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SCIENTIFIC AND TECHNICAL ADVISORY PANEL TO THE GLOBAL ENVIRONMENT FACILITY: LAND MANAGEMENT AND ITS BENEFITS – THE CHALLENGE, AND THE RATIONALE FOR SUSTAINABLE MANAGEMENT OF DRYLANDS

(Prepared by the Scientific and Technical Advisory Panel)

Scientific and Technical Advisory Panel to the Global Environment Facility:

land management and its benefits – the challenge, and the rationale for sustainable management of drylands

October, 2005

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Preface

Land degradation is one of the greatest threats to food production in drylands. Land degradation, manifested as soil compaction, erosion, nutrient depletion, and salinisation, often results in loss of soil biota, plant and animal species, with concomitant risks to sustainable production of food and ecological goods and services.

Over the years, through the work of the GEF's Implementing Agencies (UNEP, UNDP, World Bank), other multilateral institutions (e.g. FAO, IFAD, CGIAR centres), and the wider scientific community, much has been learnt about the underlying socioeconomic and policy drivers of land degradation. These include high population pressure, inappropriate sectoral and macroeconomic policies, poverty, unclear land rights and land tenure insecurity, lack of access to markets, credit and other services. Much remains to be learned, however, about the process of farmer experimentation, adaptation and adoption of technologies for sustainable land management in dry areas. For instance, the ways in which wider policy, institutional and socio-political changes influence and shape land users' adaptive strategies for land management and determine the level of success of local initiatives are not well understood. Strategies for generating global environmental benefits while addressing problems of land degradation and poverty at the local level and strategies for scaling-up successful initiatives to enable wider impact are also not well understood.

The Scientific and Technical Advisory Panel (STAP) was asked by the GEF to provide an analysis and synthesis of the available knowledge on the socioeconomic, institutional and policy conditions that influence technology adaptation and adoption for sustainable management and use of drylands for food production and provision of ecological goods and services. To meet this request STAP held a workshop 5-6 March, 2005 in Washington, DC. The workshop brought together a cross-section of experts from developed and developing countries, and was led by Timothy Williams, a member of STAP, with Habiba Gitay, the STAP Vice-chair, and representatives from the GEF Secretariat, the GEF's Implementing Agencies, as well as representatives from IFAD and CGIAR Centres, and the STAP Secretariat.

The workshop addressed the following questions: how successful have been past initiatives aimed in promoting new technologies and land management practices? Have they worked, and have land users adopted them? If not, why not? This paper[1] considers the evidence, and draws lessons for future project design.

Understanding the conditions under which technologies are adapted and adopted at local community level is essential for developing projects and institutional structures that would help communities to make the transition to more effective, culturally-appropriate and sustainable systems of land management for food production and provision of ecological goods and services. Furthermore, careful analysis to identify and distinguish between the local, national and global environmental benefits generated through successful adoption of technologies that promote sustainable land management in drylands will provide useful inputs to the GEF in defining appropriate baselines against which to measure the incremental costs of new projects that address similar problems. This analysis is linked to on-going work in the GEF's land degradation task force on identifying appropriate programme indicators for sustainable land management that captures both local and global environmental benefits, and to similar activities in other focal areas.

I hope that the analysis, the workshop's conclusions, and STAP's recommendations will be of help to the GEF as it develops its work on the sustainable land management of drylands.

Yolanda Kakabadse
STAP Chair
13 October 2005
Washington, DC

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[1]The paper is written by Mike Robbins, PhD candidate in Climate Change and Agriculture at the School of Development Studies, University of East Anglia, UK, and Timothy Williams, Head of Enterprise and Agriculture Section at the Commonwealth Secretariat, UK, and a member of STAP. The paper is a revised version first presented at the workshop, and also at a side event on 'Knowledge Generation and Research Within the Context of the GEF' at the 7th Session of the Conference of the Parties to the United Nations Convention to Combat Desertification in Nairobi, 18 October 2005. The authors would like to thank reviewers, participants at the workshop and at the UNCCD COP7 side event for their incisive and valuable comments, which have helped to improve the quality of the paper.

Executive summary

In October 2002 the GEF Assembly decided to designate land degradation as a focal area; this meant that projects to halt and reverse land degradation could be considered as primary objectives of a project, rather than a means to another end, for example, to prevent the consequent loss of biodiversity. In May 2003 the GEF Council approved Operational Programme 15 – Sustainable Land Management (OP15) – to implement projects in this focal area. A recent report to GEF Council noted that, ''Eighteen months into implementation, responses to developing GEF activities in OP15 have been overwhelming. Resource supply is not able to meet the demand''.

Land degradation[2] is a serious problem. It has been estimated that: up to 1,000 million ha are affected by water erosion alone; 75 billion tons of soil are lost through erosion every year; and the salinisation of agricultural soils is reducing the world's irrigated area by 1-2 percent a year. Land degradation has a particular impact in drylands: not only are they vulnerable to erosion, but their biomass production is relatively low, so any organic matter lost to erosion will take longer to replace. Other effects of land degradation include nutrient depletion, overgrazing of native rangeland species and deforestation through agricultural extensification. The GEF estimates that land degradation has affected 23 percent of landscapes under human use, including about two-thirds of agricultural land.

There is no doubt therefore that land degradation has a considerable effect on living standards. Intervention is not automatically desirable from many land users' perspective: some soils are worth saving and some are not. For this and other reasons, such intervention often fails, and land users are often unwilling to act. This stems in part from inadequate understanding of land users' real needs, inappropriate technology design, high opportunity costs to land users, and other factors connected with a lack of land user involvement in project design.

[2] Article 1 of the United Nations Convention to Combat Desertification (UNCCD) defines land degradation as: a reduction or loss… of the biological or economic productivity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical and biological or economic properties of soil; and (iii) long-term loss of natural vegetation.

The Scientific and Technical Advisory Panel (STAP) was therefore asked by the GEF to investigate the factors influencing sustainable land management (SLM)[3] in dry areas, and how land users' own initiatives can inform the design of SLM projects. In response, STAP convened a workshop with two specific objectives:

(a) to review land users processes of experimentation, adaptation and adoption of technologies for SLM in drylands, and draw out lessons for future project design, implementation and scaling-up of successful practices; and
(b) to analyse and identify the local, national and global environmental benefits generated through adoption and management of SLM technologies, in order to provide guidance for the estimation of incremental costs of similar new projects in dryland areas.

STAP also reviewed the benefits that agricultural and adjacent ecosystems provide, both locally and on a wider scale.

The main conclusions from the workshop were:

1. SLM has considerable local or on-farm benefits including food security, and easier maintenance of dams and irrigation structures.
2. But SLM can also deliver significant global benefits. Soil carbon sequestration and carbon retention can help to mitigate climate change. The conservation of habitat and sustainable use of biodiversity can help to maintain agroecosystem functions, and soil biota, thus reducing the need for extensification into nearby savannah, rangeland or forest, as well as enhancing food security and providing genetic resources for crop breeding and medicinal products. And SLM can also contribute to the protection of transboundary water bodies.
3. Interventions have often not worked. But where the design of SLM interventions has been land user-driven, and project interventions have

[3] Sustainable land management is defined as, "A system of technologies and/or planning that aims to integrate ecological with socio-economic and political principles in the management of land for agricultural and other purposes to achieve intra- and intergenerational equity".

been integrated more with land users' own processes of innovation and adoption, there have been positive outcomes.

4. Land users do not usually simply "adopt" a particular technology but are constantly adapting to changing circumstances. Interventions that emphasised land users' own innovation and development were more successful than those that put the emphasis on the transfer of particular technologies per se.
5. Estimating incremental costs and benefits of SLM is more complex than for other types of GEF projects because local and global benefits derived from SLM are intertwined, and both depend on maintaining the natural resource base.

STAP therefore recommends that:

(i) the best way to ensure adoption of SLM technologies is to develop them iteratively, in collaboration with land users. The GEF should endeavour to co-finance SLM projects that are flexible enough to respond to land users' innovations and inputs.

(ii) the policy environment needs to be conducive to stimulate innovation. More importantly, policies must be translated into effective action: investments in infrastructure and communication (to improve market access for inputs and produce); and facilities for credit and savings and effective extension services. (In drylands, land users' primary concern are income and improvement of livelihoods. If the land provides a worthwhile return, land users will try to protect it from degradation if they can. But this requires a responsive market and policy environment to make it worthwhile, e.g. good market access and infrastructure. Any course of action advocated to land users must be economically remunerative for them in the short term.)

(iii) SLM interventions should encourage and support a process of innovation led by land users to devise their own solutions, in which success is measured by the level of experimentation and adaptation of new technologies and management practices.

(iv) the GEF should favour projects that offer a number of different technologies and management practices, which individual land users can choose, test, adapt and adopt or discard as they see fit.

(v) a participatory approach to technology development, based on consultation, experimentation and adaptation, will work better in promoting SLM than pressing for the adoption of a particular technology.

(vi) successful projects should adapt to local needs during implementation.

This approach to SLM does pose particular problems for incremental cost analysis. The identification and quantification of global environmental benefits will be more uncertain than for other types of projects, because the final outcome will depend on a process of innovation where the end result may be difficult to predict *ex ante*. Carefully designed targeted research could reduce uncertainty in predicting global environmental benefits, and would greatly facilitate incremental cost analysis of SLM projects.

The other implication of the approach is that in the case of SLM, incremental cost analysis will not by itself result in a unique project recommendation. Other factors (such as how well the real drivers of land degradation are identified and addressed by alternative project options) may be equally important in informing decisions on which project to select.

The overall picture is one of optimism. There have been many mistakes made in attempting SLM, but much has been learned. At the same time, the off-farm benefits of SLM are now better understood. The challenge now is to transform SLM into a land-user-driven process, without imposing rigid guidelines and technologies that will lead to repetitions of past mistakes.

1 The nature, extent and costs of land degradation in dry areas

Land degradation is not new. Hellin and Haigh (2002) cite the abandoned cities and agricultural terraces of Mexico and Central America, while vast areas of 'dead cities' are found in north-west Syria, a legacy of an olive economy that was brought to an end in the later first millennium because the soil could no longer support it.[4] Lowdermilk (1948) recounted a journey through the Middle East in 1938-39 at the behest of the U.S. Soil Conservation Service: "I wondered … if Moses had foreseen what suicidal agriculture would do to the land of the Holy Earth, he might not have been inspired to deliver another Commandment… 'Thou shalt… safeguard thy fields from soil erosion... [or] thy descendants shall decrease and live in poverty or perish from the face of the earth'."

Given that land degradation can arouse such emotional responses, three main questions should be asked about it:

- what is it,
- how widespread is it, and
- how much does it matter?

Article 1 of the United Nations Convention to Combat Desertification (UNCCD) states that:

> *Land degradation means reduction or loss... of the biological or economic productivity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical and biological or economic properties of soil; and (iii) long-term loss of natural vegetation.*

This definition does not explicitly identify land-use change in itself as land degradation, and it is not always regarded as such (see for example Pagiola, 1999a). However, if loss of productivity causes farmers to bring new land (forest, pasture or rangeland) under cultivation, instead of improving existing land, there will be global externalities. Ploughing up pastures will reduce soil carbon content; for example 50 years of cropping soils in semi-arid New South Wales has on average reduced soil carbon by 32 percent relative to pasture (Chan and Bowman, 1995; quoted by Farage et al., 2003).[5] There is also a loss of biodiversity. As Pagiola points out, this occurs both directly through degradation of cropped areas, and through their expansion. The latter will cause not only loss of forest or pasture species, but also threaten populations of wild relatives of crops (Cromwell et al., 2001) – especially in West Asia, which is the centre of origin for wheat, lentil and barley. Indeed GEF/STAP (1999) points out that "habitat loss… is often the direct consequence of land degradation." Land-use change, when it leads to loss of productivity and ecosystem functions and services, is therefore considered as part of land degradation for the purposes of this paper.

How much land degradation is taking place? Recent attempts to develop practical indicators include the Land Quality Indicators developed by the international agencies (Pagiola, 1999a) and

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[4] Although loss of markets in Byzantium following the Arab invasion may also have been a factor.

[5] The opposite is also true; while cropland can sequester perhaps 0.3t/ha under improved practices, conversion to pasture can sequester 0.8 t/ha (IPCC, 2000). The GEF-supported Kazakhstan Drylands Management Project has taken advantage of this in its calculations of the benefits from converting degraded cropland to pasture in areas originally ploughed up by the Soviet Union's Virgin Lands Scheme.

the GEF-supported Land Degradation Assessment in Drylands (LADA). For now, however, “the available information remains highly fragmented, incomplete, and often unreliable”(ibid). In his discussion of soil erosion and carbon emissions, Lal (2003a) comments that “most available statistics on the extent and severity of soil erosion…[are] subjective, qualitative, obsolete, crude and unreliable.” Carpenter (1989) stresses that field measurements such as erosion rates are not statistically reliable, citing “The difficulties of field research in developing countries…[which] include bad roads, high corrosion rates on equipment, absence of spare parts, hostile local inhabitants and language/literacy difficulties.” Moreover, as Stocking (1996) has pointed out, estimates of soil erosion in Africa, and responses to them, have been coloured by the funding needs or political aspirations of those involved.

However, rough estimates have been made. For example, erosion is one of the foremost drivers of land degradation. Oldeman (1994) puts total land area affected by water erosion at 1,094 million ha, of which 751 million ha is severely affected; and land affected by wind erosion at 549 million ha, of which 296 million ha is severely affected. Eswaran et al. (2001) suggest an annual loss of 75 billion tons. This must be added to other causes and symptoms of land degradation, including nutrient mining, salinization, overgrazing of native rangeland species and much else. GEF (2003a) suggests that land degradation “adversely affects the ecological integrity and productivity of about 2 billon ha or 23 percent of landscapes under human use…. About two-thirds of agricultural land have been degraded to some extent during the last 50 years.”

Land degradation has long been associated with drylands, which cover about 42% of the global terrestrial area and are home to approximately 35% of the global human population in 2000 (MA (Millennium Ecosystem Assessment), 2005). The extent of dryland degradation is itself debated, with estimates varying between 17 and 70% (Reynolds et al., 2003). The Millennium Ecosystem Assessment synthesis report on desertification suggests that 10-20% of drylands are degraded (with medium certainty) (MA, 2005). Rangelands are especially vulnerable in dry areas; 20 percent of the world’s pastures and rangeland have been degraded to some extent, but 73 percent of rangeland in the dry areas (UNEP, 2004). Batjes (2004) quotes Oldeman’s estimate that about 31 percent of the permanent pastureland in Africa is affected by anthropogenic soil degradation. Gintzburger (1996) reports that about 9 million sq km of the world’s drylands have been rendered unproductive in 50 years. He states that farmland wrecked by unwise irrigation accounts for much of this, but adds that steppe in West Asia and North Africa now meets only about 5-10 percent of the small ruminants’ diet, against 60-80 percent in the 1950s (ibid.). So although the second question – how widespread is land degradation? – cannot be answered precisely, it seems reasonable to assume that it *is* widespread, especially in drylands.

The third question was whether it mattered. This has stimulated fierce debate. As Seckler (1987) points out, erosion may simply remove soil from upland areas where it cannot be used efficiently to lower plots where it can. In any case, productivity depends more on the quality of the soil still in the field than it does on the soil lost (Hellin and Haigh, 2002). Moreover Blaikie (1985) and Pagiola (1999a) both quote Boserup’s view that erosion may actually stimulate innovation. The Machakos district in Kenya is often quoted in this context (Tiffen et al., 1994; Adams, 2001; Barbier, 2000; Critchley et al., 2001; Pandey, 2001). Although the area suffered serious degradation in the 1930s, more recent years have seen rising levels of productivity both per capita and per hectare, despite a sixfold increase in population. By 1985, about 85 percent of the land in Machakos that required some form of conservation work was getting it (Pagiola, 1999b). This complexity makes it difficult to estimate the real cost of land degradation. Seckler (1987) points out that economics “is as limited in the kinds of evaluations it can make in soil and water conservation as it is in anything else.”

However, it is perhaps no *more* limited in that respect. Erosion, nutrient depletion, overgrazing and salinity do lower yields and increase the need for inputs, and this can be quantified. Blaikie (1985) quotes estimates that in 1976 the equivalent of five gallons of fuel per acre were being used in fertilizer to offset the effects of erosion in North America. More recently, FAO (1994) has estimated the additional fertilizer needed to compensate for loss of soil fertility (not including the effects of wind and water erosion) in South Asia. FAO assumes that either 50 or 100 kg/ha of nutrients would be needed to compensate for loss of nutrients on 42.4 million ha of degraded soils at a cost of $300 per tonne, amounting to $636 million or $1,272 million for the region. It adds that even this solution is only possible in the short term as the unbalanced use of fertilizers without other measures will soon cause diminishing returns (ibid.). In any case, this increase in inputs is not an option for the resource-poor. Nutrient losses are clearly not confined to South Asia; Pagiola (1999a) comments that: "The fertility constraints resulting from soil organic matter and nutrient depletion are thought to be a major impediment to agricultural growth in Sub-Saharan Africa."

Soil erosion is also crucial. Lal et al. (1989) argue that "erosion is a complete form of degradation because it depletes nutrient capital, decreases effective rooting volume, and reduces plant available water resources." They add that there is controversy as to how much this affects yields (ibid.), but Lal has since written that:

> *Annual reduction in total production for 1989 due to accelerated erosion in the continent of Africa was 8.2 million Mg of cereals, 9.2 million Mg of roots and tubers, and 0.6 million Mg of pulses…* [R]*isks of global loss of crop yields due to erosion* [are] *10 per cent in cereals, 5 per cent in soybeans, 5 per cent in pulses, and 12 per cent in roots and tubers.* (Lal, 2001.)

