LAND DEGRADATION
IN
RWANDA:
ITS EXTENT AND IMPACT

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Preface

This paper is part of a series of case studies, which attempt on a pilot country basis to examine the costs of land degradation. This stage of the work involves a desk analysis of:

- Impacts of land degradation
- Costs of land degradation
- Costs of land improvement measures
- Costs of policy reform and institutional development.

In general there is reasonable, though not comprehensive, information on the impacts of land degradation and a good assessment base of the proximate and root causes. Linkages with poverty are well established and the cost of current remedial programs can be identified.

There is much less information on the impact on the ground of these actions. It is clear that the impact of land degradation is a drain on economic growth in rural areas and has an affect on national economic growth patterns. Investment in remedial action is hard to quantify, but appears an order of magnitude smaller than the scope of the problem. Actual in country joint assessment with national stakeholders will be necessary to provide specific analysis of the countries concerned.

RWANDA


UGANDA
Parc National des Virunga
Kabale
DEMOCRATIC REPUBLIC OF CONGO (ZAIRE)
Parc National des Volcans
Lake Bulera
Gatuna
TANZANIA
Gabil
Parc National de l'Akagera
Byumba
Goma
Gisenyi
RWANDA
Kayonza
Kigali
Lake Kivu
Kibuye
Gitarama
Kibungu
Rusumo
Nyungwe Forest
Gikongoro
Bukavu
Cyangugu
Butare
Muyinga
BURUNDI
0
50 km
0
30 mi

LAND DEGRADATION IN RWANDA: ITS EXTENT AND IMPACT

Executive Summary

Land degradation has long been recognized as a major problem in Rwanda, especially impacting the Southwest of the country, but important everywhere. Field research stations report soil losses 35 to 246 tons ha/yr, and farmers report declining productivity of their fields. An important root cause is the pressure on farm households as a result of a steadily increasing rural population and dramatic changes in farm size to average less than one hectare.

While government measures emphasized terracing and other measures to reduce soil loss, farmers see the problem more as the reduction of available manure to fertilize the fields. A widespread response to declining fertility is to change crops, reducing cereal production and increasing less nutrient tubers. Yet per ha yields of tubers also show steep declines.

Costs of land degradation are hard to measure, but estimates of the impact of declines in productivity suggest a loss of at least 3.5% of agricultural GDP. Changes in crops are resulting in declining nutrients available to rural families and an underlying factor contributing to the social unrest and civil war in the regions.

The Executive Directors of the World Bank in commenting on the Country Assistance Strategy (CAS) noted "that a comprehensive rural development strategy, that addressed land reform and gender issues, would be critical" and also noted "the week institutional capacity and obvious environmental degradation in the country."

Mitigation responses in the past have focused on physical or biological approaches to reduce soil loss from the often steep hillsides. As these approaches have been imposed on farmers there is a legacy of resistance to soil conservation measures.

In most parts of the country improved markets are an important component of mitigation efforts. Current donor efforts have the potential to break the degradation/poverty cycle by addressing agricultural and non-agricultural sectors on a regional basis.

LAND DEGRADATION IN RWANDA: ITS EXTENT AND IMPACT

THE EXTENT AND IMPORTANCE OF LAND DEGRADATION

Rwanda is often characterized as having very high rural population densities, lush vegetation due to high rainfall, and steeply sloping highlands. Erosion and land degradation have long been assumed to be severe and a major reason for the poverty and food insecurity in the country. The colonial administration and the post-independent government responses included large, countrywide programs to dig erosion prevention ditches on the hillslopes using mandatory, communal labor. Nevertheless, researchers and farmers perceived soil fertility to be declining rapidly in the 1980's and 1990's throughout the country but especially in the Southwest, and the low productivity undoubtedly contributes to the country's poverty.

