Agrodiversity as a Means of Sustaining Small Scale Dryland Farming Systems in Tanzania

Authors: F.B.S. Kaihura[1], M.A. Stocking[2] and N. Murnaghan[3]

1. The Issues

Dryland farming systems in Africa are often characterised as being extremely degraded, vulnerable to external forces, and low in productive output. Available fossil evidence, for example, suggests that the open savannas of East Africa have the longest history of human habitation since Pliocene times. As a result, Adams (1996, p.208) observes that, "the destructive impact of long human occupation of the ecosystem has been profound. ….. Man's tendency to overexploit the basis of his subsistence is endemic." Such stereotypes of land use abound. The story of man's mistreatment of his environment has been recounted many times and continues to be told. Lord Hailey (1938) described human-induced soil erosion as "the scourge of Africa", while the FAO (1990, p.6) bemoans that, "Africa's lands are under attack." This paper targets a very different tendency – human's propensity to conserve. Some land uses, developed over centuries of pressures and difficulties, display a resilience and productivity that is truly remarkable. Both professionals and policy makers may draw some comfort that stereotypes of environmental crisis are not applicable throughout dryland Africa.

Nevertheless, environmental change is occurring. Global biodiversity loss in areas of land use is a well-attested phenomenon. Ecologists, in particular, are alarmed at how natural biological diversity is being replaced by relative biological uniformity, especially under the pressure of population growth (Cincotta and Engelman, 2000). As natural habitats decline, greater proportions of species living within those habitats become extinct. Species-area curves suggest that at about 10 percent of land area devoted to protection, only 45 to 70 percent of species remain, and as habitat declines further, extinctions accelerate dramatically (Pimm *et al*, 1995). Only Costa Rica comes anywhere near the conservationist's goal of maintaining at least 10 percent of land areas under natural habitat. However, there is good evidence that natural biological diversity may be giving way to another diversity, equally valuable and of greater immediate significance to society, which in this paper is called 'agrodiversity'. It embodies cultural and spiritual dimensions of biodiversity (Posey, 1999), as well as practical and economic values of gaining a sustainable rural livelihood for poor people (Altieri, 1999). Without in any way denying the need to conserve natural biological diversity upon which ecologists argue many of the world's life-support functions are based, this paper dwells on the benefits of 'agrodiversity' and empirical examples from Tanzania on its value to local society and, indeed, to the whole conservation agenda.

2. Introducing Agrodiversity

Awareness of global biodiversity loss has resulted in a search for where the battle-lines for its protection should best be drawn. Typically, these lines have been fortified around the various types

[1] Agricultural Research and Training Institute Ukiriguru, P.O. Box 1433, Post Office Road, Mwanza, Tanzania.
E-mail address: kaihura@mwanza.com
[2] School of Development Studies, University of East Anglia, Norwich NR4 7TJ, UK.
E-mail address: m.stocking@uea.ac.uk
[3] Overseas Development Group, University of East Anglia, Norwich NR4 7TJ, UK.
E-mail address: n.murnaghan@uea.ac.uk

of protected areas and controlled management of habitats. Increasingly, this 'fortress conservation' has become unsustainable in the face of social change and population pressures (Ghimire and Pimbert (1997). Additionally, although evidence for the relative numbers of species is elusive, there is likely to be far more biodiversity in areas of land use than in all protected areas together, principally because areas that are used are not only far greater than those protected but also these areas are the more fertile and naturally biodiverse. Consequently, it makes sense for the global biodiversity agenda to look to:

- natural biodiversity managed within farming systems, including domestication of wild species and protection of rare species;
- the farming systems themselves, including the way that biodiversity is managed for the welfare of land users such as techniques and practices of cropping, agroforestry and rangeland management;
- how biodiversity itself helps vulnerable farming groups cope with social, economic, political and demographic pressures as well as variable and marginal physical environments.