South Asia is also seriously affected by erosion, as well as nutrient depletion. FAO (1994) estimates that water erosion alone is reducing cereals production in India by 15 million tons, equivalent to 8 percent of total cereal production, and argues that taking into account other forms of production suggests a loss of 25 million tons of cereal equivalent. For eight countries of South Asia as a whole, they suggest a figure of 9 percent loss of production in cereal equivalent due to water erosion, although they stress that the figure is approximate.

Other forms of degradation also take their toll. Salinization of agricultural soils through poor irrigation management is reducing the world's irrigated area by 1-2 percent a year, with particular impact in drylands (FAO, 2002). Although only 17 percent of the world's cropland is irrigated, it provides 40 percent of the food, and it has been suggested that salinization threatens up to 10 percent of the world's grain harvest (ibid.). FAO (1994) reports that the cost of salinization for the South Asia region cannot easily be determined but quotes tentative figures for Pakistan; on the basis that a mild degree of degradation leads to 15 percent loss of wheat productivity, moderate degradation 65 percent and strong 100 percent, this gives production losses of between approximately 1.2 million and 4.1 million tons (ibid).

Soil translocated by erosive processes may block irrigation canals or dams. Flooding as a result of loss of water retention in hillsides is also an externality. These damages are difficult to quantify, but estimates exist. For example, in 1999-2000 in Kyrgyzstan nearly 100 million som ($2.37 million) in total was spent on anti-landslide construction and bank-strengthening (IFAS, 2003). Siltation of watercourses is also a significant externality, and is frequently quantified in terms of crop losses or maintenance costs – or in accelerated depreciation of a capital asset; thus FAO (1994) estimates the expected life of eight Indian reservoirs as being from 23-79 percent of their original design life, with four below 40 percent.

Some of the cost of land degradation is on-farm – that is, internal; this would be the case with the loss of crop production. If the affected area is large, this could translate into higher commodity prices in local markets and these would affect the non-farm sector, so there is also an externality; but whether this has national, regional or merely local effects would depend on the rural infrastructure, including the transport network. It could be argued that a global externality is involved if food aid is needed, but such aid amounts to a very small percentage of global GDP. So if Lal's (2001) figures for production losses are accepted, they would usually constitute either an on-farm loss, or a local or regional externality.

On the other hand, the estimates by Blaikie (1985) and FAO (1994) quoted above for extra fuel and fertilizer will be national externalities if farmers cannot afford these extra inputs without subsidies. There is also a global externality in terms of carbon emissions for fertilizer production and transport, and this should be quantifiable. However, the most obvious global externalities of land degradation are carbon emissions through loss of soil organic matter, and loss of biodiversity in terms of plant species and soil biota. These global externalities are discussed further in section two.

Costs of land degradation have a further dimension that has not been discussed above, and that is the depreciation of the land as a capital asset. As FAO (1994) point out:

> *Until recently, changes in natural capital have not been given money values, nor included in cost-benefit and other forms of economic analysis. Changes in natural capital are not currently included in systems of national accounting… Natural resources have formerly been priced only in terms of their cost of use… In the case of soils, these were treated as the 'land' factor in classical economics, priced at the market value of farmland.*

In theory, this should not present a problem. The classical view as propounded by Hotelling (1931) suggests that the value of natural resources will depend on their scarcity. If this is extended to farmland, its value should rise with its scarcity. However, the resource here is not actually used up; rather, its productive capacity falls. This happens to any productive asset, including machinery. As FAO (1994) points out, construction and depreciation have always been considered in accounting. But depreciation of land resources cannot be replaced in the same way as a machine tool. It can only really be restored through natural processes: "Assuming natural erosion to be very slow, then [at the most optimistic figures] it would mean putting land under fallow for 50 years to restore [a] lost 5 cm" (ibid.).

None of the evidence above necessarily proves that there are severe livelihoods consequences from land degradation. Scherr (2001) quotes evidence that land degradation could cause a maximum 17 percent cumulative productivity loss globally by 2030, with higher losses in the developing world. While significant, she says, "such losses would not seriously threaten international food trade because of the global capacity for supply substitution from non-degrading lands, and the dominance of temperate producers in international wheat and maize markets."

However, if a subsistence farmer's yield falls in (say) Kenya, there is no automatic mechanism to replace it with wheat from North America. So the effects of land degradation, which are not spread evenly, will have disproportionate livelihoods impacts where they do occur. These impacts are likely to be heaviest on those least able to deal with them. Scherr argues that soil degradation is likely to have such impacts on the poorest because they are more dependent on agriculture and on crops that are more easily affected by erosion. They are less likely to have good land, and, because they may lack access to inputs, are more likely to be dependent on intrinsic soil quality. Studies from China and Kenya tend to reinforce this picture (ibid.). McIntire (1994, quoted by

Scherr, 2001) reports that while the average cost of soil erosion in areas planted to maize in Mexico were 2.7 percent of agricultural GDP, economic losses were nine times higher in the highlands and semi-arid regions than in the lowland tropics. So the effects will be concentrated in dryland areas and on those that are already poor, although they may spread, as rural-urban migration induced by declining land quality could put strain on urban job markets. Scherr herself concludes that, although the world as a whole can absorb the costs of land degradation, "increased soil degradation could increase the number of malnourished children (rural and urban) in 2020 by 3-4 percent." Stocking and Tengberg (1999), discussing erosion, identify "a significant impact…, making it inevitable that rural producers find it increasingly difficult to survive."

Genetic erosion as part of land degradation

Loss of biodiversity is also one facet of land degradation. This arises in part from loss of habitat and also from loss of crop genetic diversity from farmland. For the 60 percent of farmers who are subsistence farmers, the biological qualities of landraces, or farmers' varieties, are of great importance – especially in arid or semi-arid areas: "Dryland agrobiodiversity is especially important, because of the harsh nature of such areas. That harshness means that food security is always threatened by changes in the environment, variations in the weather and assaults by fast-mutating pathogens." (El-Beltagy, 1996.)

Plant genetic resources for food and agriculture (PGRFA) are subject to serious erosion of genetic diversity (FAO, 1997). There are two main drivers of this; extensification, and – more serious – replacement of landraces in the field by modern varieties. Lack of historic data makes it hard to quantify this (FAO, 1997). However, examples are indicative. In China, the number of wheat varieties in the field declined from nearly 10,000 in 1949 to about 1,000 in the 1970s. In the Republic of Korea, 74 varieties of 14 crops grown in 1985 were replaced by 1993 (ibid.). In some areas of Asia over 80 percent of rice and wheat land is now planted to modern varieties (Cromwell et al., 2001). This erosion should be seen as both a consequence and a cause of land degradation. It is a *consequence* because extensification of agriculture due to degradation of existing land will take over the marginal lands and field borders where disused landraces and wild relatives might survive. In the Levantine Highlands of Syria, for example, over 500 species have been found on marginal land and field borders, including wild relatives of forage crops, wheat, olive and fruit trees (Peacock and Robbins, 1996).[6]

However, genetic erosion is also a *cause* of land degradation because crop genetic diversity, taken together with soil biota and diversity of cropping patterns and management practices, is part of 'agro-biodiversity' – the synthesis of all these factors, and "the principal biological means of degradation control, and, by mixing of species, the main promoter of increased and more diversified (and food-secure) output from farming systems" (Tengberg and Stocking, 2001). It has been argued that this diversity of practices as well as genetic diversity is more properly called 'agrodiversity', although the two terms are sometimes used interchangeably (ibid.; Brookfield and Stocking, 1999). There is another term, agroecology, which takes the concept further in arguing for a farming system that increases sustainability because it mimics natural processes of adaptation (Altieri, 2002). Whether this view is accepted or not, there is a link between crop genetic diversity, disease resistance and soil health, and the Convention on Biodiversity (CBD) advocates an agroecosystem approach (Cromwell et al., 2001).

The measures that can be used to reverse the types of degradation described in this section obviously depend on the problem. Specific mitigation strategies for land degradation, including loss of PGRFA, will be discussed in later sections. However, all fall into the category of sustainable land management (SLM); broadly, the use of land in such a way as not to prejudice its

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[6] GEF has supported a project, *Conservation and sustainable use of dryland biodiversity*, to promote *in-situ* conservation of these genetic resources in Syria and elsewhere in the region.

future use. Hurni (1998) defines it as follows:

> *A system of technologies and/or planning that aims to integrate ecological with socio-economic and political principles in the management of land for agricultural and other purposes to achieve intra- and intergenerational equity.*

Hurni quotes Dumanski's (1994) "five major pillars" of sustainability to which sustainable activities should conform. They should be ecologically protective, socially acceptable, economically productive, economically viable, and effective in reducing risk. It is also worth quoting Adger et al.'s (2002) criteria for environmental policy in general: efficiency, effectiveness, equity and legitimacy.

2 Sustainable land management: Local and global benefits

In the previous section, it was argued that land degradation has serious socioeconomic consequences for farmers. SLM also has concrete benefits beyond the farm, and these will be discussed later in this section. However, implementing SLM starts with the land users themselves, who must also benefit if they are to adopt; as Dumanski et al. (1998) put it: "The agricultural landscape is constituted through the individual management decisions of millions of small-scale entrepreneurs." So this section will start by looking at the direct farm-level benefits before considering the national, regional and global benefits. It will not examine the pitfalls; these will be discussed in section 3, in which experiences with SLM and soil and water conservation (SWC), and the lessons learned, will be discussed in more detail.

Four basic strategies for SLM will be considered:

- Mechanical soil conservation (construction of terraces, bunds, grass strips etc.).
- Improved tillage regimes.
- Intensification, meaning increasing inputs in order to increase the sustained value of the land's output. These inputs include water.
- Conservation of on-farm biodiversity.

On-farm benefits of mechanical soil conservation

The construction of terraces and bunds is the most obvious way of preventing soil loss. The cost of erosion, discussed in section 1, suggests that they would have good on-farm returns, but this is highly site-specific. For example, Antle et al. (2004) analysed slow-formation terraces in Peru. These are barriers that accumulate soil as the latter moves in the field; similar 'soil harvesting' techniques can be found elsewhere – the *jessour* system in southern Tunisia does much the same thing (Aw-Hassan, 1996). Antle et al. report that:

> *A number of studies report yields of crops planted on terraced fields versus non-terraced fields in Peru and other regions of the world…While these studies generally show that terracing increases productivity, there is a considerable variation in the reported productivity effects. Most of these studies are difficult to interpret because they do not specify important information such as the initial soil conditions at the time of the investment or the maturity of the investment… A fundamental fact of agriculture is* heterogeneity *in biophysical and economic conditions.* (Antle et al., 2004; emphasis in original.)

This heterogeneity affects the profitability of soil conservation and the real returns on any investment in it. Farmers on the southern Loess Plateau in China find it more economic to limit their investments in soil conservation to the better soils (Lu and Stocking (2000a, 2000b)); as in any industry, it is better to invest in a productive asset than an exhausted one. They also identified a need to integrate erosion control with other factors influencing soil quality, such as nutrient cycling and build-up of organic matter. Farm-gate prices will also define the extent of any benefit – a subject that is discussed further in section 4.

The costs, as well as the benefits, of SLM vary from one farm to another. The cost of credit and opportunity cost of labour is also site-specific. Shiferaw and Holden (2001) point out that credit may not be available for conservation purposes: "In the absence of credit, labour-scarce households are unlikely to invest in profitable [SLM], especially when this imposes a trade-off with their immediate consumption." Shiferaw and Holden found that the long period needed for investments in SLM to show a return was impracticable for farmers who needed to deal with

immediate needs. The opportunity cost of using labour in this way may also be high when off-farm employment is available – although this can cut both ways, as it also provides funds for investment in SLM (Scherr, 2000).

This evidence suggests that farmers may not always be able to justify the investments, and may need external assistance, which may be costed with reference to off-farm benefits; these will be discussed later in this section. However, there are clearly benefits from terracing and other measures; if there were not, indigenous systems such as the *jessour* would not have arisen. In the latter case, the terraces that are slowly formed by the *tabias* – the barriers which collect soil – allow production of apples, apricot, chickpea, lentils, faba beans, watermelons and vegetables, despite annual average rainfall of as little as 200mm; in areas of slightly higher rainfall, figs and grapes are grown as well (Aw-Hassan, 1996).

On-farm benefits of tillage regimes

Non-mechanical forms of SLM such as reduced or no-tillage regimes do not require the same level of investment as terraces, and can bring significant on-farm benefits. Farmers till to prepare seedbeds, control pests and diseases and stimulate mineralization which releases nutrients to the crop. But most tropical soils need not be tilled (FAO, 1998). An easier strategy is to leave crop residues in the field, where they will encourage a build-up of soil biota that will – it is claimed – aerate the soil just as well (FAO, 2002a). The supply of nutrients to the crop will be increased, not decreased, as the crop residues will be incorporated into the soil as soil organic matter by increased biotic activity. This in turn improves the soil structure; as Lal (1997) explains, micro-aggregates develop around decomposing organic matter. Higher organic matter content is therefore associated with soil that is more aggregated, allowing greater water infiltration than compacted soils. This both reduces erodibility, and promotes greater water availability in the root zone.

No-till (NT) originated in the United States, but has spread quickly in parts of South America as a response to declining productivity (FAO, 2001; Sisti et al, 2004). Brazilian farmers have reported very tangible on-farm benefits and have taken to no-till with such enthusiasm that they have formed associations with names such as "*Clube da Minhoca*" (the Earthworm Club) and "*Amigos da Terra*" (Friends of the Land), and now pay close attention to sustainability, to the extent that they plant winter crops solely to improve the subsequent maize or soybean crop (Boddey et al., 2003). In the Pampas region of Argentina, where about 30 percent of the cropped area is now under NT, most crops (excluding maize and sunflower) have shown higher yields (Díaz-Zorita et al., 2002). Moreover, because mechanized inputs are reduced (and on small-scale farms, even eliminated), yield increases can be augmented by fuel savings; FAO (2001) has claimed reductions in the cost of soybean production per acre of US $27 in Argentina, US $14 in the United States and US $11 in Brazil. Díaz-Zorita et al. (2002) also report that although yield increases were welcomed, farmers in Argentina seem to have been most motivated by the fact that better water retention gave them a wider choice of planting dates

Such gains are not automatic; Evers and Agostini (2001) report large yield variations in the early years of adoption. Overall, however, they find that these variations are reduced and yields – sometimes – improved. There were also other other benefits, incuding a reduction in run-off and erosion; this was substantial in some cases (ibid.). The study report also found a general increase in income, despite falling commodity prices; where incomes had fallen, they were found to have done so less than on conventional farms. Moreover the reduction in labour requirement had enabled diversification into livestock and added-value processing.

There is less experience with low- or no-till in very arid areas, where modified tillage regimes will never produce as much extra biomass as they will elsewhere. However, because they make better use of available moisture, these gains can still be significant in percentage terms. Recent experiments suggest wheat yields rising from 0.5 to 1.5 t/ha and even annual, instead of biennial, cropping, in areas with just 200mm annual rainfall (FAO, 2002b). Reduction in erodibility is also of particular value in arid areas because what rainfall there is, may be concentrated in time and space.

There may be special constraints to this type of SLM in arid areas. Not least would be retention of crop residues, which would have a high opportunity cost in areas of low biomass. A farmer would be unable to graze his livestock on the crop residues, or to leave them for someone else to do so – the latter case could be problematic where there is customary land tenure. There could be further problems in regions where arable farming borders on semi-arid rangeland, as crop residues from the arable land are sold off-farm and can be an important source of feed security for pastoralists; such interactions are common in dry areas (Neilsen and Zöbisch, 2001). Constraining this exchange could simply move land degradation from the farm to the steppe.

However, reduction or elimination of tillage can have worthwhile impact in terms of productivity, reduced erodibility, diversity of soil biota, infiltration capacity, and fuel use and/or labour requirement.

On-farm benefits of intensification

For this review, agricultural intensification is defined as increased average inputs of labour, manure, draft power, crop residue, bought-in minerals, feeds, veterinary drugs, pesticides or capital on a farm for the purpose of increasing the value of output per unit of land (Williams et al., 2000).

Increasing inputs does not necessarily constitute SLM. However, with the right mix of agronomic practices, it does. Increasing soil nutrients through appropriate use of organic or inorganic fertilizer will increase long-term productivity, not only directly by building up soil nutrients but indirectly by increasing organic matter content, leading to better soil structure. The key to sustainable intensification lies in a ‘sideways’ modification of technology; typically, rather than increase the output from a given crop through faster-growing cultivars or greater inputs, the farming system can be modified to give greater net output from the land in terms of value. Rotations are the classic example of this. As they are aimed at more efficient land use, it seems fair to regard them as intensification.

An example of on-farm benefits from this form of intensification is the ley-farming technology developed by the International Center for Agricultural Research in the Dry Areas (ICARDA). Introduced in the late 1980s, it is a response to concern at nutrient mining through cereals monocropping in Syria (Christiansen and Manners, 1995). Cereals are rotated with feed legumes, in this case vetch, which build up organic matter and soil nutrients depleted typically by wheat cultivation. The vetch is then harvested for feed. Rotations of cereals with legumes such as vetch and medics have been shown to substantially increase SOM (Ryan and Pala, 2002). There have also been tangible production benefits; in the Tarhin area of northern Syria, where annual rainfall is about 200-280mm, there were reports of barley yields that had increased by up to 20 percent in rotations with vetch, accompanied by a worthwhile increase in twinning rates amongst ewes (Bahhady and Robbins, 1998). Moreover earlier lambing and fattening resulted in higher prices and less exposure to winter weather. Meanwhile Morocco’s Institut National de la Recherche Agronomique (INRA) reported better bread-wheat yields in rotation with medics (Mohamed and Bounejmate, 1998). It is argued that these benefits wipe out the opportunity costs of not

continuously cropping wheat. Intensification of this type is clearly also SLM. However, such experiments were not an unqualified success; an attempt to introduce medics as fallow replacement was foiled by a Syrian Government decision to end fallow (Christiansen et al., 2000).