Early agricultural research focused on types and severity of erosion, and mechanical and biological methods to reduce erosion. The results of the research, conducted by the national agricultural research institute (ISAR) and by other scientists indicate that loss of soil due to erosion is severe, ranging from 35 to 246 tons/ha/year with most stations measuring over 100 tons/ha/year. On five of the seven research stations where erosion was measured, erosion would remove the fertile topsoil within 30 years if no anti-erosion techniques were used (König 1994). One estimate was that in 1990, erosion caused the loss of productivity equivalent to 8,000 hectares per year, enough to feed 40,000 people (Gasana 2002). The agronomic research did not attempt to estimate the monetary impact of erosion or loss of soil fertility, so these statistics are not available. Results of agronomic or economic research on the status of degradation since the 1994 civil war are not yet available. Authorities agree that land degradation in Rwanda is a major problem, but quantitative assessments of its true cost are not available.

Rwandan farmers depend primarily on seasonal crops, such as maize, sorghum, beans and tubers, and hand hoe their soil at least twice yearly exposing the soil to erosion and rapid decomposition of organic matter. The dominance of seasonal crops increased following the decline of international coffee prices starting in the early 1990s. Coffee, which had been grown in a government-mandated practice that included mulching and terracing, had been relatively common on small-scale farms but is now rare. A large increase in tree planting around homes and on field boundaries reduced the fuelwood shortage, but governmental and NGO efforts to introduce agroforestry and other forms of biological erosion control have not been widely adopted, partly because of the perception that they occupy much space on the fields and compete with crops for nutrients.

DISTRIBUTION OF LAND DEGRADATION

In a nation wide survey taken in the early 1990's it was found that soil fertility was declining in all parts of the country with only one prefecture, Gisenyi, showing a lower degree of impact (Annex 1). It was found that the area of the country that was experiencing the worst poverty and social problems was also the region experiencing the worst land degradation: the Southwestern prefectures of Gikongoro and Kibuye. Marginal environmental conditions combined with relative isolation and a low degree of non-farm economic activity are reflected in poverty and the large percentage of fields

with declining soil fertility. Farmers reported that 56 percent of the fields in Kibuye and 49% of the fields in Gikongoro had declined in fertility since the farmers had started cultivating their land. Although worst in the highlands, farmers even in the newly settled eastern savanna lands in Kigali and Kibungo reported declining soil fertility on over one third of their land. Only farmers in Gisenyi, an area of volcanic soils, were not experiencing declines despite living in the region with the highest population densities. The national message was farmers were experiencing declines in productivity of their land. Women headed households experienced the worst declines, probably due to their land tenure insecurity, loss of animals to the husband's family when the marriage ended, and their general poverty and inability to invest in soil management. Because the history of land use and population change is so important to understanding the nature and importance of land degradation, these issues are included in the regional analysis.

Conditions in Rwanda vary widely both within the western highlands and between the west and the flatter Savannah land of the east. The following sections outline the nature and extent of land degradation on a regional basis.

THE SOUTHWEST

Status

Land degradation is most severe in the Southwest of the country, especially Gikongoro, Kibuye, and the higher zones of Cyangugu, Butare and Gitarama. In these areas, the soil is ferrallitic and the slopes of the hillsides are often very steep. After many years of intensive seasonal cropping, the soils have become highly acidic (less than 4.5), are deficient in P and N, and suffer from aluminum toxicity (König 1994; Roose and Barthès 2001).

Causes

Land use change over the past four decades is an important component of land degradation. Following independence, the large amount of land that had been reserved for grazing, primarily in the valleys and steep hillsides, was distributed to farm families. Currently almost no communal or private grazing land remains and only a small percentage of farmers own a cow. As the population grew in the 1980's, young families moved to marginal lands such as steep slopes and the edge of what is now protected forest, a cold area with very poor soil, and many moved East to settle former grazing land there. Nevertheless, the population densities increased and, with a system of equal inheritance among sons, the farms because extremely small (an average of around 0.7 ha). Landlessness and near-landlessness, especially by women-headed households, is increasingly common.

