Opportunities and Challenges in Reversing Land Degradation: The Regional Experience

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1. Land Degradation Paradigm

Land resource degradation is considered to be one of the major threats to food security and natural resource conservation in the Amhara regional state. Hundreds of years of exploitve traditional land use, aggravated by high human and livestock population density lead to the extraction of the natural capital, mainly through farming of uncultivable sloppy lands and overexploitation of slowly renewable resources. The outcome is that a quarter of the highlands are seriously eroded, of which 15% are so seriously affected that it will be difficult to reverse them to be economically productive in the near future (SCRP, 1996).

Despite the current recognition of land degradation as a major bottleneck of agricultural productivity and natural resources management by farmers and policy makers, the issue of land degradation was not considered as a top priority in the national policy of poverty alleviation. Reversing land degradation in a short period requires a strong policy support through increasing credit access to farming communities and/or promoting cost sharing arrangements (Sanchez, et al., 1997). Proposals for diversity of technologies and investment of time and resources by a wide range of governmental and non-governmental institutions to address land degradation continued to prove unsuccessful, and soil fertility decline in small scale farms remained to be an intransigent problem. The rural poor in the Amhara region are often trapped in this vicious poverty cycle between poor access to resources (poverty), land degradation, and lack of relevant knowledge and/or appropriate technologies to generate adequate income and opportunities to overcome land degradation. The major knowledge gap is associated mainly with poor access to information for technologies and market. There is a direct link between land degradation and rural livelihood through three pathways. Firstly decline in soil fertility as a result of land degradation decreases farm productivity and income. As crop/livestock production is the major source of household income in the highlands, decline in soil fertility, through nutrient depletion and poor soil water holding capacity affects the on-farm income significantly. Secondly decline in soil fertility affects productivity of labour; a degraded land requires much more labour per unit area than a well managed land. Operation related to soil and water conservation and soil fertility management may compete with off-farm labour thereby reduce an off-farm income of the household. Thirdly land degradation reduces the underground and above ground biodiversity of the system, which in turn, affects the bio-chemical process of the rhizosphere and the vegetation cover of the land.

In earlier days, natural fallows were used to restore soil fertility mainly in the cereal-based highlands of Wollo and Gonder. How ever, due to increasing demand for land as a result of population pressure, natural fallows with such a long duration are no longer viable option of improving soil fertility. It has been recognized that natural fallow requires longer time to achieve the required level of soil fertility that can lead to optimum crop yields. Short duration natural fallows are now becoming more appreciable though short-duration, natural, unmanaged fallows normally do not maintain soil fertility at levels similar to those achieved under long-duration natural fallows (Aweto, *et al*., 1997), unless enriched by fast growing, N-fixing legumes. Short duration improved fallows consisting of planted and managed fast-growing species allow rapid replenishment of soil fertility. It has the advantage of *in situ* accumulation of biomass, optimising nutrient cycling through nutrient pumping from subsoil layers and litter falls, enhancing soil biological activities and maximize use efficiency of minimal external inputs (Sanchez et al, 1997). The ideal species in the improved fallow systems is, therefore, fast growing, N_2 fixing and efficient at nutrient capture and cycling (Jama, *et al*., 1998). The most common herbaceous legumes growing in pasturelands in the upper cool highlands of the Amhara region are vetches and clovers, besides the commonly grown food legumes like lentils, faba bean, and pea and grass pea.

Since land degradation is a complex phenomena affected by biophysical and socioeconomic factors, it became relevant to understand its root causes, biophysical or socio-economic, that play the major role in aggravating/reversing the trend of soil fertility. This paper also suggests methods & approaches for enhanced integrated soil fertility management and community participation towards sustainable natural resource management.

2. Understanding the Root Causes of Land Degradation

There are multiple factors that cause land degradation at short and long terms in the region. The major environmental factor that cause significant soil and nutrient loss in a short period of time is water erosion followed by wind erosion. In Sub Saharan Africa, the major agents of land degradation are water erosion, wind erosion, chemical degradation and others that affected soil loss by 47, 36, 12 and 3.5 %, respectively. Given the mountainous and commonly slopy landscape of the Amhara region, water erosion is expected to be the major environmental agent affecting land degradation. Most of the Wollo and Shewa highlands became erosion-prone due to high rainfall intensity accompanied by very steeply farmlands.