Irrigation is also a form of intensification in that water is an input used to increase the value of the land's output. It is not always sustainable, leading to soil salinity and depletion of water reserves; some estimates suggest that salt-affected soils cover about 10 percent of the world's land area, and one-third of the arid and semi-arid regions (Lal and Bruce, 1999), while FAO believes that one developing country in five will face water shortages by 2030 (Gregory et al., 1998). But irrigation that *is* sustainable could be regarded as SLM, building up organic matter; and it could have considerable on-farm benefits. Indeed Lal (2003b), reviewing potential for carbon sequestration in drylands, has advocated irrigation, including the use of sewage sludge and wastewater, as an important tactic for accumulating biomass and therefore SOC:

There is a large scope for enhancing SOC concentration in irrigated soils. In Mexico, Follett and others (2003) reported that adoption of conservation tillage on irrigated vertisols sequestered soil C at the rate of 1.8 Mg/ha/y. Furthermore, the SOC sequestration efficiency was 8–10%, similar to that observed in the northern Great Plains (Follett and others 1997). This is an exceptionally high rate of SOC sequestration and indicative of the potential of irrigated soils in carbon sequestration.

There is real potential for expanding sustainable irrigation. FAO (2003a) reports that in 1999, 42 percent of arable land was irrigated in Asia and 31 percent in the Near East and North Africa, but only four percent in Sub-Saharan Africa. Rosegrant and Perez (1997) argue that: "Although agriculture is by far the biggest water user in Africa, the full physical irrigation potential is far from being tapped. Only about one-third of the potentially irrigated area is under irrigation."

Unleashing this potential could have huge benefits, especially if allied to more rational use of water. In West Asia and the Near East, rainfed wheat yield is about 1 t/ha, but can rise to 5-6 t/ha under irrigation (Oweis, 1999). This effect could be multiplied through greater water-use efficiency. In the Middle East, using supplemental, instead of full, irrigation on wheat to deliver 50 percent of the water requirement reduced the grain yield cited above by about 10-20 percent (Oweis et al., 1999; Oweis, 1999; Oweis and Hachum, 2003). So if the 50 percent of the water that had been saved were used to irrigate *another* area of the same size, the farmer would see an effective yield increase of 160 percent while using the same amount of water.

However, even assuming management problems can be eliminated, irrigation may not always be the answer. As Rosegrant and Perez (1997) point out in the case of Africa:

> *More than one-third of the potential area is being irrigated in the Southern and Indian Ocean Islands, and the Sudano-Sahelian regions, and less than 10 percent in the Western, Central, and Eastern regions… While these numbers appear to suggest dramatic potential for future expansion, much of the potential area is in regions with abundant rainfall, (or with wetlands or flood recession irrigation), where irrigation systems are unlikely to have high economic payoffs.*

They also acknowledge that large-scale schemes in Africa have sometimes gone badly wrong, quoting construction costs of $50,000/ha and negative rates of return – a result of technical difficulties, design faults, management failures and politics. Estimating the return on irrigation projects is complicated by the fact that cost-benefit analysis usually only measures the direct benefits.

FAO (2003a) argues that, while large-scale irrigation projects have fallen out of favour, small-scale initiatives such as and treadle pumps could unleash much of the potential. It also mentions water harvesting. This has been called "the collection and concentration of runoff for increased and more reliable plant production" (Reij, 1991), and is most used in regions with 100-700mm, these being areas where irrigation of some sort would be desirable but where river or groundwater may not be available in sufficient quantities.

The number of such areas is likely to grow; Rosegrant and Perez (1997) report 28 countries as being water-stressed – that is, with less than 1,000 cubic meters per capita of internal renewable water resources; a number expected to reach 35 by 2020 (ibid.). If climate change does make rainfall more concentrated in time and space in these areas, controlling and using surface water in this way will have even more benefits in terms of crop production and erosion control. Already, in arid areas, up to 20% of annual rainfall may fall in a single day (ibid.).

Water harvesting can take many different forms, ranging from large earth structures that create catchments for whole farms, to small 'eyebrow' terraces around a single tree. It is arguably distinct from agronomic methods of moisture conservation, such as no-till, in that the crop and catchment areas are distinct. There is more similarity with mechanical soil conservation such as bench terraces and bunds; the *fanya juu* system used in parts of East Africa, and the *jessour* structures of Tunisia, clearly perform both functions.

Farmers have long practiced water harvesting. Agarwal and Narain (1999) report that it has been used in India for at least 2,000 years, stating: "There is some evidence of the existence of advanced water harvesting systems even from pre-historic times. Hindu texts like the *Puranas*, *Mahabharata* and *Ramayana* and various Vedic, Buddhist and Jain works contain several references to canals, tanks, embankments and wells." The *teras* system of Eastern Sudan is thought to date back to the Kingdom of Funj (1504-1820) (Van Dijk and Ahmed, 1993).

However, the on- and off-farm benefits of water harvesting are as tricky to quantify as those for other forms of irrigation. Critchley et al. (1992) state: "The available data on costs and benefits of [water harvesting] systems is approximate at best, and should therefore be regarded with scepticism." They quote a number of reasons why this is so, including:

- Estimates do not always allow for labour for construction, maintenance costs and equipment depreciation;
- There is a tendency to simply compare yields with those of control plots, but they are rarely subject to the same conditions or cultural practices.
- Important by-products such as stover are frequently not accounted for.
- It is sometimes unclear whether yield data have been taken for the cropped area only, or the whole area including the catchment.

The last point is crucial, as the ratio of catchment to cropped area is highly variable. Critchley et al. themselves suggest that a ratio of 3:1 is likely to be appropriate, in that it about doubles the effective rainfall without directing too high a flow during wet years (which would have erosive effects, and might destroy the water-harvesting structures themselves). Critchley et al. do quote an example in Somalia where grain yields were 820 to 1,750 kg/ha for bunded land, and 840 to 1,220 kga/ha for unbunded. However, there was no difference during 1987, a drought year. The authors do not say so, but this example might suggest greater benefits in good years than bad, implying that water harvesting did not in this case improve food security much. They do point out that any investment in water harvesting makes more sense if accompanied by improved agronomic practices, cultivars or other inputs that maximise any benefit from the extra water

availability. There are other pitfalls with water harvesting, and these are discussed further in section 3.

Water harvesting, like other forms of intensification – irrigation, fertilizer use, improved cultivars or sustainable rotations – may have one especially important benefit; it is an alternative to extensification. As stated in section 1, this paper is considering land-use change as part of land degradation, because two major global benefits produced by ecosystems – carbon sequestration and biodiversity – are reduced by agricultural encroachment.

Indeed, Vlek et al. (2004) have argued that the best way to reduce carbon emissions through agriculture is to use high levels of fertilizer to increase fertility on existing cropland. Vlek et al.'s argument seems to favour duplicating the Green Revolution; their calculations also embody some assumptions, not least that per capita food consumption would remain the same even if productivity rose. With a nearly a billion people undernourished (FAO, 2003), this seems unlikely. It is also worth quoting Lal's (2003b) view:

> [S]*equestration of 1 Pg C/y in the dryland ecosystems would require 83 million tons of N, 20 million tons of P, and 14 million tons of K, amounting to a total of 117 million tons of fertilizer nutrients. In comparison, the global fertilizer use in 2000 was 136 million tons (IFDC 2002). These are large numbers, and these nutrients must be made available from a wide range of sources.*

Lal also mentions the greenhouse-gas implications of volatilization of N (ibid.). Other significant ecosystem impacts of N could also have been mentioned.

However, others besides Vlek et al. have highlighted the link between intensification, extensification and carbon, in particular Tschakert and Tappan (2004). Intensification as SLM could be positive, not only by building up biomass on-farm but also as an alternative to an extensification pathway.[7]

On-farm benefits of on-farm biodiversity conservation

On-farm biodiversity consists not only of crop genetic diversity but also of a wide range of soil biota. It also includes genetic diversity of animals. All of these are linked, but it is plant and soil biodiversity that are significant in the context of this paper.

Bellon (2003) quotes a number of reasons why farmers would wish to conserve on-farm biodiversity. They include the ability to farm in varied environments, production of special food items and the forging of social links. The last is important because, as Bellon explains, the wide range of genetic material needed in difficult environments is unlikely to be found on one farm, and there is therefore a high level of informal exchange of plant genetic resources. Indeed social networks often decide the extent of a farmer's access to genetic diversity; for example, Mazzucato and Niemeijer (2001) found that women's natal networks helped define access to landraces in Burkina Faso. Bellon (2003) concluded from work in Oaxaca that the number of landraces found in farmers' fields was constrained by their access to different seeds. This differs from the conventional view that farmers have depleted their genetic resources deliberately in

[7] An additional benefit of this in drylands might be to prevent encroachment on areas needed by pastoralists, although crop-livestock integration might be the best solution to this in some cases; see for example Mortimore (2000) on Nigeria.

favour of 'modern' varieties, and suggests that they themselves appreciate the on-farm benefits of genetic diversity.[8]

One of them is the need to maintain yields, and therefore food security, in harsh environments. The value of genetic resources in providing this resilience may require a genetically diverse population. Holding this in a gene bank may not provide the same level of protection.

A further local, on-farm benefit of crop genetic diversity is soil health, through interrelationship between plant diversity, soil microbial diversity and organic matter content. It is recognized that the use of modern, improved varieties may force farmers to use more pesticides. Cromwell and Almekinders (2000) quote evidence that a third of the cropped area in the Philippines has been severely degraded from the over-use of pesticides and chemical fertilizers. This will have an undesirable effect on soil biota. As Altieri (2002) puts it:

> *It is crucial for scientists to understand that most pest management methods used by farmers can also be considered soil fertility management strategies and that there are positive interactions between soils and pests that once identified, can provide guidelines for optimizing total agroecosystem function. Increasingly, research is showing that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils.*

This relationship has direct effects on productivity. Giller et al. (1997) quote examples such as *rhizobium*, the loss of a single species of which can prevent nitrogen fixation by a given legume. "If there is a direct link between above-ground biodiversity in the vegetation and below-ground biodiversity," they state, "then enhanced biodiversity above-ground will contribute to the re-establishment and multiplicity of soil organisms able to carry out essential biological functions. This will restore the resilience of the soil and thus buffer agroecosystems against risk, and help to sustain productivity." Pagiola (1999a) takes a similar view: "Small organisms, such as insects and other invertebrates, play a vital role in developing and maintaining healthy soils, and help to maintain nutrient cycling, soil structure, moisture balance, and fertility."

This may be illustrated by the use of no-till or CT techniques, discussed earlier in this section. The process occurs in part because the rising level of soil biota; as Lal (1997) explains, microaggregates develop around decomposing organic matter. However, use of pesticides can reverse this process rapidly even if conventional tillage is not resumed, as Lal himself (1998) found in an experiment in Western Nigeria: "Importance of soil biota on soil physical quality is highlighted by the drastic impact of Furadan on soil bulk density and gravel content [of no-till plots]. …Soil structure essentially collapses with elimination of soil biota. Therefore, a judicious use of pesticides is critical in maintaining a favorable level of soil biodiversity."

Giller et al. (1997) warn that relatively little is known about the benefits of soil biota and call for further research that can input into policy-making – in particular, to test the hypothesis that resource-poor farmers would benefit more than most from higher levels of soil biota. Even so, soil biodiversity may be an underestimated on-farm benefit of crop genetic diversity.

[8] Farmers also conserve crop genetic diversity for reasons not explained by agronomic or environmental values, as Brush (1999) reports in the case of Andean potato varieties. This would indicate an on-farm benefit, possibly social, but one that might be very location-specific.

Global benefits: Carbon sinks

The remainder of this section looks at the global benefits of SLM. These do not include regional or national benefits – for example, reductions in imports of fuel and chemical inputs. There are clearly areas where these are difficult to disentangle from global benefits, but these issues will be discussed in section 6.

The clearest global benefits from SLM are the sequestration and retention of carbon, mitigating climate change; and the conservation of genetic resources needed for medicinal products and crop breeding. There are others; prevention of flooding through maintenance of soil structure is also very important, although this tends to be a local benefit. Another is albedo – that is to say, the reflectivity of the earth's surface, which will be affected by changes in vegetation; but the extent to which farming practices affect climate in this way is hard to quantify, although it may be significant. However, the easiest global benefit to measure is carbon.

Photosynthesis removes CO_2 from the atmosphere and converts it into plant material. About 40-45 percent of the plant material is organic carbon. Ultimately, much of it is incorporated into the soil as soil organic matter (SOM), over half of which is soil organic carbon (SOC) (Follett, 2001; Post et al., 2001). Given that the amount of carbon buried in the ground is about three times that held in the atmosphere (Follett, 2001), anything that significantly affects the soil carbon pool must be relevant to climate change. Making agriculture, including grazing and grasslands, increase or at least retain soil C content is therefore a potential mitigation strategy, as it enhances or preserves a carbon sink.

The potential for this is very high. Exposure of organic matter through ploughing or erosion causes decomposition, so that much C is converted into CO_2 by respiring micro-organisms. Intensive agricultural use causes SOC content to fall further. Lal and Bruce (1999) put the total historic loss from agricultural soils at 55 Pg C.[9] This is small against the total global soil organic C pool, which is about 1,500 PgC (ibid.)[10], or the atmospheric pool, which is about 750 PgC (Lal, 1997). However, what matters is not the percentage of total soil or atmospheric C, but the percentage of the anthropogenic *increase* in CO_2 that can be offset.

Total atmospheric C has increased from about 613 to 780 Gt C since 1850 (Carbon Dioxide Information Analysis Center, 2003). Moreover, Schlamadinger and Marland (2000) point out that considerable land-use change must have taken place before 1850, so emissions due to agriculture will have begun much earlier. If, as Lal and Bruce (1999) estimate, about 75 percent of the lost 55 Pg could be recovered, this is a worthwhile proportion of that anthropogenic increase. It looks the more so if measured against ongoing emissions; the net annual increase in atmospheric CO_2 during the 1980s was 3.3 ± 0.1 PgC/yr (IPCC, 2001). Lal and Bruce (1999) think that the C-sequestration potential of world cropland is about 0.43-0.57 PgC/yr, or very roughly 20 percent of the annual increase.[11] This is clearly significant, and although the majority of it would not be in drylands, much would – especially in salinized cropland. There would also be significant carbon in the vast areas of semi-arid grazing steppe.

The IPCC (2000: 4.4.2) has set out possible strategies for increasing soil carbon, and they are broadly congruent with those for SLM discussed earlier in this section; that is, erosion control,

[9] 1 Pg (petagram) C is equivalent to 10^{15}g – that is, 1,000 million metric tons; also used is a Tg, or teragram, of C (10^{12}g), 1,000,000 tons; and a gigaton (Gt), which is 10^9g or 1,000 tons.

[10] Follet (2001) puts it a little higher at over 1,550 Pg C.

[11] The authors actually anticipate a figure of 0.73-0.87 PgC/yr due to C offset from biofuels production. However, the economics of biofuels are contested; Gielen et al. (2002) suggest that there may be a conflict between carbon storage and biofuels as a mitigation strategy. But they mainly considered carbon storage through afforestation, not agriculture; biofuel production on land hitherto degraded or used inappropriately might sequester extra carbon as well as offsetting C emissions from fossil fuels.

conservation tillage and agricultural intensification. Follett (2001) is more specific, citing increase of land cover through winter cover crops, nutrient inputs and supplemental irrigation. However, the potential for the three broad strategies, as estimated by Lal and Bruce (1999), is given in table 1.

Table 1 *C sequestration potential of arable land management strategies (Pg C/yr)*

Land management strategy	Amount of C sequestered
Soil erosion control[12]	0.08-0.12
Soil restoration[13]	0.02-0.03
Conservation tillage and residue management	0.150-0.175
Improved farming/cropping systems	0.18-0.24
Total	0.43-0.57

Source: Adapted from Lal and Bruce (1999)

Erosion control is particularly important. The IPCC (2000) quotes Lal and Bruce's estimate that erosion displaces about 0.5 Gt of soil C a year, of which about a fifth enters the atmospheric CO_2 pool (Lal and Bruce, 1999). It calls for measures such as terracing and shelterbelts (IPCC, 2000: 4.4.2.3; fact sheet 4.4).[14] In fact, Lal (2003a) has since suggested that the amount of soil displaced is far greater, and that the total emitted as CO_2 could be as high as 0.8-1.2 PgC/yr. In that case, soil erosion emits the equivalent of about a third of the annual increase in CO_2, making erosion control an even more important strategy than the IPCC suggests.

Lal and Bruce (1999) estimate the potential gains for strategies that fit broadly under the IPCC umbrella. Intensification is omitted from this, but no-one really knows how much carbon could be sequestered in this way, or how much might be kept in the ground by preventing extensification; as discussed above, this might be significant. Also omitted from the table is rehabilitation of degraded land. The IPCC does not discuss this, but restoration could greatly increase biomass. It will not always be practical, but Lal and Bruce (1999) point out that huge areas of cropland, especially irrigated areas, are salinized; restoration of some of this might be economic. Lal (2003b) also advocates this.

Rangeland and carbon

However, rangeland may have even greater potential, and much of it would be in dry areas.

Definitions of rangeland vary. The most relevant areas are grasslands, and the semi-desert steppe that covers vast areas of West and Central Asia and North Africa, described by Gintzburger (1996) as being the domain of the pastoralists, lying between about the 150-250mm isohyets. Indeed Rango et al. (2002) argue: "For practical purposes, most of the arid and semi-arid land is rangeland which means that well over 50 percent of the world's rangeland is also arid or semi-arid."

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[12] But this figure should be compared with Lal's later (2003) estimates of CO_2 lost through erosion.
[13] This estimate does include the use of degraded soils for biofuels production.
[14] Lal (2003) suggests that 4-6 Pg C is being translocated by erosion every year, but argues that much is redistributed, ends up in depressions or becomes sequestered in aquatic ecosystems. The amount that *is* mineralized is controversial, with estimates varying between 20 and 70 per cent (Jacinthe and Lal, 2001); Lal inclines towards the lower figure and thinks the total is perhaps 0.8-1.2 Pg C a year (Lal, 2003). But that is still enough to offset much of the net annual increase in the atmospheric C pool, which is about 3.3 Pg C a year. There are other uncertainties; for example, there is no agreement on the percentage of C oxidized from sediment that is transported to marine/coastal ecosystems (ibid.). And as discussed in section 1, the real extent of erosion is not clear.