Government Responses

As the land degradation problem intensified, government policy following colonial tradition was to develop physical responses to the problem. Erosion ditches and grass lines, installed with enforced communal labor, covered almost all the hillsides by the early 1990's. Erosion probably was, however, still an important cause of soil degradation. The erosion control program was extremely disliked by the farmers, and they often insisted that it was not erosion but the lack of manure and other sources of soil organic matter (SOM) that caused the declining productivity. When the government lost its will or ability to continue the heavy-handed enforcement approach (e.g., following independence and in the early 1990's), farmers destroyed the erosion ditches as symbols

of repression. Meanwhile, soil organic matter content on farmer fields is very low and farmers have been unable to increase SOM due to their inability to fallow on their tiny farms, almost continuous cropping including hoeing the soil twice yearly, and the lack of manure due to the shortage of grazing land for cattle and other animals.

Farmers Response

A common response to land degradation has been crop substitution from grains and pulses, which no longer produce well and are increasingly subject to diseases, to tubers, especially sweet potatoes. This indicates an important loss of agricultural productivity as measured by economic or nutritive value. Very small amounts of chemical fertilizers were being used, despite the need. Government and NGO efforts to promote the use of green manure and biological erosion control through agroforestry or other means were not very successful because farmers felt that those plants occupied too much space on their fields.

The Southwest has been subject to periodic famines following relatively small climatic or other perturbations for many years because of the low food production per capita, and the lack of alternative income sources beyond farming (Nsengimana and Gascon 1991; Gascon 1992).

Summary

This region, therefore, is an example of an area where land degradation is already severe and the soil has probably reached a plateau of very low productivity. Efforts to improve productivity through a combination of mineral fertilizers and increasing SOM would probably provide an immediate and vitally beneficial impact on food security and poverty reduction. Improving returns to farming in the region, through the promotion and marketing of higher value crops or stall-fed dairy cattle, for example, could make these investments in mitigating land degradation more economical for both the farmer and the government or donor. Stall-fed cows would also provide the highly valued manure to improve the soil.

THE NORTHWEST

The Northwest of the country (Ruhengeri, Byumba, Gisenyi) experiences some land degradation and about one third of farmers identify declining productivity but this area has not experienced as severe land degradation, despite even higher population densities, because of its volcanic soil, a more economically productive farming system and critically the availability of non-farm income sources. Indeed, it has been a large supplier of Irish potatoes, beans and other crops that were traded nationally and across the Uganda border. Coffee and tea also produce well. The former government invested in this region providing a good transportation infrastructure, agricultural development projects for Irish potatoes and other crops that provided inputs and marketing, and in non-farm economic opportunities in the small towns and villages. Outcomes of the highly fertile soil and economic opportunities included lower rates of out-migration, higher rural incomes and less malnutrition (Habimfura and Fabiola 1993; Olson 1994a).

Nevertheless, the region's steep slopes and continuous cultivation threaten greater erosion levels and loss of productivity if erosion control measures are not maintained and if SOM declines. Farm sizes are extremely small and returns to labor in the current system are probably much less than one. The

region, however, has important potential to produce high value export crops because of its cool and moist climate, fertile soils, and large and skilled agricultural workforce.

THE EAST

The East of the country (Kibungo, Umutara, Kigali-rural), which is relatively dry and covered with gently rolling hills, came under widespread cultivation only since the 1970's, yet over a third of farmers complain of visibly declining fertility. Indeed, land that had been cattle ranches, wetlands and a national park has come under cultivation since the resettlement program following the 1994 civil war. Population densities are lower than in the West, but the warmer temperatures and lower rainfall preclude the West's extremely intense farming system.

Although the farms are larger than in the West, they are still small at approximately 1.4 hectares. This area, which had been a large producer of bananas and still has high agricultural potential, is the region of the country with the most agricultural income to lose from current and future degradation. In general, the soil in the East is not badly eroded and still relatively fertile compared to the West, because it has been cultivated for less time and the gentle slopes do not lead to the same degree of erosion.