While the term 'agricultural biodiversity' or 'agro-biodiversity' has tended to be used to signify the variety of plants, species and varieties on the lands of farmers and their relation to welfare (Thrupp, 1998), 'agrodiversity' is much more broadly defined. It encompasses "the many ways in which farmers use the natural diversity of the environment for production, including …. their choice of crops….[and] their management of land, water, and biota" (Brookfield and Padoch, 1994, p.9). It goes beyond the concept of species and genetic diversity of plants and animals to incorporate other aspects of the farming system that relate to obtaining sustainable livelihoods. Because small-scale farmers in the tropics usually have to rely on the intrinsic quality of their natural resources, including biodiversity and soil quality, and because they have limited resources to invest in external inputs, 'agrodiversity' is a crucial underpinning to their lives. This paper, therefore, illustrates some aspects of the importance of agrodiversity to the ways in which small-scale farmers in a dryland part of Tanzania cope with environmental and social pressures. It takes up Paul Richards' (1985, p.160) challenge that, "the evidence …. of innovativeness in the peasant food crop sector is strong, but further work is needed on …how….this pool of skill and initiative might be harnessed to national development objectives." The policy implications of agrodiversity will be developed in the last section of this paper. First, however, we describe the approach of the GEF-funded project, *People, Land Management and Environmental Change*, which is compiling a database of agrodiversity in order to demonstrate its value and potential.

PLEC Approach

The aim of the People, Land Management and Environmental Change (PLEC) project is to develop sustainable and participatory approaches to conservation within small farmers' agricultural systems, and in participation with farmers.

The specific objectives of PLEC are:

a) to establish historical and baseline comparative information on agrodiversity, including biodiversity, at the landscape level;
b) to develop participatory and sustainable models of biodiversity management based on farmers' technologies and knowledge within agricultural systems at the community and small-area levels;
c) to recommend approaches and policies for sustainable agrodiversity management to key government decision makers, farmers, and field practitioners; and

d) to establish national and regional networks for capacity strengthening within participating institutions, and to carry forward the aims of PLEC.

The core of PLEC's work is in its 'demonstration site' villages. Here, PLEC becomes the farmers' own enterprise, and scientists are the facilitators, not the instructors. The scientists identify and demonstrate farmers' practices that are environmentally, socially and financially sustainable, and which sustain biodiversity. They help farmers in achieving their own conservationist goals. Collaborating farmers manage varied biophysical conditions, growing a range of crops and using biodiversity with discretion.

The PLEC approach differs from mainstream agricultural research at experiment stations under controlled conditions. By integrating locally developed knowledge of soil, climate, and other physical factors with scientific assessments of their quality in relation to crop production, a set of sustainable agricultural technologies can be devised so that agricultural diversity is maintained. The participatory process will eventually enhance farmers' and local communities' ability to adapt to environmental, social and economic change.

The PLEC project, through demonstration sites and farmer-to-farmer extension, seeks to support existing diversity and disseminate it to other farmers whose positions might be improved as a result of new practices or techniques. PLEC relies on interaction between farmers and between farmers and scientists as a mechanism for identifying and maximising agrodiversity.

The Tanzanian element of the East African PLEC cluster focuses on two contrasting demonstration sites in Arusha region in Northern Tanzania. The characteristics of each are summarised in the following table.

Table 1: Characteristics of PLEC sites in Northern Tanzania

Characteristic	*Ngiresi/Olgilai*	*Kiserian*
Average altitude	1,900m asl	1,200m asl
Temperature range	12-30° C	12-30° C
Mean annual rainfall	2,000mm	500mm
Farming system	Mixed cropping with zero grazing	Agropastoral
Soil type	Andosols	Cambisols
Village population (1988)	2,158	3,330

In Tanzania the PLEC scientists initially met with farmers to identify environmental and social constraints and to see how coping strategies were related to those constraints. Following on from this, 'expert' farmers were identified and, using PRA techniques and training sessions, linkages were established with other farmers. The focus has been on identifying ways in which farmers have adapted their practices to, and have made use of, the environment in which they farm while at the same time conserving or enhancing agrodiversity, especially biodiversity.

Diversity in Crops and Cropping Systems

Planting a mix of crops is recognised as a way of spreading risk on a farm. Within crop groups, different varieties are planted to match the particular stresses of the local environment. Farmers seek to plant a combination of varieties that will ensure at least some yield despite extremes of climate, pests, disease, labour shortage or other constraints.

In a similar way, farmers select the crop types that they plant to enhance their food security. For example, in Ngiresi sweet potatoes are planted on steep slopes not only to provide cover and thereby reduce erosion, but also because they mature in the 'hungry period' before maize is ready for harvest. In addition, sweet potatoes will produce even in a drought year.