The economic significance of rangelands for livestock production cannot be overstated. Rangelands in general support about half the world's livestock (Allen-Diaz et al., 1996). Pastoralism is more environmentally sustainable than industrial meat production. Beef cattle farming in Australia and the United States uses about 25-50 times more energy for each kilo of protein it produces than herders in the Sahel (de Haan, 1997). Moreover, whereas industrial farming generates waste products that must be disposed of, the manure and crop residues from grazing are cycled within the system (ibid.).

Well-managed grazing will increase, not decrease, biomass and will not lead to desertification or depletion of soil carbon. More damage is done by attempting to use the land for grain production; it has been argued that in Africa, moving from grazing to cropping drives soil losses up from 5 t/ha a year to 10-40 t/ha (op. cit.). Allen-Diaz et al. (1996) quotes studies suggesting that up to half of soil C can be lost after converting native rangeland to crops. The worst dangers arise when cereal cropping is attempted on steppe where the rainfall is really too low. Gintzburger (1996) reports that in 1988, a wet year, farmers in Iraq, Jordan and Syria obtained excellent harvests from areas with a normal annual rainfall of below 200 mm. But the next few years were dry; cereal cropping on the steppe was abandoned, but the biodiversity required for the native steppe vegetation to regenerate had gone, while stubble grazing had exposed the topsoil to wind erosion.

Encroachment of crops on rangeland can also bring about conflict between settled communities and pastoralists. Since 1961, the area farmed in Chad, Burkina Faso, Mali and Niger has increased by over 4 million hectares (FAO database). This expansion has involved mainly the conversion of rangelands into cropland, with farmers overriding and ignoring the traditional use rights of other groups to these resources (Williams, 1998). Cropland expansion has resulted in a reduction of natural rangeland and seasonal inaccessibility to remaining pastures due to fragmentation caused by cropping low-lying areas previously used for dry season grazing. The net effect has been a restriction in the mobility of pastoralists' herds and the concentration of increasing numbers of livestock on smaller areas, which destroys pasture vegetation and contributes to range degradation. The loss of rangeland through alienation and encroachment of farming has heightened conflicts between farmers and pastoralists. This is sometimes cited in the media as a cause of the current conflict in Darfur, but less lethal conflicts have also been described by Mortimore (2001) in northern Nigeria.

Elsewhere, however, pastoralism may coexist as well as compete with settled farming, or may exploit areas which cannot be sustainably farmed (Shanmugaratnam et al., 1992). The exchanges of grain, crop residue and water owned by farmers for the manure produced by pastoralists' livestock have linked crop and livestock production for many years in the Sahel and served to increase land productivity (Williams, 1998). Besides, as Mortimore (2001) explains, there is an argument for increasing integration between crop and livestock systems in areas where they intersect, in that it is part of a Boserupian intensification of land use that becomes inevitable with increasing population. At the same time, at least one GEF-supported project is helping convert land into pasture in an area of Kazakhstan where cereals have proved unsustainable on former rangeland (World Bank, 2003). So while this paper treats rangeland as an agroecological system that is distinct from settled agriculture, there will often be blurred distinctions and interactions that must be factored into project design.

As stated above, rangelands and grasslands are crucial to food production in large areas of the world. Even were that not so, the implications of rangeland degradation for climate change would still make them a key area for any programme concerned with global benefits.

It is as hard to be precise about the potential for rangeland carbon as it is to estimate that for

arable farming. Ni (2002) highlights wide variation in estimates of China's grassland carbon storage, and ascribes them to differences in classification and estimation. But there is general agreement that grassland is a significant sink. Allen-Diaz et al. (1996) state that rangeland contains about 36 percent of the world's soil carbon. Sathaye and Meyers (1995) quote estimates of 417 Pg C, mostly below ground. FAO (2001) suggests a figure of anywhere between 200 and 420 Pg C – again, mostly below ground and stable; it adds that grassland contains about 70 t/ha of soil C, similar to the content of forest soils: "In general, C content of a soil under grassland is higher than under crops. But the majority (close to 70 percent)…is degraded" (ibid.).

There are various prescriptions for rangeland management. Sandford (1983) stresses moisture management, and suggests steps such as shelterbelts to reduce evapotranspiration. He also suggests concentration of run-off so that it can be used more effectively for plant production – in effect, water harvesting. As he points out, the proportion of water lost through run-off decreases with area, so it may be (say) 40% on a small-scale plot but 1% over the whole region; it is all going somewhere. One way of doing this is through ripping – bulldozing a trench across an area of steppe which will collect rainfall and encourage new vegetation .But this could disrupt the run-off of water to areas where it may in fact have been productive already, and the Egyptian authorities moved to control this technique in the 1990s as it could have unpredictable effects in the coastal zone (ICARDA, 1998). Other techniques would include small-scale earthworks to concentrate water in areas where fodder can then be grown, but pastoralists do not out of habit plant pasture and may not adopt such strategies (Critchley et al., 1992). However, they may do so if their freedom of movement is restricted – especially if the technique is already in use by settled farmers in the region. This was the case with the Sudanese *teras* described by Van Dijk et al. (1993).

Sandford (1983) suggests that range improvement in general can be divided into six broad categories:

- Mechanical or physical work (this would presumably include water harvesting);
- Planting or reseeding with selected varieties;
- Burning vegetation;
- Chemical application;
- Altering the pattern of use by livestock of particular areas;
- Regulating numbers.

All of these could in theory sequester carbon, but there is uncertainty as to how much. For example, Conant et al. (2001) state that adding manure can increase biomass and thus sequestration, recording that 13 out of 17 experiments regarding manure and C found significant increases in forage production, and nine increased soil C. However, there was considerable uncertainty as to how much of the soil C simply got there in the manure. Where soil C content did not start to build up significantly until some time after the treatment, it was clear that it was from increased production – that is to say, had been sequestered from the atmosphere. Overall, however, while it was reasonable to conclude that some C was being sequestered where production increased, it was not possible to say how much.

Meanwhile, the alternative of chemical application also has a payoff in terms of increased emissions:

> *For example, Lee and Dodson (1996) modelled the influence of pasture fertilization on soil C. They found that pasture soils sequestered 0.16 Mg C $ha^{-1}yr^{-1}$ with application of 70 kg N $ha^{-1}yr^{-1}$. However, since ~1.4 kg C is emitted per kilogram of nitrogen manufactured, net C sequestration would be reduced to*

> *0.06 Mg C ha^{-1}yr^{-1}. Nitrogen fertilizer applied to grasslands also contributes significantly to N_2O emissions (Oenema et al. 1997). Carbon and nitrogen emission costs associated with improved management must be considered when estimating C sequestration potential of grassland soils with improved management.* (Conant et al., 2001).

Nonetheless, Conant et al. still conclude that grassland management can sequester worthwhile amounts of carbon. Lal (2003), reviewing potential for carbon sequestration in the world's drylands, quotes Ojima et al.'s (1995) estimate that the world's grasslands and drylands have lost 13-24 Pg C due to desertification, and believes that significant quantities can be recovered through sowing of improved species (including legumes and agroforestry), fire management, and grazing and erosion control.

All of these raise questions, especially concerning grazing controls. Even where they are successful, questions will arise as to who, if anyone, has benefited. These issues will be discussed in the next section, when experience with SLM is reviewed. There is also considerable scientific uncertainty on carbon sequestration, as Conant et al's comments on manure application suggest. However, if FAO (2001) is correct and the world's rangeland contains anything up to 400 Pg C, then it is surely worth confronting these questions.

Global benefits of biodiversity conservation

Biodiversity is a broad term covering all life forms, including fauna; steppe areas, for example, can contain wild animals that may be under pressure from expansion of grazed area due to degradation or other causes. Thus the Italian-funded rehabilitation of the El Talila national park in Syria included not only introduction of fodder shrubs for livestock, but the reintroduction of wild species. Moreover, as discussed above, land degradation can force extensification of agriculture at the expense of marginal areas or forest that may contain plants with medicinal value or even wild relatives of crop species.

The value of these genetic resources is hard to estimate. Wild animals may have significant value to local communities; globally, however, they will have a mainly hedonic value. In theory this is quantifiable. For example, Menkhaus and Lober (1996) costed the Costa Rican cloud forest in terms of what a U.S. tourist would pay for a visit (it was $1,150). But there must be so many variables in such an argument – not least, the income levels of the tourists – that it is hard to see hedonic values being a reliable basis for the establishment of incremental values, although they may help establish local benefits.

Plants have a more direct economic value. Where they have been used for pharmaceutical purposes, there is a clear market, although this can lead to secrecy in the use of these resources (IPGRI, 1996). Genetic resources used for food production also, in theory, have a monetary value. There are now very few regions that could survive without crops originating from elsewhere (table 2). Almost inevitably they will need to improve their crops with genetic material from other continents. Thus, in the 1980s, South Asia faced genetic constraints to lentil productivity. Lentil originated in West Asia, but the variety initially released to overcome these constraints was from Argentina (Erskine and Manners, 1996). Indeed, the greatest concentration of genetic diversity of a crop is sometimes not in its geographical centre of origin (FAO, 1997).

The global value of plant genetic resources for food and agriculture (PGRFA) is, therefore, theoretically huge. Cromwell et al. (2001) quote Primack's (1993) estimation that genetic improvements in United States crops increased the harvest value by $1 billion a year between 1930 and 1980.

Arguably these are local values; farmers can pay, or be compensated for, the increases in productivity that they have received or conferred through their use or donation of genetic resources. In practice, however, these can only really be treated as global benefits. As IPGRI (1996) points out, it is hard to relate benefits to whoever's farm supplied the genetic resource. "Unlike the single active compound in many pharmaceuticals, a new crop line is likely to have a complicated pedigree and to owe its effectiveness to the combination of genes originating from many ancestors," it states (IPGRI, 1996). IPGRI quotes the example of the rice variety IR36, which has 15 landraces and one wild species in its heritage and took 20 years to breed (ibid.). The development of molecular techniques may permit the use of even greater diversity in crop breeding (Elings et al., 2000).

Table 2 *Percentage of food production in several regions of the world based on crops originating from elsewhere*

Region	Percentage
West Central Asia	31
Indochina	34
Hindustan	49
Latin America	56
Chino-Japan	62
Africa	88
Euro-Siberia	91
Mediterranean	99
Australia	100
North America	100

Source: IPGRI (1996)

Besides, the value of PGRFA would not be so large once shared out:

> *The world market for commercial seed in 1990 was valued at $15 billion of which $1.75 billion accounted for horticultural seed. …If a generous 10 percent or $53 million… were shared among providers; and two highly successful varieties of each of 15 major crops were in the market of each of the world's 10 major seed markets in any year…, this would amount to an average share of $175,000 per successful variety which then would have to be shared by several providers of source material. On the basis of less optimistic projections… the amount available to be shared per successful variety would probably be minuscule and would be absorbed by transaction costs.* (IPGRI, 1996.)

Moreover, the commercial seed market by no means covers all seed transactions; farmers in more traditional agricultural systems are more likely to rely on informal methods of supply and exchange (Cromwell et al., 2001). This makes it even harder to see how the global benefits of crop diversity conservation can be internalized by farmers. The implication of this is that maintenance of crop genetic diversity by farmers cannot really be paid for, and should be regarded as a global benefit. This also applies to rangeland plant biodiversity, although it has huge economic value to range users.

This is all the more true given that conservation of PGRFA *in-situ* adds value. One reason for this is simply that *ex-situ* conservation – that is, retention of samples in gene banks – is expensive. IPGRI (1996) reports 6.1 million samples being maintained at an average annual cost of $50,

making a total of $305 million. It adds that some genetic resources cannot easily be preserved in this way anyway. But the real value is the continuing adaptation of the plant *in-situ* (ibid.), a benefit that is arguably becoming more important because of climatic variability. The value of genetic resources in evolving landraces may also be partly dependent on their interaction with each other; Ceccarelli and Grando (1999) have described how a barley-breeding programme in Syria and Jordan, using local landraces, met with success: "This success is associated with the variability within landrace populations sampled at a given moment in the evolutionary process – a variability that could not be captured in a gene bank." Realizing the global benefits of genetic resources, therefore, demands thinking globally and acting locally.

This section has shown high local and global potential for SLM. This raises the question of why sustainable management is not therefore adopted everywhere. The reasons for this, and the lessons that can be learned from both successful and unsuccessful SLM initiatives, are examined in section 3.

3 Experience with SLM

The previous sections argued that there is serious land degradation, that there are technologies that can address it, and that there are farm-level and global benefits from doing so. This section looks at why these technologies have not been more widely adopted. Most of these reasons are now understood and are listed below. So the objective is not to dwell for too long on past failures, but to look at recent initiatives where those lessons have been incorporated into the project design, and discuss whether this has been successful. This section looks first at the relationship between poverty and environmental degradation, and asks whether the key to SLM lies there.

It is a truism that poverty forces people to degrade their environment. In fact, although poverty cannot be unconnected with land-use patterns, the exact relationship is controversial. On one side, there is the view that growing populations become poorer, forcing them to exploit their environments so that they become poorer still, so that living standards and resources are forced down in a spiral together. On the other hand, it is also argued that these increasing pressures force land-users to innovate; agriculture becomes more intensive and efficient.

The first view is exemplified by Cleaver and Schreiber (1994). Traditional extensive systems, they argue, have given way under increased population pressure:

> *As long as land was abundant, more land could be gradually brought into the farming cycle to accommodate the slowly growing populations… But in most of Sub-Saharan Africa the scope for further expansion of cropland has drastically narrowed. …On average, per capita arable land actually cultivated declined from 0.5 ha per person in 1965 to slightly less than 0.3 ha/person in 1990. …* [R]*ural people are increasingly compelled to remain on the same parcel of land, yet they continue to use their traditional production techniques. Soil fertility and structure deteriorate rapidly where fallow periods are too short and traditional cultivation methods continue to be used.*

Cleaver and Schreiber see a particularly gendered aspect to this; as fuelwood and water has to be obtained from further away, the labour burden on women has grown; the more so as men either migrate to the cities or spend more of their time on cash crops, forcing women to spend more of theirs on traditional forms of production. This, they argue, has encouraged greater fertility as women need more children to help them in their daily tasks. As the population rises, the demands on the natural-resource base grow.

This Malthusian view has been challenged strongly since Boserup (1965) propounded her view that such pressures actually stimulated innovation and intensification. This more optimistic view was supported by Tiffen et al.'s (1994) study of the Machakos district of Kenya, where a rising population had been accompanied by rising productivity. This example, mentioned above, is discussed further in the following section.

In recent years, however, a perception has emerged that poverty may cause either environmental degradation or sustainable intensification, or, indeed, some third approach such as migration. Which takes place depends on a whole range of factors, from population numbers and density and macroeconomic policy to access to inputs, markets and transport. Some of these factors can be ambiguous in themselves; as Scherr (2000) points out, nearby off-farm job opportunities can lead farmers to neglect on-farm conservation – or can help them finance it; it is not hard to find examples of either. This more considered approach, as exemplified by Scherr (ibid.), informs this

section and the one that follows.[15] However, there will be cases where poverty alleviation is an essential component of SLM, an argument that will be reviewed in the discussion of incremental benefits in section 6.

First, to learn more about farmers' priorities, it is useful to look at their response to external initiatives in SLM.

This has often been negative. For example, Bewket and Sterk (2002) looked at officially-sponsored soil conservation in the East Gojjam zone of Amhara Regional State, Ethiopia. Farmers were aware of the need for soil conservation, yet only 35-40 per cent had participated voluntarily; the remainder said they had been under pressure. In Ethiopia as a whole, about 40 percent of terraces constructed by the World Food Programme were broken a year later (Pretty and Shah, 1997).

In the East Gojjam case, the farmers stated that the bunds demanded by the project simply concentrated water and then broke, causing more erosion than they prevented.[16] Similar patterns have occurred elsewhere. In an area of north-west Rwanda studied by Lewis (1992), farmers were made to construct terracing on very shallow soils and an acidic B-horizon was brought close to the surface at the back of the terrace, where yields were reduced. Farmers compensated by hoeing down soil from the front of the terrace above, so that erosion was exacerbated, not prevented.

Farmers' reasons for non-adoption of soil-conservation technologies

- Technologies demand changes that are alien to the farming system
- No secure access to land
- Labour costs
- Technology may not stop soil loss, or increase yields
- Physical earthworks may not in themselves increase productivity
- Technologies force land out of production
- Farmers aren't convinced that erosion is a key problem
- Resistance to 'top-down' programmes
- Technologies exacerbate other problems – waterlogging, weeds, pests, diseases
- Farmers don't feel they own the technologies
- Increases in risk or debt

Source: Adapted from Hellin and Haigh (2002)

Farmers may also reject measures because they are not economic. This is especially so with terracing. Tropical soils can often tolerate considerable soil loss before it is worth addressing (Hellin and Haigh, 2002). Even where it cannot sustain such losses, the quality of the soil may not justify its conservation. Blaikie (1989) uses the example of a gully appearing in a farmer's field in Lesotho: "It is more cost-effective… to find employment in the South African mines than to expend… scarce resources patching up land of such low productivity."

Experience with water harvesting has been just as complicated. Its roots in farmers' own practices

[15] Interesting case studies on factors affecting land-use may be found in Pender et al. (1999) for Honduras, and Olson et al. (2004) for East Africa.
[16] The technique used was the *fanya juu* bund, which has been widely used in East Africa.

do not mean that it is necessarily appropriate or will be adopted, as Reij (1991) points out in his discussion of water harvesting in Africa: "We should avoid deifying indigenous SWC techniques as they are in many instances no longer sufficiently efficient. A marriage between indigenous and modern techniques may be required to increase technical efficiency (coping with degradation) as well as returns to labour (higher incomes)."