Although the degree of soil erosion is highly related to the interaction of Wischmeier factors, the type of land use and management may have played an important role in the highlands. The contribution of different management factors towards land degradation in Africa is estimated to be 49%, 24%, 14%, 13% and 2% for overgrazing, agricultural activities, deforestation, overexploitation and industrial activities (Vanlauwe et al, 2002). The livestock sector is a very important component of the system both as an economic buffer in times of crop failure and economic crisis and as a supportive enterprise for crop production. There is a considerable concern, however, that the number of animals per household is much higher than the carrying capacity of land resources. Overgrazing due to very high livestock population density in the Amhara region is expected to contribute most to land degradation. Another very important factor that aggravated land degradation in the Ethiopian highlands is deforestation. The forest cover went down from 40% at the beginning of this century to less than 3% at present. Deforestation accelerated land degradation in many ways. Firstly deforested land is easily susceptible to erosion, both wind and water, and hence causes a considerable nutrient movement. Secondly the amount of litter that could have contributed for maintaining the soil organic matter is considerably reduced. Thirdly deforestation in the highlands caused lack of fuel wood, and hence farmers use manure and crop residue as cooking fuel, which otherwise could have been used for soil fertility replenishment.

Overexploitation of land resources with out returning the basic nutrients to the soil is also an important factor that contributed most for soil fertility decline in the region. For instance barley is the single dominant crop in the upper highlands of Wollo. This system has very low crop diversity with legume component of less than 3%. The barley-dominated system receives external inputs very rarely with a fertilizer rate of less than 5 kg/ha (Quinones et al., 1997), and the practice of applying this limited amount of mineral fertilizer is a recent practice. Data from the region on the amount of nutrients returned to the soil in comparison to the nutrients lost through removal of crop harvest showed that only 18, 60 and 7 % of nitrogen, phosphorus and potassium is returned to the soil, respectively (Sanchez et al., 1997). Hence there is an over extraction of nutrients from the same rhizosphere for years and years.

Another possible cause of land degradation is lack of early awareness about soil erosion and soil fertility decline by farmers. For instance in Uganda, McDonagh, et al., (2001) reported that when farmers were asked to describe their indicators of soil erosion they stated gully/rill formation, exposed underground rocks, land slides, wash away of crops, shallowing of soils and siltation of the soil. These are soil traits that appear in a much later stage of soil degradation, after the soil organic matter and nutrients of the soil are removed. If farmers respond to soil erosion at this stage, the probability of reversing the fertility status to its earlier value would be difficult. Similarly farmers indicators of soil fertility decline include stunted crops, yellowing of crops, weed infestation, and change of soil color to red or Grey, traits that appear at the later phase of soil fertility decline.

An important factor that used to affect land management in Ethiopia is lack of appropriate land policy (Desalegn Rahmeto, 2003, personal communication), not only inappropriate national policy but also absence of bylaws that guarantee community level interventions. It could also be hard to differentiate whether land degradation was a consequence of poor resource management or a policy intervention, and hence difficult to convince policy makers about the causal factors. Although there are good reasons to believe the appropriateness of the current land policy of the government (only the right to use and transfer to their children), there are convincing data showing that farmers/communities may not be willing to invest on their land for a long term benefits unless they have the ownership card (Zeleke, 2003). Technologies like planting tree on-farm, construction and maintenance of soil conservation measures, medium and long term fallowing and alike would suffer most.

3. Towards Integrated Soil Fertility Management

Traditionally, the major nutrient management strategy to increase crop yield and improve soil fertility was through application of mineral fertilizers. The 0.5 ha demonstration plots that have been advocated and practiced by FAO and the ministry of Agriculture for years is one example. As this mono-technology approach failed to address the problem of soil fertility an integrated nutrient management approach that suit local biophysical, social and economic realities should be promoted. Integrated nutrient management technologies can be nutrient saving, such as in controlling erosion and recycling of crop residues, manure and other biomass, or nutrient adding, such as in applying mineral fertilizers and importing feed stuffs for livestock (Smaling and Braun, 1996).