Farmers, therefore, select crops and varieties using different criteria – some strains will be selected because they are high yielding in optimum conditions, others because they are tolerant to drought, others because they are resistant to storage pests, have a high market price, good taste or are easily processed. Each selection involves an assessment of the potential risks and rewards of planting a particular crop or variety. Such decisions are influenced not only by the physical characteristics of the environment, but also by socio-economic factors such as available labour and proximity to markets.

Farmers view the selection of crop varieties as a continuous process. Some varieties that are tried in the field become part of the farmer's own landrace, whereas others, whose characteristics prove to be less suited to the local environment, quickly disappear from the field. Crops and varieties that continue are those identified as being a best match for the field conditions, the wider environment and the farmer's own situation.

In the Tanzanian PLEC sites maize, beans and bananas are very widely grown. Within these crop types a wide spectrum of varieties is planted. The following table lists some of the varieties identified on farms. This table clearly illustrates that, while research stations may breed for high yields, drought tolerance and pest resistance, farmers consider a wide range of other characteristics before selecting which seeds to plant. Issues such as intercropping compatibility and labour availability are also relevant to farmer decision-making. So for example, trailing beans are less popular than the bush varieties because they get entangled with the maize intercrop. More labour is required to disentangle them and beans are lost when pods burst during this process.

Most farmers plant up to five different varieties of beans and bananas on their land. This reflects not only risk-spreading decisions, but also the matching of particular varieties to scattered plots having different biophysical characteristics.

Traditionally, maize and beans have been intercropped in the two sites. No standard proportions are used, rather the exact combinations grown depend on assessments by individual farmers of the specific plot, previous experience on that plot, market conditions, location and topography of the field etc. Typically, in Kiserian, a higher proportion of beans are planted (2 rows of beans for every row of maize). This reflects not only the fact that beans are a highly valued food crop in their own right, but also the higher market prices that can be achieved for beans over maize and bean crop residues over maize stalks (as livestock fodder). The greater susceptibility of beans to pests and diseases is also cited as another reason why farmers plant more beans, so that they can be guaranteed some yield from this important crop.

Table 2: Maize, Bean and Banana Varieties Grown in Arumeru

Crop varieties	***Economic uses***	***Plant characteristics***
Zea mays (Maize)		
Kienyeji	Food, income, crop residues fed to animals	Not very sweet, tolerant to storage pests, good milling quality, low yielding, drought susceptible.
Katumani	Food, income, crop residues fed to animals	Drought tolerant, early maturing, low yielding, good milling quality, tolerant to storage pests.
CG4141 (Lowlands)	Food, income, crop residues fed to animals	Good milling quality, drought tolerant.
UCA (Highlands)	Food, income, crop residues fed to animals	Good milling quality, drought tolerant.
Kilima	Food, income, crop residues fed to animals	High yielding, susceptible to storage pests, good milling quality, high water demand, high quality flour.
Phaseolus spp (Beans):		
Soya kijivu	Food, income, crop residues fed to animals.	"No gases after eating", early maturing, good taste, climbing type, sweet, high price, grey.
Kachina	Food, income, crop residues fed to animals.	High market price, early maturing, spoils quickly after cooking.
Lovirondo	Food and crop residues fed to animals	Climbing type, "causes bloating and gases after eating", laborious to harvest, low market price.
Bwanashamba	Food and crop residues fed to animals	Most popular in Kiserian, high yielding, good taste, susceptible to diseases and aphids.
Masai red ndogo (namira)	Food and crop residues fed to animals.	High yielding, good tasting, "no gases after eating", needs wide spacing for high production.
Karanga	Food and crop residues fed to animals.	High yielding, good tasting when cooked (flavours food).
Masai-red kubwa (namriri)	Food and crop residues fed to animals.	High market price, bush type, early maturing, good tasting and flavours food, susceptible to diseases.
Lyamungu 90	Food and income	Good tasting and flavours food, early maturing, drought tolerant, high yielding, high market price.
Kiburu	Food and crop residues fed to animals.	Drought tolerant, grows well on soils with poor fertility.
Engichumba	Food and income	Very high yielding, violet bean
Engichumba-ng'iro	Loshoro (traditional food)	High yielding, sweet, grey bean
Engichumba-narok	Food and income	Similar to Engichumba-ng'iro, black bean
Moshi	Food and income	Very high yielding, sweetest, yellow bean
Kibumulu	Food and income	Fast cooking, high price, dark red bean
Musa spp (Bananas)		
Kisimiti	Income, brewing, animal feed (stem)	Early maturing, drought tolerant, good milling quality
Ng'ombe	Loshoro, brewing, income, roofing, fodder to animals.	Hard when cooked.
Mshale	Matendela (traditional food), income	Good for roasting, long and thick banana fingers.
Uganda fupi	Banana soup (mtori), fruit, income, peels fed to animals	Early maturing, small with mainly fingers, susceptible to pests and diseases.
Uganda ndefu	Banana soup, fruit, peels fed to animals	Large with few fingers, susceptible to pests and diseases.
Kisukari	Fruit, income, animal feed (stems)	Very sweet, drought and disease tolerant, low nutrient demand
Mzuzu	Roasting for tea	Tolerant to drought and disease
Malindi	Food (matendela), animal feed	Drought tolerant
Mnanambu	Soup, roasting	Shade
Mkonosi	Roasting	Disease tolerant
Mkono wa tembo	Roasting	Disease tolerant
Ndishi	Loshoro, income	Susceptible to diseases
Olmuririko	Loshoro, brewing	Modest tolerance to diseases