He adds that indigenous techniques may have been developed in a context that has changed. This could be due to the evolution of a local environment, as in the Yatenga case in Burkina Faso, where a decline in rainfall drove agriculture down into valley bottoms that had previously been waterlogged and considered marginal for agriculture. In the meantime, contour bunding with stones became popular in order to rehabilitate land farther up the slopes that had previously been more important (Critchley et al., 1992).[17] But changes in the use of indigenous technology may have deeper roots. Reij (1991) points to the decline in the use of indigenous SWC techniques in Africa brought about by changes in, among other things, population density, as the outward flow of labour makes structures such as the Tunisian earth dams, or *tabias*, harder to maintain.

Moreover with water harvesting, as with soil conservation, the technologies offered to farmers must work. As Critchley et al (1992) point out, water-harvesting structures must be designed, and catchment areas defined, so that they can cope with too *much* water during wetter seasons – if they are not, the results could be similar to those experienced by the Ethiopian farmers interviewed by Bewket and Sterk. Indeed Critchley et al. present a list of reasons for non-adoption of water-harvesting technologies not unlike Hellin and Haigh's list quoted above.

The lessons to be drawn from this seem simple: that SLM strategies must work, and that they should be economic for the farmer. However, these factors may vary not just from region to region, but from farm to farm. Elias and Scoones (1999) surveyed farms in North Omo, Ethiopia, and found the least erosion on middle-income farms. The poorest lacked the means to prevent it; the richest lacked the incentive, as they could replace degraded land with other land or assets. Technology can also be highly site-specific. This is true of reduced tillage; this requires leaving crop residues in the field, but in some environments they may fail to break down (McDonagh et al. 2001). In dry areas, in particular, not tilling may affect nutrient cycling and crop response to fertilizer (Mrabet et al., 2001). And as discussed in the previous section, in arid and semi-arid areas where biomass production is low, there can be a high opportunity cost in retaining crop residues in the field, and this might have off-farm consequences; as Williams (1998) and Nielsen and Zöbisch (2001) point out, dry areas often feature product exchange between on-farm and pastoral activities.

The message to be drawn is therefore more complicated, and suggests that SLM technologies are so site-specific that they cannot be transferred to farmers as such. This might be suggested by the recent USAID-funded SOCSOM project, which reviewed the possibilities for linking climate mitigation to poverty alleviation through sustainable agricultural development in a semi-arid area of Senegal. Expansion into marginal areas has caused loss of soil organic matter, soil carbon and biomass. This is a case where intensification might be an alternative to extensification, but this requires better management of nutrient cycling, manuring and residue management (Tieszen et al., 2004). However, when a cost-benefit analysis of these strategies was carried out, it was found that the profitability of a given practice depended on the resource endowment of the farmer concerned, as did the circumstances that affected whether farmers intensified or extensified. The research suggested that farmers needed to be able to implement dynamic and flexible management, using opportunities as they became available (Tschakert, 2004; Tschakert and Tappan, 2004). The same flexible processes are identified in intensification in the Nigerian Sahel

[17] This example is also discussed by Mazzucato et al. (2001).

by Adams and Mortimore (1997), who point out that besides resource endowment, decisions on intensification are also partly social, involving questions of 'who does what'. This indicates the need for farmers to iteratively develop their own land-use strategies, sequentially adopting and assessing different technologies, rather than being asked to meet a target in relation to a fixed technology. This message is also suggested by the site-specificity of erosion control and tillage regimes.

The need for process- rather than target-based strategies was also highlighted by McDonald and Brown (2000). They reported the results of a workshop which sought to establish why farmers often did not adopt soil and water conservation (SWC) measures beyond the end of a project. A key trend that emerged was the need to start a farmer-led process of innovation in SWC, rather than to meet targets for the adoption for a specific measure: "The best indicator of success may well be the spontaneous adoption and adaptation by the farmer and his or her neighbours, and on-going innovation" (McDonald and Brown, 2000). This is echoed by Hellin and Haigh (2002): "The degree of adaptation may be a better indicator of success than simple adoption of a technology or practice." Such a flexible process is also necessary if indigenous conservation knowledge is to be taken advantage of – an area discussed more fully in the section 4. At least 40 different indigenous SWC systems have been recorded in Africa and the Middle East (Pretty and Shah, 1997; Ellis-Jones and Tengberg, 2000).

This farmer-oriented view is not universal. As Robert Chambers states in the landmark book *Farmer First* (1989):

> *The new behaviours and attitudes… conflict with much normal professionalism and much normal bureaucracy. Normal professional training and values are deeply embedded in the transfer-of-technology (TOT) mode, with scientists deciding research priorities, generating technology and passing it to extension agents to pass to farmers.* (Chambers, 1989.)

Section 4 of this document will look at the ways in which this gap can be bridged, but the remainder of this section will review cases where the 'farmer first' paradigm has prevailed and discuss what lessons may now be learned for future projects.

Farmer-driven technology

Chuma and Murwira (1999) and Hagmann and Chuma (2002) describe the 'Kuturaya' method pioneered in Zimbabwe, in which farmers are encouraged to experiment with different SWC options rather than asked to test or adopt specific recommendations; meanwhile, channels of communication between farmers are provided so that they can share their results with each other. Previous extension inputs were seen as having discouraged experimentation, as they presented a prescribed solution to a problem. The Kuturaya programme, which developed from a conventional conservation tillage project, was based on the premise that "innovation is rather a social process than a technology transfer issue" (Hagmann and Chuma, 2002).

The researchers also identified a difficulty in communication between researchers and farmers; the concept of tonnes per hectare, for example, had not been understood. So farmers were introduced to models that simulated biophysical processes. These included glass boxes with outlets for water; one was filled with soil that had a good structure, the other with soil that was eroded. Farmers were able to see at once why the first soil had better moisture retention. Other tools, such as rainfall simulation trays, demonstrated how soil could be lost and the way in which this could be affected. This started a process of experimentation. It was found that about half the innovations farmers produced were modified versions of introduced technologies; the remainder were the farmers' own ideas. The ideas were then communicated through competitions and field

days. The model was called the Participatory Extension Approach (PEA), but it seems to have been something more than this. "The major difference," say the authors, "is that we no longer can clearly distinguish between research and extension processes."

Hagmann and Chuma comment that it was not easy to separate the different programme components in terms of their effect, but observed that the tools used to inform farmers about biophysical processes had great impact on the farmers' understanding of the environment and how to manage it – a view that was shared by both farmers and extensionists. More than 20 technologies were reported to have been developed and spread. In some communities, some technologies were adopted by 80 percent of households. Resource management was said to have improved substantially, with re-emergence of springs in some cases. Hagmann and Chuma also report major increases in productivity between 1991 and 1995, in particular on the poorest farms. The best showed rather less improvement, presumably because they started from a higher base; but they were said to have improved risk management. Scaling-up of the approach within the extension service has been "a highly complex and challenging process", but over 400 extension agents in Zimbabwe have now been trained in PEA and it has also been adopted in the Northern Province of South Africa.

This is a participatory approach in a full sense, in that farmers were helped to develop the technology rather than simply being asked to adopt it. A similar approach was followed in the Middle East in an ICARDA-led project in the olive groves near Afrin in Northern Syria. Olive cultivation in the area goes back over 5,000 years, but underwent mechanization in the 1970s; the use of tractors meant that ploughing was now downhill for safety reasons, and this reduced soil depth from 1m to 25cm in places (Masri et al., 2005). Farmers were aware of erosion and of unstable and declining yields, but felt that the investment needed to reverse the process was too great (ibid.). The researchers therefore realized that technologies were needed that would enhance productivity and income (ibid.; Zöbisch et al., 1996).

The approach taken was to devise packages of technology with farmers on the basis of their own priorities, rather than the researchers'. One of the first concerns raised was frost damage to olive trees after pruning. The project therefore started by taking a group of farmers to groves in another part of Northern Syria where this had been avoided this by pruning later. Representatives from ICARDA and from Syria's Olive Bureau were on hand to provide technical backstopping, but were careful to let the two groups of farmers lead the discussion. After this meeting, the Afrin farmers confirmed that they would like to cooperate with the project (Zöbisch et al., 1996).

The next step was to choose the technologies, still with the emphasis on immediate increases in productivity as much as on soil conservation. Both agronomic and mechanical techniques were used, including vetch intercropping, reduced tillage with animal traction, incorporation of organic matter, fertilizer application and the construction of small earth bunds. In 2000, those plots where agronomic treatments only had been used showed production increases of 60-80 percent over farmers' practices, rising to 80-95 percent where terracing was used. In 2002 the yields fell back a little but remained higher than farmers' practices, and the fruits were larger and matured earlier. Vetch intercropping has since expanded in the village. Masri et al. (2005) conclude that: "The introduced land-husbandry practices have proven to be suitable to reduce soil erosion and increase olive productivity in the region. …The continuous interaction with the farmers ensured that the husbandry practices – which were jointly identified – were suited to the farmers' circumstances and their priorities. In particular, the increase in vetch intercropping in the village can be cited as a success criterion."

Rangeland issues: Restriction, free-for-all or community control?

Historically, outside planners dealing with large-scale rangeland environments have tended to

impose controls on herd numbers and movements in order to prevent rangeland degradation. This was intended to replace what appeared to be free access to scarce grazing. It is not hard to follow the logic of this response, best expressed in Hardin's tragedy of the commons article in *Science* (1968), in which it is argued that rational self-interest will force individuals to overexploit a resource before someone else does.

In recent years this model has been subject to serious criticism – for example by Sandford (1983), who protests that this is a deductive model rather than one based on field study, and that degradation can be just as grave where there is private ownership of land. Moreover, argues Sandford, there is an alternative form of rational self-interest, and that is for individual groups to come together in agreements that will preserve the resource for all. Historically, this is what pastoralists have done, but this has not been obvious to outsiders, and this has led to the imposition of external controls that fail because they do not recognize the realities on the ground; yet at the same time they may displace traditional arrangements that probably did work after a fashion:

> *Even where such a project does not conflict with the local institutions it has ignored (and of course it might), such ignorance is still unfortunate. Traditional forms of grazing organization and regulation may not be perfect, but if they exist at all then it is far easier, and more efficient, to adopt and build upon them than it is to establish totally new ones; evidence for this abounds.* (Rae and Arab, 1996.)

These misunderstandings, and their consequences, are compounded by the biophysical nature of range and steppe environments. Despite the very large areas involved, rangelands and steppe must be treated as a totality in terms of both physical and human geography. Remote sensing and GIS have made this more feasible, but have also revealed the spatial scale of interlocking biophysical phenomena. Campbell and Stafford-Smith (2000), in their discussion of climate change and its implications for range management, explain that in such sensitive systems, "small changes in external conditions take the system over a threshold. Such systems are naturally subject to change. …Humid semi-arid margins of China and the Sahel are located where…different facets of sensitivity coincide, and it is therefore predicted that these are likely to be particularly sensitive regions."

But pastoralists need more, not less, freedom in such non-equilibrial environments. Rangeland response to grazing and rainfall has normally been predicted on a successional model (Sathaye and Meyers, 1995). But on a large steppe, a variation by a kilometre or so in the location of scarce rainfall can completely alter the location and extent of available grazing.[18] Modern thinking on range ecology recognizes that 'tracking' of fodder is a typical management response to this spatial and temporal variability (Behnke, 1994; Scoones, 1999; Bruce and Mearns, 2002).[19]

Historically, pastoralists have functioned in this way, leading observers to assume that they are seeing a 'tragedy of the commons' – implying an urgent need to impose controls (Rae et al, 2001). This runs counter to the real needs of pastoralists. That does not imply a system with *no* constraints, but there is a need for interventions to recognize indigenous networks of grazing rights even if their existence and efficacy are not immediately obvious. In recent years, project

[18] Wilfred Thesiger recalled how, in his crossing of the Empty Quarter by camel, he and his companions scanned the horizon for clouds as they were a sign that there might be a little grazing in that direction, however sparse.

[19] This approach is not without its critics. Pratt, Le Gall and de Haan (1997) argue that the opportunistic management implied by this approach is not appropriate for every ecological zone, especially desert or semi-desert; they also see dangers in distinguishing too neatly between equilibrial and disequilibrial environments. For areas where pastoralists come into contact with settled farmers (such as the *badia* in Syria), it is also worth bearing in mind Mortimore's (2001) argument that the future lies in more crop and livestock integration.

planning has been better adapted to these realities. An example of the benefits may be seen in a successful GEF-supported project in Sudan, *Community-based rangeland rehabilitation for carbon sequestration and biodiversity*. This five-year UNDP-implemented project was approved in 1994.

Rangelands are a critical resource for Sudan, which has a livestock unit to every two people (UNDP, 1994). The project was implemented in Gireigikh in North Kordofan, Sudan, an area of about 250mm annual rainfall. There was serious damage due to overgrazing, but 80 percent of the animal population had died in a drought in 1989, so the most immediate danger came from drought, fuelwood gathering – and cultivation (UNDP, 1994). The latter is a frequent problem in steppe areas which are marginal for this purpose; crops often fail, leaving the land surface vulnerable to wind erosion and denuded of native grazing species. In this case, cultivation produced a crop only two years out of five (UNDP, 1994). The population is divided between pastoralists and agropastoralists, with substantial socioeconomic interaction between the two; other pastoralists use the area as a corridor for transhumance. The project's objectives were: to increase soil cover and carbon sequestration; to increase plant and, eventually, animal biodiversity; and to ensure sustainable resource use (ibid.). It was acknowledged from the beginning that the usual forms of rangeland management did not work, and that it would be necessary to work with local people on resource management, while "relying on and upgrading traditional systems of rangeland use and control" (ibid.).

This was done by forming implementation committees, with further committees at village level, overseen by an overall coordination committee with representatives from the pastoralists. From the village committees and pastoralists, 18 people (seven of which were women) were selected for training so that they could carry out extension activities and mobilize community support. The project had an early lesson in the importance of such support. The 2001 project review describes how, during the first two years of the project – during which the project was not very well-managed – dune stabilization activities were initiated near two villages, but these were perceived as a mechanism that would later allow the project to claim ownership of the land. These activities therefore had to be halted, but were later implemented successfully in another part of the project area following wider consultation with the local community (Dougherty et al., 2001).

At the end of implementation, the project was able to report some 700 hectares of improved and sustainably-managed rangeland, against the 100 originally planned for; moreover households set aside about 500 hectares of private cultivated land for conversion to rangeland. These extra outcomes were the result of private initiatives. There was also unexpected success in the 90 percent uptake of fuel-efficient stoves to reduce fuelwood use. The review report commented that:

> *Livestock herders have learned how to determine the carrying capacity of their rangelands and this has begun to have an impact on stocking rates. The ultimate outcome of these measures is the reduction of grazing pressure on rangelands, thereby helping to restore plant cover to protect erosion-prone soil and enhance carbon sequestration. Moreover, the understanding of the community to shift from cultivation to grazing in such fragile environment is a major step towards reversing land degradation trends.* (Dougherty et al., 2001.)

The review team found that, a year after the cessation of the project, the village committees remained active – as did, on a voluntary basis, 14 of the 18 who had received training. It was also noted that the effects of the project had spread to communities not involved. In its final discussion, the review team thought that community participation had been especially successful when focused on cohesive, homogenous social units: "The more nuclear the group," it stated, "the

more effective the results."

Bruce and Mearns (2002) discuss the West Africa Pilot Pastoral Program (WAPPP), a World Bank-supported project that began in 1994 and sought to embody the lessons of earlier work in the region. These were seen as having failed to involve pastoralists sufficiently in project design and implementation, but also to have laid too much emphasis on fixed stocking rates. Begun in Chad, the WAPPP later worked in areas in Mauritania, Mali, Burkina Faso, Senegal and Niger. It built on the concept of 'holistic resource management' (HRM), resolving pastoral conflicts in ways that were acceptable to all stakeholders, and then scaling-up the strategies used for this.

Key features in recent thinking on rangeland management were embodied in WAPPP's implementation. The methodology was to build on local knowledge rather than control or technical inputs, and local communities retained responsibility for determining access to resources – avoiding the displacement of customary controls by less effective external initiatives that might not have survived the project. WAPPP applied this principle to conflict resolution, forestalling conflict by strengthening customary mechanisms for its avoidance or solution. Together with this went a policy of encouraging herd mobility; as Bruce and Mearns point out, herders will accept those from another area on the basis of reciprocal access. All of this was linked to sustainable management, with resource users agreeing to manage resources according to agreed goals.

Bruce and Mearns also quote the example of the Burkina Sahel Programme (PSB), a GTZ-supported initiative to resolve conflicts between herders and settled farmers in Oudalan province of Burkina Faso. The conflicts recall those in Nigeria cited by Mortimore (2001) in Nigeria – for example, the denial to pastoralists of crop residues by hoisting them into trees (ibid.). The PSB worked with local and transhumant groups to draw up agreed protocols for the use of (for example) salts licks and water-pumps:

> *The PSB offers an example of good practice in an externally facilitated approach to pastoral and agro-pastoral land tenure and resource access that tries to deal with social diversity and complexity, typical of the Sahel, through establishing platforms for negotiation and consultation. Future challenges lie in strengthening the fragile cohesion between different groups and in legally ratifying the consultative committee and management rules it has devised.* (Bruce and Mearns, 2002.)

The project had not, initially, been successful; although participatory in approach, it had not reflected the views of the transhumant pastoralists or the different conflict between groups. It had therefore been put on hold for a year while these areas were reviewed and the emphasis switched from territorial units to social groups. In the Sudan case, too, flexibility of project implementation had been an important factor, allowing it to attune itself to local needs and priorities (Dougherty et al., 2001). This was also a key strength of the ICARDA-led work in the Syrian olive groves: it began by addressing farmers' priorities, not its own, and adapted itself as it went along.