The traditional field operations in the highlands that could be characterized by multiple-tillage, cereal-dominated cropping and very few perennial tree components in the system were very erosive for soils and nutrients. Continual farming in the highlands without considering conservation measures caused severe land degradation in the highlands. FAO study in Zimbabwe showed that each hectare of well-managed maize growing land lost 10 tones of soil per hectare. Depleted soils commonly reduce payoffs to agricultural investments for various reasons. Degraded soils rarely respond to external inputs, such as mineral fertilizers, and hence reduce the efficiency and return of fertilizer use. Degraded soils have also very poor water holding capacity partly because of low soil organic matter content that in turn reduce the fertilizer use efficiency. Results from the dry regions of Niger, Sadore, showed that application of fertilizer increased the millet yield by 71% and also improved the water use efficiency by 70% (Bationo et al., 1993). Hence improved soil fertility enhances the water use efficiency of crops in drought prone areas. Low soil organic matter accompanied by low soil water content may also reduce the bio-chemical activity of the soil that may affect the above and below ground biodiversity of the system. Degraded soils have also low vegetative cover that may accelerate further soil loss and runoff. In Andit tid, the amount of soil loss due to water erosion was 230 t/ha/year under hacked plots. However, it was possible to reduce the soil loss to 30 t/ha or less under crop covers or fallow grass lands (SCRP, 1996).

The effect of soil fertility decline goes beyond nutrient and water losses. There are conviencing results showing that the incidence of some pests and disease is strongly associated with decline in soil fertility. Results from the Amhara and Tigrai region showed that the effect of the notorious parasitic weed, striga, on maize and sorghum was severe in nutrient depleted soil (Esilaba, et al, 2000). It was possible to decrease the population & the incidence of striga significantly by improving the fertility status of the soil through application of organic fertilizers. Similarly the incidence of root rots in beans, stem maggots in beans, take all in barely and wheat is associated with decline in soil fertility (Marschner, 1995). The positive effect of application of organic and inorganic fertilizer on the resistance of the host crop is mainly through improving the vigorosity of the plant at the early phonological stages.

Amede et al., (2001) outlined the need for a combination of measures to reverse the trend of soil fertility decline in the African highlands as presented in the following section.

3.1 Participatory soil and water conservation measures

Firstly, it is fundamental to minimize soil and nutrient loss through application of system compatible soil conservation measures. Research conducted in Andit tid and Gununo showed that increasing the vegetation cover of the soil could decreases soil loss and runoff significantly (SCRP, 1996). When a cropland covered by crops or grasslands is compared to a frequently hacked farmland, run-off was reduced by about 90 and 100 % and soil loss by 68% respectively. Hence soil nutrient loss and runoff could be minimized through increasing the frequency of crop cover, especially by those crops with mulching habits and higher leaf area index to minimize the rainfall effects. Results from SCRP showed that perennial crops like enset and fruit trees or annuals with mulching and runner habits, like sweet potato, could reduce erosion effects significantly. Recent simulation studies in Northern Ethiopia showed that crop lands allocated for cereal crops like teff were found to be very prone to erosion (Woldu, 2002), and proposed that growing small seeded cereals, like teff, in sloppy farmlands should be discouraged.

Following the 1984/85 drought, there was a huge campaign in this part of the country on constructing terraces in sloppy lands for soil and water conservation purposes, using the food for work scheme. However, the approach was top down and did not participate the local community during planning and implementation stages. The consequence was that farmers failed to maintain the terraces and in some case farmers have destroyed the terraces for various reasons. When farmers were asked to list the reasons for rejecting soil and water conservation technologies they listed five major driving forces (Amede, 2002, unpublished) namely, high labour cost, decrease in farm size, its inconvenience during farm operations especially for free movement of oxen plough, and multiplication of rats in the stone bunds. By considering those farmers criteria and by adopting participatory planning and implementation approaches farmers have adopted and disseminated soil conservation technologies in one the African Highlands Initiative benchmark sites, Areka (Amede et al, 2001). The major driving force for the adoption of the technology was its integration with high value crops (e.g. bananas, hops) and fast growing drought resistant feeds (e.g. Elephant grass, pigeon pea) grown on the soil bunds. How ever, the sustainable integration soil & water conservation technologies depend heavily on the effectiveness of by-laws to limit free grazing and movement of animals during the dry spells. Hence there may be a need to reconsider the local policy so as to facilitate the integration of natural resource management technologies to local communities.

3.2 Integrated Nutrient Management

Building the organic matter of the soil and the nutrient stock in short period of time requires a systems approach. These include the combination of judicious use of mineral fertilizers, improved integration of crops and livestock, improved organic residue management through composting and application of farmyard manure, deliberate crop rotations, short term fallowing, cereal-legume intercropping and integration of green manures. Because of the inconsistent use of mineral fertilizers and the very limited returns of crop residues to the soil, most of the internal N cycling in small holder systems results from mineralization of soil organic N. Such process may contribute most of the N for the annual crops until the labile soil organic fraction (N-capital) are depleted (Sanchez et al., 1997).