Diversity at Landscape Level

It is typical in Ngiresi/Olgilai for farms to be made up of a number of different plots scattered throughout the village. The evolution of these farm types is explained first by the periodic clearance of more land as additional areas were brought into production and second by the practice of dividing farms between sons. In such divisions parents are inclined to split every plot into smaller plots to ensure that all sons receive land of similar quality.

Farmers in Ngiresi and Olgilai use different parts of the landscape in different ways, matching crop suitability to available land. In matching crops to plots of land, farmers not only consider biological suitability, but also the value of the crop, the labour required to manage the crop and the risk that the crop might fail. Therefore, high value crops and fruit trees are planted close to the home to reduce the risk of theft, whereas hillside plots are planted with sweet potatoes to reduce soil loss from erosion. Field borders are often planted with bananas and trees to demarcate boundaries.

Farmers recognise the suitability of different plots to different cropping strategies. For example, Mr. Yangan from Ngiresi/Olgilai, has nine different field types making up his farm. Some of these are detailed below.

Table 3: Some Field Types on Mr. Yangan's Farm

Location	*Field Type*	*Rationale*
Near house – flat/gentle slopes	Tethering pasture	Convenient for milking morning and evening.
	House garden	Convenient to house
	Coffee/banana	Allows for easy transport of manure to the field. Also convenient for regular chores such as spraying coffee.
Middle distance – gentle slopes	Maize/beans	Convenient enough for transporting inorganic fertilisers. In situ green manuring replaces animal manure.
Remoter – steep slopes	Sweet potatoes Fodder grasses	Crops don't need a lot of inputs, but provide good cover for hillsides prone to erosion. Sweet potatoes in particular attract a lot of mice so it is preferred that these are not grown close to the house.
Boundaries	Bananas	Tree crops in particular are used to mark out boundaries.

Some of the older farmers in Kiserian have a deep understanding of the different soil types found in the village. Soils are classified locally by colour, fertility, depth and moisture holding capacity. Based on this categorisation crops are selected to match different soils and planting dates are determined. In order to spread risk some plots and crops are dry planted, others are planted immediately after rain, while still others are planted a few days after the first rains. In these ways farmers are able to minimise the risks of poor crop yields due to low levels of soil fertility and moisture stress.

Diversity in Resource Management

Management practices reflect the value placed on the land and on the current crop by a farmer. Land tenure is often critical in determining how farmers manage their land. Secure tenure has been shown to be an incentive to careful stewardship of the land. Open access property or fields held on short term rents are often less well tended. In the case of Kiserian the contrast in management practice is evident in the condition of communal and clan woodlots compared to those owned individually. The former are degraded while the latter are actively managed by the owner (for example, through the application of crop residues).

Management practices also vary with landscape. Fertility management, in particular, differs depending on the spatial arrangement of a farmer's fields. In general, farmyard manure will be applied to fields close to the house/cow stall. Fewer farmers are likely to transport manure long distances for application on hillside plots. Instead they may use other biological means of enhancing soil fertility, or they may apply chemical fertilisers, which are easier to transport.

The following table details some of the soil management practices that are applied by farmers to fields in Olgilai/Ngiresi

Table 4: Soil management strategies under the major cropping systems in Olgilai/Ngiresi villages.