This has now been made a cornerstone of an initiative by another CGIAR centre, the Centro Internacional de Agricultura Tropical (CIAT). It is implementing a six-year programme that will target resource-poor farmers in sub-Saharan Africa, Central America, Asia and in the degraded pasture lands of South America (CIAT, 2004). CIAT argues that previous attempts to stem land degradation have concentrated on reducing rather than reversing it: "Many interventions have thus had little to offer farmers in the way of immediate, tangible benefits," it says. "For many farmers, …proposed options have been seen not only as too costly a step forward, but also too big a leap of faith." The CIAT programme will subject any technology options to a cost-benefit

analysis to determine its probable profitability for farmers and will work with them to select and adapt them at community level. The programme also cites the site-specific nature of solutions to land degradation as a major reason for stakeholder involvement.

Biodiversity and the community

The need to understand farmer priorities has also informed projects that enhance on-farm genetic diversity. Worede et al. (1999) point out that the value of landraces to farmers in a country like Ethiopia is "as a dependable source of planting and breeding material. It is important, therefore, that locally adapted or enhanced seeds are multiplied for distribution to farmers whose production needs have not been adequately met by modern high-input cultivars."

As noted in the previous section, a major constraint to the maintenance of on-farm genetic diversity is seed supply. This has been recognized in recent years. Interventions to address this can include strengthening of seed-exchange networks. Subsistence farmers often obtain seed through informal exchange; McGuire (2000) found that one-third of 250 farmers interviewed in Eastern Ethiopia gave or sold seed to others, with the poorer farmers often being the recipients. Such informal seed distribution has its drawbacks, including the spread of disease and varieties that may not be what they seem. Yet modern seed systems, with their stress on hygiene and approved varietal releases, may constrain the supply of seed of diverse landraces, especially to the poor. As Cromwell and Almekinders (2000) point out, formal seed systems will always face high costs in supplying marginal areas.

However, there are compromise solutions: "Since resource limitations will continue, formal seed supply may increasingly… take advantage of local seed systems for producing and distributing seed"(ibid.). Kugbei and Fikru (1997) have described an initiative of this type taken by the Ethiopian Seed Enterprise (ESE) for *teff*. This has a high level of genetic diversity, and wild relatives have often been used to enhance drought tolerance and disease resistance; this makes it all the more worthwhile to devise a seed system that will not reduce on-farm genetic diversity (ibid.). However, seed of white and red *teff* must not be allowed to cross, as they are used for different purposes; too often, production on state farms allowed this to happen. The ESE therefore started an innovative scheme by which local farmers were contracted to produce certified seed, and this was sufficiently successful for the scheme to be extended to barley.

Another Ethiopian initiative, community seed banks (CSBs), has performed a similar function – in this case, with GEF support. The 12 CSBs have been placed in areas of high potential where local varieties have been displaced in the last 30 years, including those of durum wheat, of which Ethiopia is a centre of diversity (Feyissa, 2002). The CSBs store farmers' varieties both in mother form, and in enhanced form developed jointly by farmers and scientists. They are managed by Crop Conservation Associations, or CCAs, with the help of groups of trained farmers.

The objective of this section has been to review experience with the technologies and strategies with SLM, and to indicate why, in the past, they have not been adopted. It has also considered several projects where these lessons have been incorporated with positive results. The main lessons are that technologies fail when they do not match farmer's priorities and resource endowments; and that such a match will not occur unless the target group helps design the project and develop it as it progresses.

There are also strong lessons to the effect that projects need to respond not just to the needs of the farmers as a group, but to the needs of individuals, who need to experiment with technologies and fit them around their particular farm and resource endowments. The implication is that technologies for SLM cannot be devised and transferred, but must be developed by farmers

themselves, with the outside interventions, researchers or projects backstopping rather than leading their efforts. The project in Zimbabwe described by Hagmann and Chuma (2002) suggests that this can be done. The next section therefore considers farmers' own processes of innovation and how they can best be stimulated.

4 Farmer-driven innovation and adoption

The previous section concluded that the way ahead for SLM was through farmers' own processes of innovation, adaptation and adoption. This section discusses how external intervention can assist those processes, and also looks at the broader factors that may do so. First, a theoretical basis for innovation will be briefly described.

Innovation can rarely be seen in terms of one researcher suddenly crying 'Eureka'. This is especially so in agriculture, in which technologies are adapted and modified far more than they are created. The following definition of innovation, although not meant specifically for agriculture, fits it fairly well:

> *Innovations are new creations of economic significance. They may be brand new, but are more often new combinations of existing elements. Innovations may be of various kinds, e.g. technological as well as organizational. The processes through which technical innovations emerge are extremely complex; they have to do with the emergence and diffusion of different knowledge elements, i.e. with scientific and technological possibilities, as well as the "translation" of these into new products and production processes. This translation by no means follows a "linear" path from basic research to applied research and further to the development and implementation of new processes and new products. Instead, it is characterized by complicated feedback mechanisms and interactive relations involving science, technology, innovation policy and demand.* (Edquist, 1997; quoted by Hall et al., 2001.)

Sunding and Zilberman (2000) divide innovations into 'embodied' and 'disembodied', the first type of innovation being 'embodied' in capital products such as tractors or inputs, and the second being less tangible, e.g. integrated pest management. This distinction only works up to a point, as some innovations that require no visible capital goods may require considerable investment in labour with concomitant opportunity costs. However, it is worth remembering that much SLM is based on management practices that Sunder and Zilberman would call 'disembodied' innovations, and may not always require direct cash investment; so explanations for innovation decisions must be found that are unrelated to direct capital costs. The social networks described by Mazzucato et al. (2001), described later in this section, would fit this description.

Concepts that are also useful for this section are the three major approaches to soil and water conservation: paternalist, populist and neo-liberal (Biot, 1995; quoted by Mazzucato et al., 2001). The first consists of top-down interventions on a large scale and often with large-scale machinery, with little voluntary participation by local people. These approaches should not be dismissed too quickly; heavy earth-moving equipment can have both advantages and disadvantages, as Critchley et al. (1992) explain. Overall, however, as the previous two sections have described, paternalist approaches have not been successful in SLM.

The second approach, populism, stresses small, scale, bottom-up participatory interventions using indigenous technology, while the third, neo-liberalism, looks to institutions and incentives and the interaction of population growth, the environment and the broader economy. The phrase 'neo-liberal' suggests a link to the free-market economics of the 1980s and 1990s, but the notion that individual behaviour – and soil erosion – is linked to a broader economy is to be found right across the political spectrum. This section will look at some of the evidence in favour of populist and neo-liberal approaches without assuming that they are mutually exclusive. It will also reflect Edquist's warning that innovation is a complex, non-linear process.

The farmer as researcher

Farmers have always been innovators; as Saad (2002) points out, this began with the domestication of the first crops. The earliest cultivators used about 1,500 plant varieties and cropped 500 vegetable varieties (Rhoades, 1989). They have also long been aware of the need for efficient resource use. Reij (1991) notes a wide variety of techniques for indigenous soil and water conservation (ISWC) in Africa, including the bench terraces that farmers have been so unwilling to construct under duress. These are widely used in many parts of Africa, as are manuring, irrigation and other elements of SLM. The Dogon people of Mali even "transport soils to bare rock in order to cultivate rice or onions" (ibid.). Indeed Reij argues that the colonial invasions of Africa, by driving farmers onto the poorest land, sometimes forced them to develop ISWC so that that poor land could best be used (ibid.).

There is also evidence from pre-colonial times of high land-use intensity giving rise to highly sophisticated conservation techniques. This remains the case; Mazzucato et al. (2001) point out that farmers in Burkina Faso have maintained labour productivity in terms of yields, despite rising population density, a relative lack of inputs, a 20% decline in annual rainfall and a fall in the area cultivated per agricultural worker. This suggests an ability to innovate for productivity.

But there is often little synthesis between farmers' technology and external interventions. Thus Longtau and Gwaivangmin (1999) describe complex grass and stone terraces on the Biu and Jos plateaux of Northern Nigeria, yet note that very little attention is paid to indigenous technology as part of official conservation efforts. Elsewhere too, officials have become frustrated at the slow adoption of external SLM interventions although farmers are simultaneously carrying out ISWC measures – a situation recorded by Kerr and Sanghi (1992) in India.[20] Mazzucato and Niemeijer (2001), in a discussion of indigenous land management in Burkina Faso, suggest: "A major reason for the overestimation of land degradation has been the underestimation of the abilities of local farmers. There is much more to soil and water conservation and technological intensification than agricultural statistics reveal. Farmers have … developed flexible, efficient, and effective land management strategies to deal with the limited availability of labour and external inputs, as well as the harsh environment in which they work."

Why is the connection rarely made? In part it may simply be that farmers use agronomic SLM techniques that, unlike earthworks, are not immediately obvious to the outsider (Mazzucato et al., 2001). Other reasons are more subtle. Longtau and Gwaivangmin (1999) think that "policy-makers [are] still mesmerised by the potential of high-input agriculture." Rhoades (1989) associates this with the impact of the Green Revolution and a feeling that harvests were rising: technology, it seemed, was a success. It may also be that introduced technologies clash with those emerging from the traditional system. This emerges from Kerr and Sanghi's (1992) analysis of ISWC in four states in India's semi-arid tropics. Not least of these is the design of the technologies themselves. As described in the last chapter, farmers may doubt – sometimes with reason – that they will work. But they can also be unsuitable because they clash with farmers' objectives. Measures designed to preserve the maximum amount of soil will follow contours in a field, but Kerr and Sanghi found that indigenous measures were boundary-based.[21] This allowed straight bunds, and therefore easier farming operations; they also demarcated the field boundaries. Kerr and Sanghi also noted that boundary-based measures reduced the need for cooperation with neighbouring farmers. In any case, as they point out, external initiatives will be designed simply

[20] Kerr and Sanghi say that whereas neglected or degraded land was easy to spot, land that had been conserved by ISWC was often less obvious. This may partially explain why there is a gap in perception between officials and farmers.
[21] Although farmers did use contour-based bunds on irrigated land, where returns on investment in SWC made the loss of some area worthwhile.

to save the most soil, whereas the farmer may prefer to concentrate it somewhere where it can best be used, for short-term productivity. For these and similar reasons, a number of differences were found between recommended and indigenous practices in the villages visited.

If farmers have long developed their own technology, and it is more appropriate than external interventions, is there any point in such interventions? The evidence suggests there is.

Chuma and Murwira (1999) outline several limitations to farmers' processes of innovation; such experiments are, they say, undirected, have a weak analytical base and are subject to unplanned chance variations. "Farmers sometimes do not understand the underlying reasons for a good or poor yield and could attribute the success of a technology to the most obvious difference," they add, but argue that these problems should not be seen as invalidating the concept of farmer experimentation; rather, they present opportunities to improve the process. Reij (1991) also argues that external interventions may be necessary; indigenous techniques may be more appropriate but they may no longer be efficient enough. They are highly location-specific, making them difficult to transfer. They may also have developed in a socioeconomic context that has changed, so that labour availability, returns on investment and opportunity cost no longer support the traditional measures – the *jessours* of southern Tunisia are an example (Aw-Hassan, 1996; Reij, 2001).

Reij therefore argues for a "marriage between indigenous and modern techniques", and quotes the stone lines used by farmers on the Central Plateau in Burkina Faso; these were made more efficient, not by importing a different technology but by teaching farmers to use simple survey equipment to find contour lines. Nzuma et al. (1999) describe research into soil fertility management options in Zimbabwe in which incorporation of indigenous knowledge into technology development was a stated aim. The Kuturaya programme in Zimbabwe, described in the previous section, is also an example.

Such experiences suggest that researchers or projects can indeed enhance farmer processes of experimentation. However, there is also a risk that they could stifle them. Saad (1999) points out that while there is a large literature on indigenous knowledge, there is relatively little on the actual processes by which it is produced. She quotes a number of researchers who have argued that the formal processes of inductive science – the formulation of hypotheses, the design of hypotheses, the collection of data – are absent. It is also argued that farmers do not create the controlled environments seen on research farms (ibid.), but this may be because they are irrelevant; a research centre will aim for crops or technologies that can be applied in many places, but farmers are working in context and need to have all the variables present, rather than eliminate them – which they cannot do anyway. In any case, as Scoones and Thompson (1994) point out, the priorities are different; the researcher is answering a question, but the farmer innovates as a reaction to events: "For the researcher… what counts is replication and comparison. For the farmer, what counts is fitting available resources to changing circumstances well enough to make it through the season." There is therefore a view that farmers' and external innovation processes may work against each other rather than together.

This view is not universal. Sumberg and Okali (1997) found no evidence for it in a study of farmer experiments in Ghana, Kenya and Zimbabwe. In fact, they discovered that some farmers did use semi-formal methods of experimentation, such as using a control. But they do warn against attempting to make farmers adopt features of formal research, such as fixed plot sizes, that increase cost and risk. Besides, as Sumberg et al. (2002) argue, it is the difference between formal and informal methods of experimentation and innovation that may produce synergy between the two, not their similarities.

A further constraint to linkages between formal and informal research is the sequential and fragmentary way in which farmers test, adopt and adapt new practices and germplasm, mixing the old with the new. Rhoades (1989) discusses examples of such processes with modified crop varieties and storage of potato seeds in diffused light – the latter being a well-known case. The practice had been developed by farmers in Kenya and elsewhere, and was seen and disseminated to other farmers by the Centro Internacional de Papa (CIP). This was widely accepted, but not in the manner expected:

> *When* [Robert] *Booth and I conducted a follow-up in several countries, we were surprised that adoption had not proceeded as expected. Out of some 4,000 cases, at least 98 percent of the farmers had not 'adopted' the technology as it was presented in extension efforts, but had 'adapted' the idea to their own farming conditions, household architecture and pocket books. Farmers do not think in terms of adoption or non-adoption as we do, but select elements from technological complexes to suit their constantly changing circumstances. The dichotomous terms of adoption, non-adoption, traditional-modern, native-improved, are irrelevant and misleading from the farmers' point of view.* (Rhoades, 1989.)

In any case, farmers cannot simply 'adopt' because they are constantly adapting to changing conditions. In fact most farmers experiment to a greater or lesser extent (Sumberg and Okali, 1997; Sumberg et al., 2002). They have no choice; as Bunch (1989) points out, markets and input prices change, rendering technologies obsolete, while insect pests develop resistance. As Dumanski et al. (1998) put it: "Static agricultural systems are not sustainable systems."

This would seem to confirm the conclusions of McDonald and Brown (2000) and Hellin and Haigh (2002), reported in the last section – that the best form of adoption is sequential and selective adaptation. If so, the best strategy for any external intervention is to find out what farmers are trying to do, give them germplasm or elements of technologies that might help, and ask them to adapt them and bring their conclusions back. This was made possible in the case described by Hagmann and Chuma (2002) in Zimbabwe. It has also been the basis for adaptive research by ICARDA in the Middle East, both in crop breeding and natural-resource management. In the former case, farmer participation in barley breeding has been successful because farmers helped identify the breeding material for the programme, and then tried it out on their own farms (Ceccarelli and Grando, 1999). In the latter, a basket of technologies was made available to olive farmers in northern Syria, and the research proceeded on the basis of the farmers' own priorities (see previous section).

This accords with Sumberg and Okali's (1997) view that "The need is not to improve the methods that farmers use to experiment, but to increase the supply of "raw material" (i.e., seed of new crop varieties, ideas, etc.) that they can incorporate into their ongoing experimental activities. One important source of that raw material is the formal research system. … Seen in this way, development-driven farmer participatory research is first and foremost a particular model of agricultural extension." True, outputs from these processes may not be of use to anyone more than a few kilometers away. As has been discussed, farmers' needs are highly site-specific. However, if Sumberg and Okali are correct, this misses the point: "High-quality agricultural extension should be defined in terms of its success in fuelling farmers' own search for site- and situation-specific solutions and opportunities."

That does not mean that farmer-led technologies can never reach a wider audience. However, such scaling-up would be constrained by the gap between scientific and farmer-led innovation described earlier on. Maurya (1989) uses the example of the seed-drill in England. In the late 18th century it was regarded as too complex and unreliable, and yet the far better and much older four-

row seed drill used in South India was unknown until an example was brought to England by a Captain Halcott in about 1795. But despite the superiority of the Indian design, this technology had not spread as quickly in Asia as it did in Europe. The reason, states Maurya, "may well be the lack of a link with science – or at least the lack of interaction between farmers and those who wrote books about botany or agriculture. Indeed, the ground rules for classifying peasant knowledge and linking it with scientific method still need to be developed." In recent years there have been attempts to bridge this gap – for example, through the World Overview of Conservation Approaches and Technologies (WOCAT). The CGIAR, long associated with more upstream research, may also be a positive influence in this respect. Rhoades (1989) quotes the findings of Goodell (1982) that 90 percent of the technologies being promoted by the International Rice Research Institute (IRRI) had originated with Asian farmers, and had been brought to IRRI by visiting researchers.

A further constraint to scaling-up may be farmers' unwillingness to share the results of their experiments. Thus, whereas farmers in northern Ghana have been found to work as a group, avoiding duplication and sharing their results (Patiño, 1990, Millar, 1993, Pottier, 1994; quoted Saad, 1999), those in Rwanda and Colombia guard their knowledge carefully. According to Scoones and Thompson (1994), the reasons for this may lie in the power relations within the community, and between the farmer, the extensionist and the researcher. They warn that all aspects of rural knowledge and its linkages to more formal systems need to be seen in this context.

Even where the results of innovations are not secret, farmers may be reluctant to implement them cooperatively, as the benefits of any such cooperation will be unequal (Kerr and Sanghi, 1992)[22]. Formal interventions by researchers will clearly have lower returns if the results are not disseminated to wider groups of stakeholders.