Land degradation threats include:

- In recently drained swamps and lowlands, salinization and soil compaction may become a problem if drainage and other land and water management practices are not well planned and executed.
- The soils of the semi-humid savanna areas being put under crops are vulnerable to rapid decomposition of SOM, increased water and wind erosion, and loss of nutrients due to twice yearly plowing of the soil to produce seasonal crops.
- Herds of cattle and other animals concentrated in relatively small areas lead to erosion around their paths, and to compaction and other forms of soil degradation in the grazing areas.

CAUSES OF LAND DEGRADATION[1]

Research in the 1990's on the socioeconomic factors that led to the severe soil degradation in the South identified the factors influencing farmers to change their soil management, and how they were adapting to the degradation (Olson 1994b, 1994c). Although degradation is most severe in the South, the socioeconomic causes of degradation are similar throughout the country.

Halt In Manuring And Fallow

The findings pointed to the almost complete halt to the application of animal manure and the practice of fallowing starting in the late 1970's, which caused a rapid decline in soil organic matter and loss of soil nutrients. Farmers blame the declining productivity especially on the lack of manure; cattle

[1] Much of this report on Rwanda is based on the Ph.D. dissertation research of the author (see Olson 1994b) except where specific citation is provided.

and cattle manure are highly valued in Rwandan culture (Sirven, Gotanegre, and Prioul 1974; Newbury 1988). Survey results showed that the fields nearest the homestead, where manure and other organic inputs were applied, were the least degraded but even these fields were experiencing declining fertility. The lack of manure and ability to fallow was due to the loss of communal pasture land to raise animals and the small farm sizes, land issues that stemmed from land tenure changes related to political events, rural population increases and a poor and stagnant agricultural economy. Non-agricultural sources of income in the country were very limited and after the 1980's new land to clear was no longer available, so rural households had few alternatives to farming their old land. Governmental programs to replace coffee or provide other economic options were not successful in raising incomes. Meanwhile, government and donor investment in health, education and other services declined during the same period.

Decline In Farm Size

The crops produced especially in the Southwest were of low economic value with returns to agricultural labor being less than one. The small farms, in a country where the average farm size is less than one hectare, are in the worst situation. In analyses of national survey data, a strong inverse relationship was found between farm size and land productivity, and the opposite for labor productivity. Returns to land were the greatest, and to labor the least, on the smallest farms. The smallest farms used the most intensive erosion control measures but their erosion losses were approximately the same as on other farms (Byiringiro and Reardon 1996). Returns to investing in soil erosion control or other practices to reduce soil degradation were not profitable especially where soil was already severely degraded. Farmers termed the inability of the poorest to manure and otherwise care for their soil "social fertility," in which their low soil fertility mirrors their own social status (Olson 1994b).

Crop Changes

Nevertheless, farmers were found to be adapting to the degradation by switching to crops more tolerant of poor soils such as tubers and certain trees, reserving tiny patches of fodder grasses and trees to raise at least one small animal for its manure, and "deep hoeing" to replace the topsoil lost from erosion. Non-agricultural responses included searching for short-term agricultural labor, delaying marriages and reducing the number of children born to the family (den Biggelaar 1994; Olson 1994b, 1994a). These responses did not compensate for the losses due to degradation; for example tubers are much less nutritious than cereals or legumes.

Despite the wide variability throughout the country, nation-wide statistics of agricultural production reflect an evolution of productivity associated with:

1. New land being put under production due to clearance of new lands in the East, cropping land considered previously to be too marginal, and a growing agricultural population, and

2. The impact of soil degradation and decreasing farm sizes on the amount being produced per capita and a switch in the type of crop produced. Table 1 below reflects the large increase in tuber production (mostly sweet potatoes and cassava, which are less nutritious than legumes or cereals) compared to other crops, and the decline in per capita production of cereals and legumes (beans and peas) (König 1994).