Apart from the occasional application of small amounts of mineral fertilisers, all the other organic resources form the principal means of increasing soil nutrient stocks and hence soil fertility restorers in small-scale farms. If these approaches are used in combination and appropriately, they could reverse the trend and consequently increase crop yields and, thereby alleviate food insecurity. However, the continued low yields are an indication of insufficient inputs and/or inappropriate use of these technologies. The majority of the small-scale farmers are still aggravating the soil/plant nutrient deficit through improper land management and over-exploitation of the nutrient pool. However, there is still an opportunity to replenish the soil nutrient pool using integrated approaches depending on the degree of soil degradation, the production system and the type of nutrient in deficit.

One potential source of organic fertilizer is farmyard manure. There is a large number of livestock in the Amhara region that could produce a considerable amount of manure to be used for soil fertility replenishment. However, there is a strong competition for manure use between soil fertility and its use as a cooking fuel. Recent survey in the upper central highlands of Ethiopia showed that more than 80% of the manure is used as a source of fuel. Only farmers with access to fuel wood could apply manure for soil fertility replenishment. Experiences from Zimbabwe showed that most manures had very low nutrient content, N fertlizer equivalency values of less than 30%, sometimes with high initial quality that did not explain the quality of the manure at times of use (Murwira et al., 2002). This could be explained by the fact that most manures were not composed of pure dung but rather a mixture of dung and crop residues from the stall. Besides the quality the quantity of manure produced on-farm is limited. Sandford (1989) indicated that to produce sufficient manure for sustainable production of 1-3 tonnes/ha of maize it requires 10-40 ha of dry season grazing land and 3 to 10 of wet season Range land, which is beyond the accessibility of Ethiopian farmers due to land shortage. Moreover, the potential of manure to sustain soil fertility status and productivity of crops is affected by number and composition of animals, size and quality of the feed resources and manure management. Wet season manure has a higher nutrient content than dry season manure, and pit manure has a better quality than pilled manure. Similarly, Powell (1986) indicated that dry season manure had N-content of 6 g/kg compared with 18.9 g/kg for early rainy season manure when the feed quality is high.

Another potential organic source is crop residue. Returning crop residue to the soil, especially of legume origin, could replenish soil nutrients like nitrogen. However, there is strong tradeoff for use of crop residue between soil fertility, animal feed and cooking fuel. In the upper Ethiopian highlands crop residues are used as a major source for dry season feed and supplementary for wet season feed. Hence little is remaining as a crop aftermath to the soil. Although legumes are known to add nitrogen & improve soil fertility, the frequency of legumes in the crop sequence in the upper highlands is less than 10%, which implies that the probability of growing legume on the same land is once in ten years. The most reliable option to replenish soil fertility is, therefore, promoting integration of multipurpose legumes into the farming systems. Those legumes, especially those refereed as legume cover crops, could produce up to 10 ton/ha dry matter within four months, and are also fixing up to 120 kg N per season (Giller, 2002). Those high quality legumes adapted to the Ethiopian highlands include tephrosia, mucuna, crotalaria, canavalia, and vetch (Amede & Kirkby, 2002). However, despite a significant after effect of LCCs on the preceeding maize yield (up to 500% yield gain over the local management) farmers were reluctant to adopt the legume technology because of trade-off effects for food, feed and soil fertility purposes (Amede, unpublished data, 2002). In an attempt to understand factors affecting integration of soil improving legumes in to the farming systems of southern Ethiopia, Amede & Kirkby (2002) identified the most important socio-economic criteria of farmers namely, land productivity, farm size, land ownership, access to market and need for livestock feed. By considering the decision-making criteria of farmers on which legumes to integrate into their temporal & spatial niches of the system, it was possible to integrate the technology to about 10% of the partner farmers in southern Ethiopia.