But perhaps this need not happen through traditional extension mechanisms alone. Hagmann and Chuma (2002) stress the importance of community development and knowledge-sharing in the PEA programme in Zimbabwe. ICARDA has organized study tours for farmers from Egypt, Jordan and elsewhere to meet farmers who have implemented its ley-farming and rangeland rehabilitation technologies in Syria (Ramadan, 1997; Bahhady et al., 1997).

The importance of knowledge-sharing is taken further by Mazzucato et al. (2001), in their description of the way in which social networks not only spread sophisticated knowledge of SLM techniques, but also assist the farmer to implement them:

> *Farmers have a large repertoire of soil and water conserving technologies. However, it is not enough to know about them; one also needs to have the resources, such as labour, to be able to implement these technologies. For example, manure application requires both manure and labour; fallowing requires land to move to; and weeding requires labour*. (Ibid.)

The authors describe how neighbouring farmers 'trade' fallow with each other so that fields can be fallowed far more efficiently. They also make the point that such social networks extend beyond the village, so that such 'trades', as well as technology transfer, can take place across a wide area. This is, they say, a strong argument for interventions that are based around social rather than geographical boundaries, although the latter ('*Gestion de Terroirs*') approach has hitherto been used in Burkina Faso.

[22] Although they suggest that farmers in Africa have a greater tendency to cooperate.

Linking project interventions, or formal agricultural research, with farmers' own activities can stimulate processes of adaptation and innovation, but there are limits to the process. Two key points emerge from the discussion above: first, that the site-specificity of farmer-led innovations means that the best role for outside interventions is to supply farmers with the raw materials (seeds, suggestions on row spacing or planting date, etc.), and then accept that the impacts will be mainly local. Second, where there are outputs with broader applicability, scaling-up will depend in part on facilitating flows of information between farmers, and exploiting social networks that already exist. But it will also depend on the inclination of project managers and researchers to disseminate information more widely. In the latter case, the CGIAR may already be playing a role to some extent.

The broader context

Project and research linkages may not be the only, or best, way to stimulate innovation and adoption. Biot et al. (1995) suggest that the difficulties of implementing such participatory approaches has led some researchers to reject what they call the 'populist approach' – broadly, faith in farmers and lack of faith in authority and traditional power structures – in favour of a broader approach, in which farmer innovation is driven by the economic and policy environment. In this approach (the 'neo-liberal'), it is held that: "Suitable technologies presently exist or can readily come into existence; the problem is to understand the present structure of incentives that prevents land users from adopting them, and to design incentives that will induce adoption" (ibid.). This view is echoed by Campbell et al. (2002), who carried out a survey of rural livelihoods in semi-arid areas of Zimbabwe; they regard incentives, in the form of an enabling policy environment, as being of paramount importance.

Direct incentives do not have a good history in soil and water conservation. However, what is meant here is a broader structure of incentives embedded within the economy and in policies – a definition closer to that accepted by the CBD.[23] This reflects the Boserupian view that market access defines farming systems, and suggests that the wider policy and market environment is crucial to the extent to which farmers will innovate. This accords with Blaikie's argument that soil erosion is essentially determined by a wider environment, and that while that may not rule out local action, one must follow a 'chain of explanation' up from the degraded field to find the ultimate cause (Blaikie, 1985, 1989, 1999). After all, as Blaikie (1989) puts it: "There is virtually no land which produces economically useful products… which cannot be managed to maintain yields indefinitely. Even for the least resilient ecosystems, there are techniques of land management providing protection from degradation."

The implication is that if farmers have not developed such techniques, either there is a constraint to their doing so, or it must be made profitable by improving their access to markets and thus farm-gate prices. However, higher farm-gate prices might increase the viability of more erosive crops as well as less erosive ones (Barbier and Burgess, 1992). The effect of such prices also depends on whether they increase the short-term profitability of the farm; as Shiferaw and Holden (2001) have pointed out, poorer farmers cannot always take the long view. This need not prevent innovation for sustainability. Laing and Ashby (1993) describe how farmers in Honduras quickly adopted an innovation brought by Guatemalan and Mexican immigrants – replacement of the normal maize cycle with a single yearly planting intercropped with mucuna beans, a practice that had considerable soil-fertility benefits. It increased long-term sustainability, but it was not adopted for that reason; it was adopted because it increased short-term profitability.

Kerr and Sanghi (1992) point out that soil conservation activities are simply one more factor that a farmer has to consider along with other investment options. They also highlight the importance

[23] Biot et al. classify this strand of thought as a neo-liberal policy.

of off-farm employment as a disincentive to invest in the land: "Investment in soil conservation on dryland appears to be lower near large towns and cities than in more remote areas, because employment in the towns gives higher returns than working on soil conservation. Seasonal migrants have a high opportunity cost of time in the slack season, when most farmers do soil conservation work," they explain.[24] And, as discussed above, Elias and Scoones (1999) found that the extent to which erosion was permitted in Ethiopia depended on whether the farmer could afford to let the land degrade. If farmers are to innovate for SLM, it has to be worth their while. Their chief concern will be income, and if land degradation threatens this, they will make the necessary investments if they have the means. It may be that the best way to encourage farmer processes of adoption and innovation is to increase the profitability of agriculture.

Pandey (2001) describes how road construction in Thailand improved market access and helped farmers fund soil-conservation measures. He also records that ending regional self-sufficiency in Vietnam allowed farmers to switch food production to more suitable land, discouraging shifting cultivation that had caused degradation of fragile uplands. Barbier (2000) analyses the often-quoted example of the Machakos district in Kenya; as discussed briefly in the previous section, this semiarid area was regarded as seriously degraded in the 1930s – indeed, up to the 1970s; but by the 1990s, it supported a population five times as large as it had 60 years earlier, with agricultural production that was three times greater per capita. Barbier ascribes this to innovation, including improved land-management techniques such as terracing and use of animal manure. Indeed, more than 200,000 ha had been terraced at a cost of over $50 million at 1990 prices. A number of positive factors assisted this process, including the fact that farmers were able to experiment with and adopt various practices at their own pace, leading to a high degree of compatibility with existing farming systems. The investments were funded by farmers themselves, partly using the proceeds of off-farm labour – a case where the latter is a positive factor. But sale of commercial crops also helped, as did good road links with the major market of nearby Nairobi.

"Increased market-orientation of agriculture in the region and higher farming incomes raised the returns and value to the land, which in turn facilitated the adoption of new agricultural and land management practices that encouraged more intensive and sustainable land uses," states Barbier, adding that "policy approaches that promote improvements in the general economic and market conditions faced by poor farmers on existing agricultural land could be much more cost-effective and have wider impacts than more conventional land management programmes that focus on encouraging farmers to adopt a limited set of prescribed crops, farming systems and soil conservation measures."

This accords with two of the authors of the original Machakos study, who have recently written that "while donors have been debating public investment options, this research has shown that dryland communities – including poor people – have all along been willing and (to an unexpected extent) able to sustain small-scale private investments in natural resource-based livelihoods" (Mortimore and Tiffen, 2003). A similar view has been expressed by Reij and Steeds (2003) in a paper prepared for the Global Mechanism of the UNCCD. Conversely, lack of market access can have negative effects; Robbins (2004) has argued that the high level of subsidies for olive oil in the European Union may not only have caused soil erosion in southern Europe through over-intensive production, but may also have indirectly caused it in North Africa, where lack of market access may have contributed to outmigration and thus to lack of maintenance of the traditional

[24] Although, as discussed above, off-farm work can also finance innovation in SLM (Scherr, 2000). This was the case in Machakos, discussed below. Mortimore and Tiffen (2003) found evidence in four African countries that non-farm income was funding private investment in dryland agriculture, as well as providing a market. They therefore challenge what they call the "long-term antipathy to rural-urban migration".

system of soil and water conservation. Blaikie (1985) also notes that deterioration of soil-conservation structures has followed outmigration in some areas.

It would be easy to conclude from this that the removal of agricultural subsidies in developed countries, and improved market access and infrastructure elsewhere, would lead to farmer-led innovation in SLM. However, there are often other factors. In southern Tunisia, for example, outmigration may also have been encouraged by subsidies for mechanized farming elsewhere (Reij, 1991), and technologically inappropriate interventions have not helped (ibid.) In Machakos, there has also been considerable extensification onto land formerly unusable because of tsetse-fly (Barbier, 2000). Besides, the effect of market access on land management can be ambiguous. Barbier reports that the effect of structural and market reforms on Africa has not yet been thoroughly analysed, and quotes López's (1997) study of western Ghana, which suggested that market liberalization, and improved farm-gate prices, had led to a combination of extensification and shorter fallow periods, reducing biomass and reducing long-term productivity. So although better market access can drive farmer-led innovation and adoption, it is unwise to conclude that this *always* leads to more sustainable management. There are many other factors interacting with farm-gate prices, including the cost of inputs (Barbier and Burgess, 1992) – and land tenure.

It is widely held that insecure land tenure is a constraint to innovation (Reij, 2001). This is not automatic; tenure is sometimes conferred on the basis of investment, thus encouraging adoption and innovation (Neef and Sangkapitux, 2001). But insecure tenure is generally a negative, as Ståhl (1993) found in Ethiopia, Kenya, Tanzania and Uganda. Tschakert (2001) reports that the system in Senegal, where usufruct rights can be withdrawn after two years, prevents farmers from adopting effective fertilization and fallowing practices.[25] However, although market access is balanced by many other factors, it can clearly have a positive effect.

But it can only do so if the technologies are there to be adopted. The 'neo-liberal' approach, if that is what it is, should not be taken so far as to expect that these technologies will emerge by magic through the market. Farmer-driven technology development is still needed. It is also important that there be channels through which farmers can express their demand for such technologies. This point is raised by Sumberg (2005) in his discussion of the challenges facing agricultural research in Africa:

> *For all intents and purposes the demand-side of the innovation system is absent. The complexities of small-scale farming and rural livelihoods, and the resulting high level of fragmentation in the demand for innovations, as well as the often deferential attitude of the rural population toward agents of the state mitigate against such an articulation. This problem has been recognised and there have been a number of attempts to give voice to farmers' demands for innovation, including farmers' advisory groups, farmer representation in research planning meetings and input into funding decisions.*

In the previous section, it was suggested that attempts to transfer SLM technologies had often failed due to inappropriate technology and misunderstanding of farmers' real priorities; and that the best way to avoid this was to facilitate farmers' own processes of innovation and adoption.

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[25] This does induce a form of perverse innovation. "People have become more suspicious, but also more innovative," records Tschakert. "We have encountered farmers who fake cultivation, by sowing only 1/10 of their plot, and pretending a state of stubbornness close to mental illness – with which administrative officials usually don't want to deal – simply to let their land lie fallow."

As has been seen, there are two basic ways in which this can be done: through linking formal agricultural research and farmer-led innovation (populism); and improving market access so that innovation becomes more profitable (neo-liberalism). Both paths have pitfalls, but as the PEA programme in Zimbabwe and the example of Machakos indicate, they also have great potential.

They should not be seen as mutually exclusive.

5 Lessons for future initiatives

This section will provide a summary of the evidence presented so far and suggest lessons for future project planning.

First, dryland degradation is real and pressing. However, its extent and impacts are often uncertain. Moreover, it affects mainly the land users themselves; the world as a whole can absorb the damage in terms of food output, and therefore has no incentive to do anything about it. At the same time, the land users have no incentive or means to prevent wider impacts of land degradation such as off-farm siltation and carbon emission. The two groups must acknowledge their responsibility to each other. There is now a lively debate about the extent to which externalities such as carbon emissions should be internalized by farmers, and how it should be done (for example, through emissions-trading markets, or the Clean Development Mechanism). This paper has not attempted to review that debate, but those who care about land degradation should now engage with it.

Second, sustainable land management (SLM) does have concrete benefits for land users. There are better returns from investment in dry areas than most policymakers realize. This point is made forcefully by Fan and Hazell (2000a, 2000b), Mortimore and Tiffen (2003), and by Reij and Steeds (2003) in their paper for the Global Mechanism of the UNCCD, which quotes rates of return of 20-40 percent for large- and small-scale irrigation and soil and water conservation projects in Niger, Nigeria and Ethiopia. Reij and Steeds do conclude there is little firm data of this sort for most projects. There is also evidence that even where SLM is profitable on paper, the long timescales are impracticable for resource-poor farmers. But there are very concrete global benefits from reversing land degradation, mainly carbon sequestration and crop genetic diversity. These points have implications for incremental funding, which will be discussed in section 6.

Third, this paper has looked at why SLM technologies have often not been adopted. There is abundant evidence that they either did not work, or were uneconomic. But this is well-known. What this paper has stressed is that SLM technologies tend to be very site-specific and, even more important, *farmer*-specific. An example of why, would be a package of agronomic practices that recommends increased use of fertilizer; adoption would be constrained not only by the cost of the fertilizer, but by proximity and ease of access to the field. Where use of manure is recommended, the number of animals owned by a household would determine feasibility (Williams et al., 1995) or could change the balance of profitability – a point brought out by the cost-benefit analysis performed by Tschakert (2004) in Senegal. Availability of labour to carry the manure would also count; a farmer with few children might reject a technology on those grounds, but not the bigger family next door. So devising and transferring packages of SLM technology to farmers is often a waste of time; they would strongly prefer a basket of technologies from which they can individually select the components they need. They can then test these sequentially.

This leads directly to the fourth main strand in the literature – that the transfer-of-technology (TOT) model is flawed and that SLM is best attained through farmers' own innovation, adoption and adaptation. The challenge is for formal projects, and research bodies such as the CGIAR and its national counterparts, to take part in these processes rather than attempt TOT. This view is not new; it emerged in the late 1980s and was marked by the publication of *Farmer First* (1989) – a book that embodies many of the ideas behind the 'populist' approach – and *Beyond Farmer First* (1994).[26] The latter book went further, suggesting a need to review the relationships between knowledge, power, and institutions. This may be taking the debate into areas of ideology and

[26] Cited as Chambers et al. (1989) and Scoones and Thompson (1994).

epistemology beyond the scope of this paper.

However, this paper has reached some conclusions on farmers' spontaneous processes of innovation and adoption. The following lessons on adoption are offered for both development projects and research.

- The best way of helping land users to innovate is not to produce packages of technology that land users must either accept or reject; it is to provide a basket of technologies that farmers can test as individuals. This was the approach used in the ICARDA-led work in the olive groves of Northern Syria, described in section 3. Land users have to make decisions based on their own resource endowments, and cannot usually accept packages of transferred technology. But the project, for instance, can provide useful inputs such as improved germplasm and suggestions on planting rates, and the farmers can then modify and adapt them in their own way.

- This leads to the second lesson: project interventions should be designed to complement land users' processes. In the Syrian case, the farmers tested the technologies, but the researchers planned the Gerlach troughs and conducted the assessment of soil loss under different treatments (Masri et al., 2005) – something the farmers could not easily have done. This underlines Sumberg and Okali's (1997) view that while farmers can carry out extensive innovation processes, they should not be asked to replicate formal research. This borderline was less clear in the PEA programme described by Hagmann and Chuma (2002); in this case, researchers demonstrated the biophysical processes that cause land degradation to farmers in order to guide their own experiments. This had very positive outcomes. Here too, however, farmers were not asked to carry out formal experiments with fixed plot sizes or Latin squares. There is a division of labour here. The researcher does not disappear. Instead, s/he acts as toolbox rather than teacher, and the traditional distinction between researcher and extensionist is broken down. That does not mean that formal research becomes redundant, but, as Williams et al. (2000) put it, research "should be geared to producing a diversified range of technical options to suit the needs of farmers with different resource endowments, management skills and ability to bear risk."

- The third lesson for projects is that SLM must produce near-immediate gains for land users. It is obvious that they will not wish to adopt technologies that are not profitable, but it is now also understood that they must pay off the investment of labour and capital in the short term. Shiferaw and Holden (2001) make this point in regard to soil conservation in Ethiopia, and it has been made elsewhere. Well-targeted credit schemes can help small-scale farmers to undertake the necessary investments required for soil conservation. Badly planned credit schemes may not help and will only drive resource-poor farmers into debt. Besides, as Campbell et al. (2002) have pointed out, credit schemes are not always the answer for semi-arid regions, where shocks such as crop failure due to drought can cause a sudden high default rate. This implies that, where projects offer technologies for long-term sustainability, they must also offer opportunities to increase income in the short term; otherwise they are asking farmers to make what CIAT (2004) calls a 'leap of faith'.

- The fourth lesson for project design concerns the scaling-up of outputs. As has been seen, technologies are often site-specific and farm-specific, and what needs to be transferred is often not the technology but the methods by which it is produced. If a project gets this as well as the process of technology transfer right, there will be spontaneous adoption of technologies beyond the target group. But there is also a need to understand how outputs from farmer-driven innovation can best be transferred. Hagmann and Chuma (2002)

describe how the PEA programme built contacts between farmers through competitions for the best innovations, and through visits in which groups of farmers and researchers jointly evaluated other farmers' ideas. A farmer can convince a farmer more easily than a project worker can. It has to be accepted that this will be easier with some groups of farmers than others; as described in section 4, farmers in some regions are not willing to share their ideas, while those in others are expected to do so as part of their duty to the community.

- The fifth lesson is that land degradation must be tackled in an integrated and coordinated way at different scales and with the involvement of a wide range of stakeholders. This is because land degradation is a multi-faceted problem that is driven by many factors and spans a range of processes and scales. The piecemeal approaches of the past have not worked and the more successful approaches reported in this paper are those that adopted the participatory, integrated approach to redressing land degradation.

These are the main lessons for project design. However, there is a sixth conclusion from this paper as a whole: that there must be the right policy and infrastructure for agriculture. Without it, it is not worthwhile for the resource users to tackle land degradation.

To some extent this has to be tackled internationally, as export subsidies and producer support to farmers in wealthier countries is part of the problem. In 1999, the combined amounts paid to support farmers in 30 OECD countries exceeded the GDP of Sub-Saharan Africa (FAO, 2001). In 2000, total transfers to OECD farmers were $327 billion (ibid), dwarfing total aid flows from those countries, which were $47,580 million in 1997 (Thomas and Allen, 2000). FAO's Director-General, Jacques Diouf, has pointed out that in 1999 each OECD farmer received US$11,000 of support, but an agricultural farm worker in a developing country received a mere US$4.3 from overseas development assistance (FAO, 2001).