Table 1. Agricultural Production in Rwanda 1966-1986. (König, 1994)

	1966	***1976***	***1986***	***1966-1986***
Total Production (1000 tons)				
Bananas	1452	1820	2266	+56.1%
Legumes (beans, peas)	195	237	314	+61.0%
Cereals	194	234	297	+53.1%
Tubers	513	1301	1679	+227.3%
Total	2354	3592	4556	+93.5%
Production per capita				
Legumes	736	798	701	-4.8%
Cereals *what are units?*	61	53	48	-21.3%
Tubers	61	52	46	-24.7%

Since the 1994 civil war, the government and NGO's have implemented a major resettlement and land re-distribution program throughout much of the country. This has consisted of moving families to live in houses within villages so they are no longer living on their farms, redistributing farmland among households, and, in some areas, distributing former ranching and protected area land among farming and pastoralist households. Possible consequences may include longer distances farmers need to walk to reach their fields and a feeling of tenure insecurity, both of which may result in reduced ability to or interest in investing their labor and capital in soil management. (See Annex 2 for some recent studies of Rwanda land degradation).

COST OF LAND DEGRADATION

As noted earlier there are few numerical estimates of the costs of land degradation in Rwanda, though a case could be made that the real costs are a component of the civil strife that has beset this country especially since 1994.
Among the costs that can be identified are:

- The costs of loss in productivity through soil and nutrient loss
- The costs of crop change in value and also in nutrient level
- The costs of social upheaval due to land pressures

Loss of Productivity

National statistics illustrate the general problem in Rwanda. In the period 1982 to 1994, while the index of agricultural production rose a little from 107 to 110, per capita agricultural production fell from 97 to 75 and the food production index fell by a similar amount. Even more significantly yield per hectare dropped by 2 per cent for cereals and by 20 percent for tubers. The latter represents a loss of over 1200 Kg/ha on tubers.

Losses of cereal production and tuber production can be roughly quantified as $20 per ha and with 1,160,000 ha in cultivation this translates into $23,200,000 a year. With agricultural GDP at $650 m, the drop in value is 3.5% of agricultural GDP. While these are generalizations from specific data in a poverty stricken country hopes of economic growth in the agricultural sector will depend on reversing the productivity decline including dealing with the land degradation problem.

Costs of Social Upheaval

The civil war and massacres of 1994 and subsequent years had many causes. But one clear contributing factor was the pressure brought about by the difficulties of adjustment to rapidly declining rural productivity in many areas and the lack of alternative livelihood systems. An agriculturally based country of 2.1 million people in 1950 became a country of almost 8 million in 1995 without the general emergence of a rural infrastructure and with dramatically declining farm size and per capita productivity. The costs in human life and social disruption were enormous.

MEASURES TO PREVENT AND MITIGATE LAND DEGRADATION

It has been indicated earlier that while official attention has been directed to issues of soil and nutrient loss, farmers have been more concerned with the reduction in the amount of manure available as fertilizers. Research also has focused on soil conservation technologies.

In the past, the government focused almost exclusively on controlling erosion to the exclusion of other soil management or improved agronomic practices. An approach that had been promoted by the government, “radical” terraces (bench terraces) would be more effective in reducing erosion compared to the erosion ditches and grass lines established in the 1980’s. The construction of such terraces, however, would require a significant amount of labor and probably an intensive community-based program with technicians and extension agents.

Technical Approaches

Much research has been conducted in Rwanda testing various techniques to reduce erosion (Moeyersons 1994). A replicated finding is that biological controls, such as lines of agro-forestry trees or grasses planted along the contour, eventually forming “micro-terraces,” reduce the loss of soil more effectively than the type of ditch terraces installed by the government in the 1980’s. The relative costs of biological measures in terms of labor and land, and the effects of competition with the crop for light, water and nutrients, would need to be considered before specific techniques could

be promoted. Farmers have been already using various forms of biological control to reduce erosion, including leaving crop residues on the fields, planting trees and bushes around the fields and multi-cropping to cover the soil during the rainy season.