Management Objective	*Cropping system*	*Soil Management Strategies*
Soil fertility improvement	Coffee/banana/maize/beans in rotation with round potatoes	FYM application, incorporation of crop residues, house refuse and weeds and application of ashes, planting of Sesbania sesban, grevillea and composting (few).
	Maize/beans	Incorporation of FYM, grevillea biomass, crop residues, green manuring, trash lines.
	Maize/beans rotation with sweet potatoes	Application of FYM, incorporation of crop residues and Sesbania biomass.
Soil moisture management	Coffee/banana/maize/beans in rotation with round potatoes	Incorporation of crop residues, mulching and trash lines, shading by coffee/banana/fruit trees/ canopy, planting of seteria.
	Maize/beans	Self-mulching, crop residues, trash lines, incorporation of crop residues (few).
	Maize/beans rotation with sweet potatoes	In-situ crop residues mulching, trash lines, sweet potato cover.
Soil erosion control	Coffee/banana/maize/beans in rotation with round potatoes	Rain interception by trees canopy, Mulching, trash lines, construction of flower hedges, trees canopy interception, planting of Sesbania sesban.
	Maize/beans	Trash lines, crop canopy
	Maize/beans rotation with sweet potatoes	Incorporation of crop residues, trash lines, application of ashes, planting of fodder grass strips.

In general, there is less emphasis in Kiserian on soil fertility management, with less use of both organic and inorganic fertilisers. Instead, in order to increase crop yields, farmers rely on bringing more land into cultivation, mixed cropping and variations in planting dates.

Agrodiversity – Expert Farmers

The PLEC approach is to identify 'expert' farmers and to facilitate the dissemination by them of their knowledge and experience. In this context expert farmers are those who have maximised the production potential on their farms in a sustainable and conserving way. In both Ngiresi/Olgilai and Kiserian this involves diversification and intensification of crop production.

Gidiel Laizer farms six separate plots in Ngiresi/Olgilai. He plants different crops on different plots depending on their distance from his home, their topography and the other resources available to him (especially labour). In 1998 Gidiel changed his planting strategy on a 0.25 ha plot surrounding his house. He now continuously crops this field. This plot is planted with the traditional perennial intercrop of coffee and bananas. However, Gidiel no longer plants the usual intercrop of maize and beans. Instead, in response to the availability of local markets (Arusha town is just a few kilometres away), he plants cauliflower and round potatoes for sale in addition to maize for home consumption. This serial cropping system, yielding three crops per annum, is called a 'matatu' system and involves continuous cultivation of the plot. In the following table Gidiel's planting and harvesting calendar is summarised.

Table 5: Matatu cropping system

Month	*Activity*		
	Planting	*Harvesting*	*Other*
March	Plant cauliflower		Manure applied
April			
May	Plant round potatoes	Harvest cauliflower	
June			
July		Harvest round potatoes Harvest bananas	Manure applied
August	Plant maize	Harvest bananas	
September			
October			
November		Harvest coffee	Manure applied
December		Harvest coffee	
January			
February		Harvest maize	

In addition, further crops are planted along the plot boundary providing further sources of food which include taro (*Colocasia esculenta*), fodder (C*ariandra caryopsis*) and grevillea (G*revillea robusta)* for which he sells timber to get cash. Gidiel is also planning to introduce yams (*Dioscorea spp*) into the border of the field as an additional source of food.

High levels of diversity are supported on Gidiel's farm. In addition to the 'matatu' cropping system, which supports diverse crops in a single field, varietal diversity is also evident. Gidiel cultivates five different varieties of bananas and he is attempting to crossbreed two varieties of maize to develop his own strain combining the desirable traits from those that he is currently growing.

Gidiel selectively applies farmyard manure to the plots close to the house where he practises the 'matatu' system. He identifies those areas of the field where the yield was poor for the previous crop. Those parts of the field receive the first and greatest application of manure in order to improve their productivity under the next crop.

As a result of health concerns and for financial reasons, Gidiel does not use commercially produced chemical pesticides. Instead he uses a mixture of fermented cattle urine (collected from the stall) and water, which he prepares himself. Spraying this mixture on the plants also introduces additional nutrients to the crop. Another use of fermented urine (mixed with botanicals) is to control ticks in livestock.