Although most farmers are convinced of using farm-based organic fertilisers, they are challenged by questions like which organic residue is good for soil fertility, on how to identify the quality of organic resource, how much to apply, when to apply, and what should be the ratio of organics to mineral fertilisers. This calls for development of decision support guides to support farmers' decision on resource allocation and management. Scientists from Tropical Soils Biology and Fertility Institute of CIAT developed decision guide to identify the quality of organic fertilisers based on the polyphenol, lignin and nutrient content as potential indicators (Palm et al., 1997). As those parameters demand laboratory facilities and intensive knowledge, Giller (2000) simplified the guide by translating it to local knowledge as highly astrigent test (high polyphenol content), fibrous leaves and stems (high lignin content) and green leaf colour (high N content) to make the guides usable to farmers.

There is an increasing trend of mineral fertilizer use in the Ethiopian highlands over the past decades, as fertilizer imports into the country have increased from 47000 tonnes N & P in 1993 to 137 000 tones in 1996 (Quinones et al., 1997) as a result of a strong campaign of Sasakawa-Global 2000 in collaboration with the Buro of Agriculture. However, there is a declining trend in fertilisers use in 2001/2002 due to increasing cost of fertilizers, lack of credit opportunities to resource poor farmers and low income return due to market problems.

Organic resources may provide multiple benefits through improving the structure of the soil, soil water holding capacity, biological activity of the soil and extended nutrient release, but it could be unwise to expect the organics to fulfil the plant demand for all basic nutrients. Most organic fertilizers contain very small quantities of some nutrients (e.g. P and Zn) to cover the full demand of the crop, and hence mineral fertiliser should supplement it. Combined application of organic fertilizers with small amount of mineral fertilizers was found to be promising route to improve the efficiency of mineral fertilizers in small holder farms. For instance, Nziguheba et al., (2002) indicated that organic resources enhanced the availability of P by a variety of mechanisms, including blocking of P-sorption sites and prevention of P fixation by stimulation of the microbial P uptake. Long term trials conducted in Kenya on organic and mineral fertiliser interaction also showed that maize grain yield was consistently higher for 20 years in plots fertilised with mineral NP combined with farmyard manure than plots with sole mineral NP or farmyard manure (S.M Nandwa, KARI, unpublished data 1997).

4. Systems Approach for INRM

Sustainable rural development and natural resource management in the region demands an investment in and improvement of the natural capital, human capital and social capital. As the natural capital in the region had multiple problems that needs multiple solutions, there is a strong need for holistic approach to deliver options for clients of various socio-economic category.

Given the complexity of the problem of land degradation, and its link to social, economical and policy dimensions, it requires a comprehensive approach that combines local and scientific knowledge through community participation, capacity building of the local actors through farmers participatory research and enhanced farmer innovation. This approach requires the full involvement of stakeholder at different levels to facilitate and integrate social, biophysical and policy components towards an improved natural resource management and sustainable livelihoods (Stroud, 2001). Watershed management as a unit of planning and change imposes the need for increased attention to issues of resource conservation and collective action by the community. The issues of land degradation may include afforstation of hillsides, water rehabilitation and/or harvesting and soil stabilization, soil fertility amendment through organic and mineral fertilizers and increasing vegetation cover by systematic use of the existing land and water resources. This could be achieved by working closely with communities and policy implementers in identifying and implementing possible solutions to address land degradation and other common landscape problems, like grazing land improvement, gully stabilization and by monitoring and documenting the processes for wider dissemination and coverage.

Some of the watershed conservation related solutions should be tried and implemented on specific test locations using farmers' own contribution and the INRM team's technical supervision. However, a wider application of these solutions to larger areas may require attracting additional funding investments from the district, donors or other NGOs in the area. The local village communities may also effect changes in the norms and rules governing the use of natural resources in their vicinity. Traditional rules and local by-laws (e.g. written and unwritten and called "afarsata" or awatcheyache) regarding the use and sharing of resources exist in most villages and these need to be identified and studied with a view to effect reform or renew their emphasis in the community. Integration of Agroforestry technologies in the farming systems of the Ethiopian highlands failed because of absence of national and/or local policies /by-laws that prohibit free grazing and movement of animals in the dry season. Experiences from the 1980s campaign of 'Green Campaign' in Ethiopia also showed that it is almost impossible to address the issue of land degradation without the full involvement and commitment of the local community. The local by-laws in resource arrangement and use should be facilitated and supported, as the rules and regulations at the local level could be implemented effectively through elders and respected members of the community with tolerance and respect. There may be a church and/or witchcraft dimensions to these, and there may be changes over time that might help to understand why people are doing what they are doing. In addition, the influence of national and regional policies on local resource management should be understood. These will form an important subject of community wide discussion and deliberation (Stroud, 2001).

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