The biological erosion control methods also produce fodder or green manure that increase soil organic matter and nitrogen. On-station research indicates, however, that controlling erosion and increasing organic matter using animal or green manure is insufficient to increase productivity on the acidic, ferrallitic soils of Rwanda due to P-deficiency. Applications of mineral fertilizers and dolomite, in addition to erosion control, produced a reasonable yield (Roose and Barthès 2001).

Additional improved techniques, such as careful composting of animal manure to reduce the loss of N and K, economically viable opportunities to increase the number of animals raised, and increasing vegetative cover with perennial crops or by using mulch, would also improve soil productivity.

Economic Considerations

The approaches described above all require varying amount of land, capital and especially labor. Soil erosion control, mineral inputs and other soil management practices compete for the extremely scare resources of the Rwandan farmers. Erosion control through forced labor, the former approach, has perhaps been proven to be effective in establishing the infrastructure, but when the threat of enforcement is gone, the farmers have shown that they will let the terraces crumble or actively destroy them.

The resources farmers invest are highly dependant on the potential increase in agricultural production, as well as what resources are available for the farmer to invest. The amount of investment made at the farm level is closely tied to the potential increased productivity to be gained. The value and marketability of the crops produced are therefore critical factors in the decision to invest in the soil. Farm level investments in coffee, for example, included mulching and mineral fertilizers that were done without the heavy enforcement required for building terraces. Once the coffee market collapsed, however, the use of mulches and fertilizers declined and were rarely used on lower value crops.

In comparing the Southwest with the Northwest, it is clear that the Southwest's lower value crops, the lower inherent soil fertility, and the lack of non-farm income sources led to a spiral of low productivity/ low investments/ increased soil degradation. Farmers do not have the resources themselves to break this cycle without economic assistance and an improved market for their crops and animal products.

Programs to prevent and mitigate land degradation will therefore need to be conducted within a broad economic development plan that includes the agricultural and non-agricultural sectors.

Social Factors

In Rwanda, farmers have shown themselves to respond quickly to new or to declining economic opportunities. Nevertheless, certain aspects of the society affect the willingness and ability of households to implement soil management practices. For example, the percentage of households

headed by women is very large, especially following the civil war, and the needs of these women farmers must be considered. Traditionally, women were not permitted to own land or graze animals, and they frequently became landless and extremely poor after the break up of their marriage following death or separation. Considering the importance of women headed households, their tenure security will need to be ensured before they are willing to invest in the land. Agricultural extension and economic program staff will need to consciously cater to women farmers to ensure the relevance and appropriateness of the programs.

Land Use and Tenure Requirements

Land tenure security is a pre-condition in Rwanda before farmers can be expected to invest long-term in their soil. Before the 1994 civil war, the main land related problem felt by farmers was the extremely small farm sizes, the scarcity of additional land, and land degradation. Since the war, additional problems the country is facing include the return of numerous recent and older refugees (800,000 to 1 million), many asking for land (Van Hoyweghen 1999). In response, the government carried out a policy throughout most of the country of villagization (regrouping of families into villages, or *imidungudu*) and redistribution of farmland among families. The government implemented it rather forcefully in some areas (HRW 2001). Although the goals for the policy were ambitious and positive, consequences that are being experienced include a sense of land tenure insecurity, a new group of near-landless, and long distances some farmers must walk to reach their fields. They also fear theft of their production from fields that they cannot monitor. These consequences may further impede farmers' willingness or ability to invest in erosion control or conduct other soil management practices.

