Plant Breeding (PPB) may be broadly defined as “a range of approaches that involve users more closely in crop development or seed supply”. The last decade has seen a considerable increase in interest in PPB, from three different perspectives (McGuire *et al*, 1999):

- Improving the effectiveness of crop development
- Supporting conservation and use of crop genetic diversity
- Contributing to empowerment of farmers and other actors.

Within the formal sector farmer participation in the plant breeding process is increasingly recognised as having demonstrable value by increasing the effectiveness of the breeding effort. This is particularly relevant in marginal environments (Witcombe, 1998) but it is also argued that PPB methods can be equally cost-effective in high potential production systems (Witcombe, 1999b).

Eyzaguirre and Iwanaga (1996a) highlight the importance of participatory breeding as an element of *in-situ* conservation, and Hawtin *et al* (1996) outline ways in which participatory breeding approaches can contribute to rural community development and at the same time help to ensure the continued existence and evolution of farmers landraces. Joshi *et al* (1998) suggest that “a small effort made to improve local land races by incorporating at least a few important traits could lead to an increase in output and improve the value of such varieties to the farming community. In this way improvements in food security could be combined with maintaining agricultural biodiversity in the form of local land races.”

Sperling and Ashby, (1997) outline the learning and decision-making benefits to farmers.

PPB (sometimes referred to as Collaborative Plant Breeding (Cleveland *et al*, 1998) is usually separated into Participatory Varietal Selection (PVS), or "the activities in which farmers evaluate and select from among released, pre-released or advanced varieties" and Participatory Plant Breeding (PPB) in which "farmers select plants or seeds from and within a genetically variable population or variety" (Almekinders and Louwaars, 1999). Frossard (1998) describes one of the few cases of farmers actually making crosses as opposed to selecting from advanced or segregating materials.

Most of the literature to date concentrates on PVS. Subedi *et al.* (1998) define PVS as the selection of released or pre-released varieties by farmers in target environments and goes on to state that when the possibilities for PVS have become exhausted then PPB is used to select genotypes from segregating material by farmers.

Others differentiate between 'farmer-led' and 'breeder or formal-led' PPB. McGuire *et al* (1999) is a comprehensive analysis (albeit from a 'formal' sector research programme) of farmer-led PPB, while Smith *et al* (forthcoming) examines formal-led PPB.

Witcombe *et al.* (1996), Joshi and Witcombe (1996) and Sthapit *et al.* (1996b) are three early papers on PPB. Other key resources are the proceedings of a conference on Participatory Plant Breeding (Eyzaguirre and Iwanaga, 1996b) which contains case studies and discussion on the subject. Also of interest are the proceedings of a workshop on data collecting and analysis as part of the IPGRI in-situ crop conservation project, involving a series of participatory breeding programmes in different locations (Jarvis and Hodgkin,1998). Sperling and Loevinsohn, (1996) contains case studies on 'developing approaches through learning and doing by themselves without formal sector support'. Ceccarelli *et al* (1997) discuss a number of methodological issues relating to PPB.

Soleri et al (1999) show that farmers have a good understanding of such concepts as heritability, response to selection, and environmental effects and suggest that breeders can work with farmers to improve their selection strategies.

Ashby *et al.* (1996) outlines the CIAL (Comités de Investigación Agropecuaria Local) method of adaptive technology testing by forming committees of farmers based in rural communities to carry out technology testing together with public sector agricultural research and extension agencies and intermediate organisations (NGOs and farmer co-ops).

Leading on from PPB approaches van der Burg (1999) proposes 'participatory seed technology development' as a means of learning from and improving farmers' traditional practices and addressing the failures of formal seed systems.

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