The PLEC approach seeks to encourage the communication of information by farmers to farmers. This is facilitated by farmer demonstrations, where farmers are invited to visit the farm of an 'expert' farmer who explains his practices. In addition to the innovative matatu cropping system, Gidiel cultivates a large number of plants with traditional medicinal uses. Following demonstration meetings held at his farm, local farmers took away cuttings and seedlings from plants used in traditional medicine to propagate them on their own farms.

In Kiserian, the strategies followed by Lais Kitia, another expert farmer, differ from those of Gidiel Laizer, largely due to the different environments in which they farm. Lais Kitia has established, over many years, a very successful agroforestry cropping system. In addition to cereals and legumes, Lais maintains a wide variety of useful trees, many of them local species, well adapted to the arid conditions. His agroforestry and cropping systems mean that he harvests a crop, be it cereal, beans or fruit, every few months. The fruits are mostly harvested during the dry season and provide an important source of food for his family. Because Kiserian is more remote from markets, Lais's production is focused on foodstuffs for home use rather than for sale in the market, although produce from his agroforestry system can be converted into cash if necessary.

Lais's farm has ten diverse field types. The crops grown in a single plot of less than 0.3ha are summarised in the following table. In addition to two annual crops (maize and millet), this field supports a wide variety of fruit trees and is used for tethering cattle and sheep.

Table 6: Farming on One Field at Mr. Lais Kitia's Farm in Semi-arid Kiserian

Type of plant	**Varieties**	**Economic uses**	**Plant characteristics**
Maize (*Zea mays*)	Malawi	Food, income, animal feed, firewood	High yielding, large grains, easy to mix with trees, good milling qualities.
Finger millet (*Eleusine indica*)	Enyangai (local)	Porridge, income, brewing, animal feed	High price, tolerant to drought and storage pests.
Mangoes (*Mangifera indica*)	Embedodo	Fruit, income	Large fruit, sweet, good aroma, good market price, keeps, green when ripe, drought tolerant.
	Embe mviringo	Fruit, income	Very sweet, fibrous, heavy, green when ripe, drought tolerant.
	Saforoni	Fruit, income	As sweet as honey, drought tolerant.
	Boribo	Fruit, income	Very sweet, high water content, orange and red when ripe, drought tolerant.
	Achari	Fruit, income, combines with chilli pepper, tomatoes, onion and coconut juice to make appetiser.	Very sweet, drought tolerant.
Pawpaws (*Carica papaya*)	Kienyeji 1	Fruit, income	Watery, very sweet, soft.
	Kienyeji 2	Fruit, income	Moderate water content, moderately sweet, hard.
Lemons (*Citrus limoni*)	Kienyeji	Income, porridge appetiser	Very sweet, drought tolerant.
Zambarau (*Syzygium guineense*)	Local	Fruit, income, shade.	Drought tolerant
Oranges (*Citrus cinensis*)	Local	Fruit, shade	Drought tolerant
Ukwaju (*Tamarindus indica*)	Local	Wild fruit, income	Drought tolerant, soil fertility improvement
Bananas (*Musa sapientum*)	Kisukari	Fruit, income, fed to animals.	Very small fingers, very sweet, drought tolerant.
	Kisimiti	Fruit, income, brewing, fed to animals.	Drought and disease tolerant
Mnafu (*Solanum nigrum*) (volunteer crop)	Local	Wild vegetable	Drought tolerant.
Wild amaranthus (*Amaranthus thunbergii*) (volunteer crop)	Local	Wild vegetable	Drought tolerant
Livestock	**Varieties**	**Economic uses**	**Characteristics**
Cattle (tethered on wild trees)	Local breed	Draught power, milk, manure, income, security, dowry, prestige.	Pests and diseases tolerant.
Sheep (tethered on wild trees)	Local	Meat, dowry, fatty foods to breast feeders.	Pests and diseases tolerant.

Conclusion and Policy Implications

Dryland farming systems in Africa display a remarkable resilience. If the past predictions of their demise were to have been true, we should be seeing far more environmental degradation and loss of biodiversity than we do today. Part of the reason for the resilience lies in the ability of farmers to adapt to changing conditions. The Boserupian hypothesis of adaptive change through the local application of technology and sustainable intensification is alive and well in many, but obviously not all, parts of Africa. This paper has sought to show that farmers in Arumeru, Tanzania, are no exception. They have developed some sometimes-intricate sets of techniques to manage their natural resources, they have used the biological diversity they have to hand, especially in regard to food crops, and they have organised their use of the whole landscape to secure their livelihoods and biodiversity.