Donor Programs

As security issues become resolved to some extent donors begin to work with the GOR to provide support for rehabilitation. The World Bank Poverty Reduction Strategy Paper (PRSP) presents a broad strategy for poverty reduction, addressing among other issues rural development and agriculture transformation and economic infrastructure. A 48 million dollar loan from the World Bank is targeting the whole issue of agricultural productivity and maturity. Phase 1 will focus on building the institutional and technical capacities needed to support the generation and adoption of efficient cropping and post-harvest technologies and hence launch the intensification process. Phase 1 includes seven components: The first component will empower beneficiary farmers to efficiently manage marshland/hill-side cropping and livestock activities and promote the adoption of improved soil, water and, fertility conservation techniques; and private operators to intervene in land and water infrastructure construction and maintenance. The integrated management of critical ecosystems component will strengthen the capacity of local communities to effectively manage critical ecosystems. The promotion of commercial and export agriculture component will develop export crop agriculture through facilitation of access to investment capital and strengthening of capacities of farmers and exporters. The fourth component will strengthen the capacities of agricultural research and extension systems. The fifth component will strengthen the capacities of local communities, private sector operators, farmers and other private sector operators, and water management infrastructure to develop small-scale infrastructure. The sixth component will lead to higher levels of off-farm employment and incomes. The last component will support project coordination.

This project approach appears to have the breadth and vision to begin to address sustainable land management issues. The active participation of local people in the implementation will be a key component of success.

CONCLUSION

The situation of high population densities and land degradation Rwanda, though extreme, is similar to regions of other countries in Africa. Several lessons can be drawn from its experience:

1. The processes that led to changing land management and severe land degradation in Rwanda are tied to economic, social and political processes that occurred during several decades. Addressing land degradation will, therefore, require not simply technical solutions but also changed and improved economic and social conditions.

2. Regional differences in land degradation are important in Rwanda. The Southwest has the worst degradation, and mitigating its effects and improving productivity will provide critical food security in an impoverished region. Degradation is not as severe in Northwest or the East but investing in degradation prevention may well provide economic returns due to the chances of high value agricultural production.

3. The level of non-farm as well as farm incomes are critical factors affecting households' ability to invest in land management, and their ability to recoup those investments by marketing higher value agricultural products.

4. Some segments of society, especially those with the smallest farms and women-headed households, are disproportionately affected by soil degradation and are the least able to address the problem. They would require particular attention, from a social/ legal (for women) as well and economic standpoint.

5. Land tenure security is a necessary condition for farmers to invest in their soil. National and local land policy and especially its implementation must do everything possible to ensure tenure security.

6. Erosion control measures are not sufficient to reduce land degradation and increase productivity. A combination of erosion control, increasing organic matter and adding mineral fertilizers is required, especially in areas where degradation is already severe.

7. Rwandans place an extremely high value on the role of animal manure to prevent degradation and improve productivity. Programs to enhance farmers' ability to raise animals on their small plots would probably be highly appreciated and successful.

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ANNEX 1- Table 2. Farmer Perceptions of Changing Soil Fertility since Cultivating Field, by Prefecture (% of fields). Source:

	PREFECTURE				
	Gitarama	Kibungo	Kibuye	Kigali	Ruhengeri
CHANGE IN SOIL FERTILITY					
Deterioration	34%	34%	56%	37%	36%
No change	49%	50%	38%	46%	58%
Improvement	14%	17%	6%	18%	6%
TOTAL	100%	100%	100%	100%	100%
MEAN CHANGE IN FERTILITY (from –3 to +3)	-0.45	-0.34	-1.06	-0.41	-0.73

Olson 1994b.