This need not prevent governments taking action at local level, however. Good infrastructure - roads, transportation system and communication networks – clearly does help, as in the case of Machakos. So do policy changes that help farmers make the best use of available resources. Pandey's (2001) example of ending regional self-sufficiency in Vietnam shows how this can work. But increasing market access can provide an incentive for resource *degradation* if it is not part of a balanced package. Input and output prices must be at an appropriate ratio. Again, this is a point made by Williams et al. (1998); in their discussion of intensification in crop/livestock systems in Sub-Saharan Africa, they call for "vertically coordinated schemes, that provide credit, access to new technologies and a stable output market, [of the type] that has worked so well for cotton in Burkina Faso and Mali."

In the Summary, it was explained that there were two main objectives:

- *"Review land users' processes of experimentation, adaptation and adoption of technologies for SLM in drylands and draw out lessons for future project design, implementation and scaling-up of successful practices; and to*
- *"Analyse and identify the local, national and global environmental benefits generated through adoption and management of SLM technologies in order to provide guidance for the estimation of incremental costs of similar new projects in dryland areas."*

This section has summarized this paper with regard to the first of these questions. The second question was covered to some extent in section 2, but the question of incremental costs, and the establishment of baselines, has not been discussed. This will be done in the final section.

6 Incremental costs and land degradation

As stated in the introduction and summary to this paper, GEF funds the incremental costs of projects that deliver global environmental benefits only. It will therefore only fund the extra component of a project that makes it provide such benefits. An example GEF has used to illustrate this is a project, financed by (say) the World Bank, that is updating the power-generation capacity of a partner country. The project may include the construction or repair of coal-fired power stations. Using solar energy instead would have global benefits in terms of lowering carbon emissions, but would be more expensive. The cost of the project with the coal-fired power stations is the baseline, and the extra to upgrade to solar power is the incremental cost. It is this difference between a costlier, more environmentally friendly option and a less costly but environmentally damaging option that the GEF will fund.

This ensures that GEF funding is spent on its mandated objectives and not on other development goals. As GEF (1996) explains:

> *First, …scarce funds will be dedicated to achieving global environmental benefits rather than to achieving development and local environmental benefits, for which other sources of funds are appropriate. Second, and equally importantly, eligible countries need not divert scarce development finance to achieve global objectives nor give up their national development goals to do so.*

But with land degradation, assessing baselines for incremental cost analysis can be quite complicated because of the incidence of benefits at multiple levels, the difficulty of separating local benefits from global benefits, scarcity of data and scientific uncertainty about the processes of degradation. An additional complexity is introduced by the participatory approach to SLM advocated in this paper; this will make *ex-ante* identification of global environmental benefits difficult, due to lack of prior knowledge of the mix of technologies and management practices that stakeholders will adopt. The purpose of this section is to highlight the implications of these complications for incremental cost analysis of SLM projects and to flag up potential issues for discussion. It does not represent GEF policy, and in no way indicates that GEF itself wishes to raise these issues, or that it regards them as problematic.

Attempts to clarify the issues around incremental costs have been on-going since the 1990s. Documents have been produced by the GEF Secretariat to define GEF policy on baselines and incremental costs and streamlined procedures for their estimation and reaching agreement with partners (GEF, 1996, 1998, 1999a, 1999b). These documents were developed before land degradation became a specific mandate (a focal area) of GEF,[27] and before the existence of OP15, the operational programme on sustainable land management. However, even in those days, GEF was already concerned with land degradation as a crosscutting issue affecting existing mandates, such as biodiversity, climate change and international waters. The remainder of this section uses these documents as background, but touches on other issues not covered in them.

It will finish by suggesting areas in which eligibility for GEF funding might be broadened when addressing land degradation. This is not intended to encourage ‘mission creep’, with GEF assuming responsibilities that are rightly those of other bodies. Rather, it is intended to give GEF more flexibility in addressing the real drivers of loss of genetic resources and organic carbon that occur through land degradation.

[27] This happened in 2002.

Establishing baselines for SLM projects

With land degradation, both local and global benefits depend directly on maintenance of the natural-resource base, so untangling the two to establish baselines is inherently difficult. For example, although some of the benefits from successful conservation of rangelands would be global, others would clearly not be. Increases in pastoral incomes and improved nutrition are an "on-farm" good, stable meat and dairy prices a local one; while environmental benefits such as reductions in dust-storms might be regional or national. Conservation of rangeland biodiversity would also have mostly (but not entirely) local impacts. The carbon sink *is* a global benefit, but it must be established that it came about through project interventions over and above what would be obtained without intervention. However, if carbon sequestration was enhanced through reseeding with pasture species not considered necessary for other purposes, there would be an incremental cost.

Enhancement of on-farm crop genetic diversity throws up similar issues. While the global value of *in-situ* crop diversity is not in doubt, it is not easy to separate additional global from regional, national and particularly on-farm benefits in order to estimate a baseline. As discussed in section 2, farmers often maintain a diverse range of landraces for their own reasons. It is extremely difficult to establish baselines for these local values; as Brush (1999) points out, they are hard to assess not only because of their subjectivity but because completely different types of valuation exist. Indeed, diversity is sometimes conserved for inherent values not explained by environmental or agronomic factors, as in the case of potato varieties in Andean Peru (ibid). Where a range of landraces is being maintained for yield stability, there is a clearer economic value; even here, however, the link between diversity and stability is not always 100 percent proven (ibid.), and its inclusion as part of the baseline is open to discussion.

Conversely, farmers do not always wish to conserve crop diversity for their own reasons; if they did, there would be no issue. Bellon (2003) quotes the example of the Wagwag rice variety in the Philippines, which farmers would like to grow but which, because of its long duration compared with modern varieties, deprives them of a second crop. In such cases, it can be possible to identify incremental benefits from on-farm maintenance of landraces, but direct incentives would be needed to ensure adoption, and this needs to feature in the incremental cost analysis.

However, as discussed in section 2, maintenance of on-farm diversity can also maintain overall ecosystem function, preserving structure and organic matter content; because of its carbon implications, this is a global benefit. This implies that the overall ecosystem function enhanced through on-farm biodiversity can be regarded as an incremental benefit. In this case, any project intervention strengthening such an integrated approach would entail an incremental cost and be eligible for GEF funding. This is compatible with the approach taken by the GEF Secretariat in its submission to the GEF Council in November 2004,[28] in which it was stated:

> *GEF adheres to the principle of incrementality in financing projects in the land degradation focal area. Incrementality primarily emerges in the form of additional activities and processes* [to] *implement an "integrated ecosystem based" approach to land management.*

But at the same time, as stated here, the alternative without incremental funding should still be sustainable, implying that ecosystem integrity should not actually be *threatened* under the baseline. Given this paradox, there is a need for a pragmatic approach.

[28] GEF/C.24/6, cited as GEF (2004).

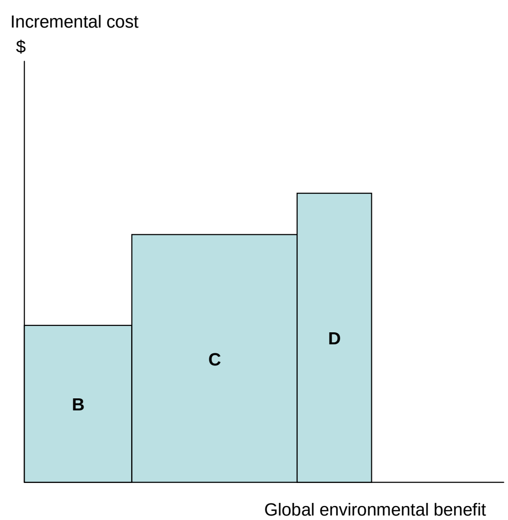
Complexity of SLM and incremental costs

Assuming a baseline has been established, the approach advocated in this paper – offering land users a large choice of technologies and management practices for SLM – poses other complications, two of which are discussed below.

First, the approach implies that more than one alternative plan or project must be considered in relation to the baseline, with all the attendant problems associated with data gathering for incremental cost estimation. In the simple graph shown in Figure 1 it is assumed that the baseline has already been established, so the rectangles shown are the alternative projects. It is further assumed that the different alternative projects will provide increasing levels of the same type of global environmental benefit. In this situation, the project manager needs to compare the different levels of the global environmental benefits produced and ask if the next level is 'worth it', i.e. is the additional environmental benefit produced by, say, project C, worth its additional monetary cost?

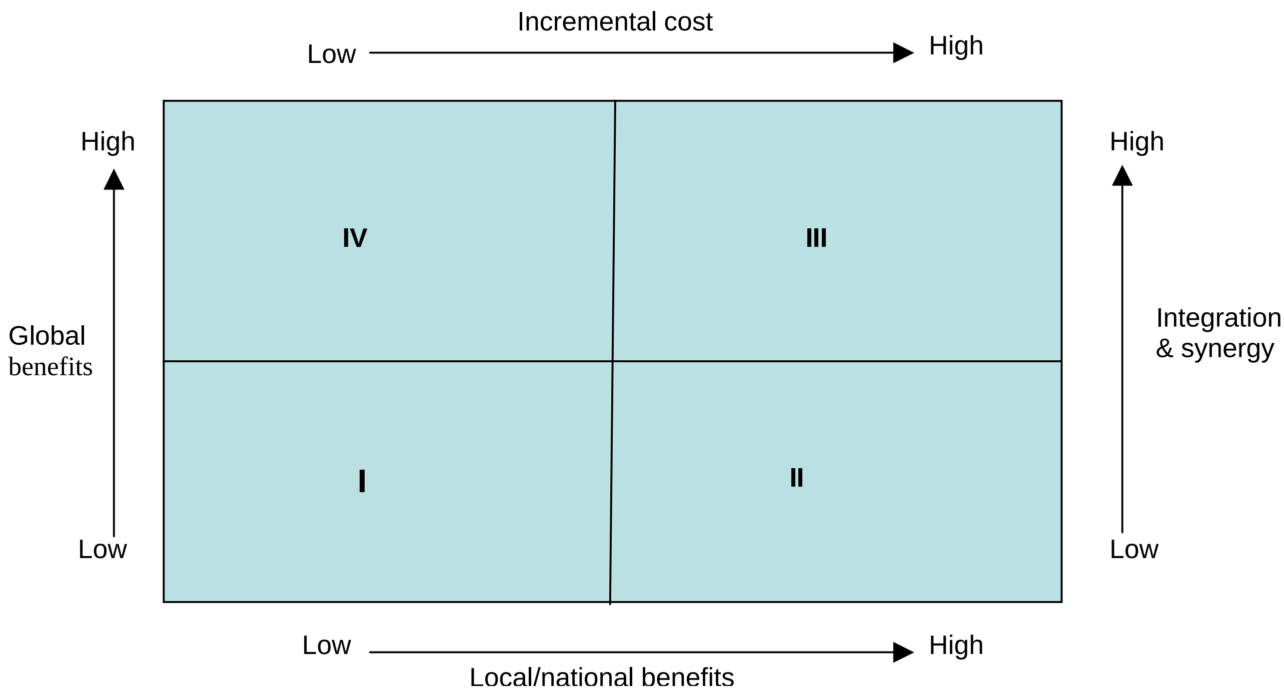
Secondly, the approach makes *ex ante* identification of global environmental benefits difficult, because the mix of technologies and management practices that will be adopted by land users cannot be determined in advance. The uncertainty that is introduced and which must be dealt is depicted in Figure 2, where each quadrant represents an alternative project whose flow of local and global benefits can range from low to high. The goal is to implement a project, made up of integrated and synergistic activities, that provides significant environmental global benefits. Because it is assumed that the baseline has already been established, each alternative project generates an incremental cost; but the alternatives are not equally attractive in terms of attracting GEF funding.

Figure 1 Incremental cost graph



If the uncertainty regarding the type and magnitude of environmental global benefits generated is left aside, a decision still needs to be made on which of these alternative projects to fund. The project represented by quadrant I may be deemed unattractive to fund on account of the low global benefits produced, despite the low incremental cost. Similarly, the alternative project in quadrant II that generates high local and national benefits will be ineligible for GEF financing even with the global benefits that it generates.

Figure 2 Alternative projects with varying environmental benefits and incremental costs



The alternative in quadrant IV should be eligible for GEF funding on account of the highly integrated set of activities that produces significant global benefits. But the problem here will be how to secure the cooperation of land users and their governments given the low level of local and national benefits associated with this alternative. The question with respect to the alternative represented by quadrant III is whether the additional global benefits generated is worth the incremental cost. Further, the issue of cost sharing will be relevant in this case.

The analysis here leads to the following conclusions.

- Identification and quantification of the global environmental benefits associated with alternative SLM options should precede any meaningful estimation of incremental costs. Targeted research carefully designed to reduce uncertainty in the prediction of global environmental benefits will greatly facilitate incremental cost analysis of SLM projects
- Cost sharing in financing alternative SLM projects can be made more transparent through the use of a schematic framework similar to the type shown in Figure 2
- Incentives to secure stakeholders' cooperation in SLM will become relevant where activities that generate global environmental benefits are not in their direct interest
- Incremental cost analysis, particularly in the case of SLM, will not by itself result in a unique project recommendation. Final choices will depend on information generated outside the framework of incremental cost analysis, such as how well the real drivers of land degradation are identified and addressed by alternative project options.

One aspect of the latter point is discussed further below.

Poverty and land degradation

If it is accepted that poverty is a driver of land degradation, then poverty alleviation is necessary

to generate global benefits.

As explained at the beginning of section 3, the link between poverty and land degradation is not uncontested, and where it is accepted, it should not be oversimplified. As Biot et al. (1995) point out, it raises the question of why some poor societies do not degrade their land while some rich ones do. Stocking and Murnaghan (2001) state that poverty reduces the range of options open to the land users and force them to concentrate on immediate needs – but also point out that there are cases where richer land-users degrade the land while the poor cannot afford to. Poverty might even drive people off the land and give it a chance to recover. "Poverty is… a somewhat ambiguous factor, that needs careful analysis and interpretation in its effect on land degradation" (ibid.).

Because of this ambiguity, this paper has had little to say directly on the link between poverty and land degradation. But section 4 did show that the capacity to take conservation measures is crucial. It is not hard to find examples of links between (for example) resource endowment and maintenance of soil nutrients, with lack of such maintenance encouraging extensification into forest and marginal land. There is such an apparent link in a recently approved GEF project that seeks to encourage SLM in the north of Rio de Janeiro State in Brazil:

> *The incidence of poverty among rural households in the State of Rio de Janeiro is about 27 percent (440,000 people), or about 2.5 times the poverty levels found in urban areas. This percentage increases to 35-39 percent in some municipalities… of the State, levels similar to those found in some of the poorest parts of the country…With regard to environmental degradation, particularly the Northwest region exhibits a dramatic scenario of environmental degradation, with generalized removal of forest cover…* (GEF, 2003b.)

Other factors are also present in this case, and the coincidence of two events (poverty and land degradation) does not constitute causality. However, Tschakert's (2004) work in Senegal and other sources do suggest a link between resource endowment, maintenance of soil fertility and, sometimes, extensification.

This implies that poverty alleviation would constitute an incremental benefit if it were in an appropriate form. This might include a wide range of measures designed to increase access to inputs (particularly fertilizer) and markets (to generate income to fund conservation). These would have to be demonstrably relevant to resource degradation and unlikely to feature in any baseline scenario. Provided these conditions were strictly met, however, such measures would not constitute mission creep.

Capacity building, already eligible for GEF financing, has similar characteristics and is very relevant for SLM. To a degree, this is inherent in an ecosystem approach, in the form of encouraging an integrated approach between ministries and other bodies. However, capacity building could also include the ability to monitor Land Quality Indicators or to take part in the work of LADA; this would help establish the nature and extent of land degradation, which, as discussed in section 1, needs clarification.

The same is true of monitoring carbon fluxes and organic carbon pools. There are several methods for this, including the use of Bowen Ratio equipment, stratified accounting using remote sensing and perhaps infrared spectroscopy (Robbins, 2004). All could work, but not necessarily in the same places, or with the same skills base; moreover there is as yet no general agreement on how soil carbon should be monitored, making it hard for researchers to refine the techniques (Post et al., 2001). However, this is now being done. Strengthening local capacities in this respect could

then have local advantages, as it would provide more accurate information on soil health and biomass. But it would also have incremental benefits through a more accurate global carbon budget. It would also enable a country's farmers to take part in carbon trading schemes, either on the commercial market or under the Kyoto flexible mechanisms, enhancing the global soil carbon pool. All the measures above would also serve the ends of the major international environmental treaties (CND, UNCCD, UNFCCC and perhaps Ramsar); this would be a clear incremental benefit.[29]

The type of capacity-building eligible for incremental funding could be further broadened. In section 4 of this paper, it was argued that stimulating farmer innovation in SLM required the provisions of baskets of technology from which farmers could choose, plus mechanisms for farmer-to-farmer communication. However, this paper has also quoted Robert Chambers' warning that the 'transfer-of-technology', or TOT, model is still fundamental to thinking in research and extension. If, as the GEF Secretariat has recently argued (GEF, 2004), encouraging an ecosystem approach is an incremental benefit, then addressing the TOT paradigm in research and extension should be no different in principle. There is, again, a danger of mission creep, but the key is to ensure that baselines include 'normal' support to research and extension, with the modified approach clearly picked out as an incremental benefit.

This section is not intended to advocate an inappropriate expansion of GEF's role, or a dilution of the principle of incremental funding. Rather, it has been to suggest how that principle can be fitted around the requirements of OP15.

[29] But this could not include building capacity to fulfil the *reporting* requirements of these treaties, as this is specifically excluded from incremental funding (GEF, 1996).

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