Of particular relevance to developing lessons from these empirical findings are the ways in which farmers both understand and manage complex associations of plants, which then in turn provide food security to local households. Scientists and policy makers must be very careful not to write off the value in current practices of small-scale farmers as being of no relevance to today. Debates about the unsustainability of dryland farming in Africa are rife with accusations about the degrading practices of small farmers. However, if land users have themselves developed sustainable and productive practices, then this is as worthy of publicity as the examples of bad practices. Bad news may sell newspapers; but good news should surely be equally prominent in giving policy makers a balanced picture.

The Arumeru farmers have developed an extraordinary diversity in crops and cropping systems (see Table 2). The PLEC project will be looking into what resources farmers need to access this rich harvest of information. However, it is already clear that poor farmers can, and do, practice sustainable use of biodiversity, and many use genotypes, varieties and landraces of crops that are now rare. Food security for the many marginal populations in Africa, a crucial area of policy debate today, may well rest on these poor farmers' efforts. The Kiserian semi-arid site, for example, has bean varieties that withstand drought as well as provide both food to humans and crop residues to animals. Multi-purpose varieties and plants that meet several needs are important for dryland farmers. If they also avoid – or minimise – the inherent riskiness of the climate, such plants are worthy of conservation. They may not yield as highly as improved varieties, but for food security at household level this is not the key criterion.

The PLEC experience in Tanzania has also highlighted the beneficial, mutual interaction between professionals, field workers and farmers. Working closely with farmers on demonstration sites, our scientists have come to appreciate that they each have different kinds of knowledge, which are of equal importance. The "white-coat" syndrome that all that comes from scientific experimentation is superior – and by extension, all that comes from small-scale farmers and peasants is inferior – has bedevilled science. Our colleagues in PLEC have learnt to harmonise their experience with farmers and to attempt to interleave their knowledge from science with farmers' own experiences and advice. It has been a good mutual learning exercise for all involved. Policies on extension, agricultural education and interactions with clients (i.e. farmers) have much to gain.

Finally, PLEC in Tanzania has demonstrated the heterogeneity in rural society. There are innovative and expert farmers who are carrying on agricultural activities that have substantial scope for replication. These self-same farmers have training abilities also. Farmer-to-farmer extension has been a particular success in Arumeru, where field days and farmer-organised demonstrations have influenced many land users. We have witnessed substantial change through such informal means of dissemination. We have seen women farmers teaching each other, swapping planting materials, and enthusiastically engaging in community works. By formally valuing the human resources at local level and appreciating the agrodiversity farmers have developed themselves, PLEC is empowering people and giving them a dignity that more traditional projects fail to emulate. Time will tell if the process will continue. Much will depend on political stability, social order and the continuing willingness of scientists and land users to collaborate. However, the signs are positive. Agrodiversity can help to support the global agenda of conservation of biodiversity, while at the same time providing for development of local people and the meeting of their needs.

References:

Adams, W.M. 1996. Savanna environments. In: Adams, W.M., Goudie, A.S. & Orme, A. (eds.) *The Physical Geography of Africa*. Oxford University Press, Oxford, pp. 196-210.

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, ecosystems and Environment* 74: 19-31.

Brookfield, H. and Padoch, C. (1994) Appreciating Agrodiversity: a look at the dynamism and diversity of indigenous farming practices. *Environment* 36, 5, 8-11, 37-43.

Cincotta, R.P. and Engelman, R. 2000. *Nature's Place: Human Population and the Future of Biological Diversity*. Population Action International, Washington DC, 80pp [on-line at http://www.populationaction.org]

FAO (1990). *The Conservation and Rehabilitation of African Lands: An International Scheme.* The UN Food and Agriculture Organization, Rome.

Ghimire, K.B. and Pimbert, M.P. (eds.) 1997 *Social Change and Conservation*. Earthscan, London.

Hailey, Lord. 1938. *An African Survey*. Oxford University Press, Oxford.

Pimm, S.L., Russell, G.J., Gittleman, J.L. and Brooks, T.M. 1995. The future of biodiversity. *Science* 269: 347-350.

Posey, D.A. (ed.) 1999. *Cultural and Spiritual Values of Biodiversity*. IT Publications, London for the United Nations Environment Programme, Nairobi.

Richards, P. 1985. *Indigenous Agricultural Revolution: Ecology and food production in West Africa*. Unwin Hyman, London.