	PREFECTURE				
	Butare	Byumba	Cyangugu	Gikongoro	Gisenyi
CHANGE IN SOIL FERTILITY					
Deterioration	32%	30%	44%	49%	26%
No change	56%	63%	48%	45%	66%
Improvement	12%	7%	8%	6%	8%
TOTAL	100%	100%	100%	100%	100%
MEAN CHANGE IN FERTILITY from –3 (worst degraded), 0 (no change) to +3 (most improvement)	-0.39	-0.58	-0.80	-1.01	-0.41
N (fields)	1121	608	383	576	503

ANNEX 2. Recent Studies of Rwanda Land Degradation

Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments

This paper examines the effects of farm size, soil erosion, and soil conservation investments on land and labor productivity and allocative efficiency in Rwanda. There were several key results. First, there is a strong inverse relationship between farm size and land productivity, and the opposite for labor productivity. For smaller farms, there is evidence of allocative inefficiency in use of land and labor, probably due to factor market access constraints. Second, farms with greater investment in soil conservation have much better land productivity than average. Those with very eroded soils do much worse than average. Smaller farms are not more eroded than larger farms, but have twice the soil conservation investments. Third, land productivity benefits substantially from perennial cash crops, and the gains to shifting to cash crops are highest for those with low erosion and high use of fertilizer and organic matter. Program and policy effort to encourage and enable farmers to make soil conservation investments, to use fertilizer and organic matter, and to participate in cash cropping of perennials will have big payoffs in productivity. Land markets that allow smaller farmers to buy land could also increase aggregate productivity.

Source: Byiringiro, Fidele & Reardon, Thomas. Agricultural Economics. Vol. 15, 2, November 1996, pp 127-136

Agroforestry, water and soil fertility management to fight erosion in tropical mountains of Rwanda

African tropical mountains are often overcrowded because the climate is healthy and favorable to intensive agriculture. Consequently the density of population in the mountains of Rwanda and Burundi has reached an exceptional level (150 to 800 inhabitants/km^2) that leads to delicate problems of soil protection against runoff and various types of erosion on steep cultivated hill slopes. Previous measurements on runoff plots have shown that sheet and rill erosion risks have reached 300 to 700 t/ha/year on 20 to 60 % slopes with regional rainfall erosivity (R_{usa} =250 to 700), very resistant ferrallitic soils (K=0.01 to 0.20) and traditional farming systems (C=0.8 to 0.3). Curiosly, the runoff rate (10 to 30 %) is relatively moderate so that it is possible to restrict erosion with a natural or leguminous fallow, a pine plantation (litter effect) or by mulching coffee, banana or cassava plantations. The problem is now to produce enough biomass to mulch the whole surface with the help of agroforestry. A new strategy (GCES = land husbandry) was suggested to meet the major farmer problems: what should be done to increase the soil productivity rapidly and protect the rural environment? A part of the answer is to be found in the efficient management of water, organic matter and soil fertility restoration (Roose et al., 1998). This strategy was first tested in 9 runoff plots (5x20 m) on a 23 % slope of a very acid ferrallitic soil (pH = 4). Three types of living hedges (leucaena, calliandra, calliandra+setaria) twice replicated, were compares with the international bare standard plot and with the regional farming system (maize+beans during the first season, and sorhum during the second season). After 2 years, living hedges reduced runoff to less than 2 % and erosion to 2 t/ha/year: they produced fire wood and high quality leguminous forage (3 to 8 kg/m) and return to the soil as much as 80 to 120 kg/ha/year of nitrogen, 3 kg/ha/year of phosphorus, 30 to 60 kg/ha/year of calcium and potassium, 10 to 20 kg/ha/year of magnesium. Thanks to agroforestry it was possible tor educe erosion hazard but not to restore the soil productivity. Without 2.5 t/ha/ 3 years of lime to increase the pH up to 5 and reduce the aluminium toxicity, without 10 t/ha/ 2 years of farm manure and mineral fertilizers to nourish the crops, the yield remains very low (800 kg/ha/season of cereals). Thanks to agroforestry and a mineral fertilizer complementation, erosion hazard was controlled and the productivity of soil and labour intensified more than 3 times.

Source: Roose, Eric & Ndayizigiye, François. Soil Technology. Vol. 11, 1, May 1997, pp 109-119.