CONSERVATION FARMING ON STEEP LANDS

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Foreword

Soil degradation is one of the major problems confronting agriculture throughout the world. Deforestation, intense cultivation of vulnerable land, overgrazing, and poor soil and water management all reduce the productive capacity of soils and pose constraints to increased food, feed, and fuel production. The ability of developing countries to feed rapidly growing populations relates directly to wise natural resource management. Scientists and development planners alike agree that a sound agriculture rests on a stable natural resource base. Both groups of experts now stress the importance of maintaining and improving the productivity of the world's soil resources and call for efforts to reduce soil erosion and degradation.

While many experts believe that the majority of expansion in agricultural production between now and the year 2000 will come from land that is cultivated at the present time, marginal land—both steep and flat—is becoming increasingly important in many parts of the developing world due to rapid population growth and the shortage of good arable land. As a result of poor soil quality and unfavorable climatic conditions, misuse of this land can result in serious and often irreversible degradation.

Historically, most natural resources were considered common property and provided a productive base for crops and many other basic necessities of life. This system worked well when resources were plentiful and people were few. Ecosystems had ample time to regenerate after periods of heavy use. Today, this is no longer the case. Continued dependence by larger numbers of individuals on a finite natural resource base results in the degradation of the resources and a serious loss in their productive capacity. In addition, misdirected development policies and other policies that discriminate against agriculture deprive farmers of the capacity and incentive to adopt productive, conservation-conscious farming practices and technologies. In developing countries, high prices for cash crops encourage farmers to allocate their best land to crops they will sell—often nonfood crops—to the exclusion of food crops, which are relegated to marginal land more prone to degradation. Artificially low food prices, on the other hand, discourage soil and water conservation and the use of appropriate inputs that promote higher, sustainable yields.

Security of tenure is another important factor affecting long-term investment in soil and water conservation. Many countries have found that ensuring secure rights to land and improvements induces significant increases in household investment.

Soil degradation is a complex process in which physical, chemical, and/or biological factors contribute to the loss of a soil's productive capacity. Forms of soil degradation vary from region to region. For example, in Latin America, soil erosion by water is the major form of degradation that mainly affects areas cleared of vegetation for shifting cultivation and for settlements, cattle ranches, and other purposes. In Southeast Asia and North Africa, the most dominant problems are those associated with irrigation, while in sub-Saharan Africa, the most severe degradation is that associated with the intensive use of arid and semiarid land.

Soil erosion and land degradation are not problems confined to the less developed countries, however. The United States, for example, loses about three billion tons of its valuable topsoil each year. That, despite 50 years since establishment of the Soil Conservation Service and expenditures of tens of billions of dollars since the Dust Bowl. Similarly, soil degradation has become a problem in all regions of Canada as a result of changes in production practices since World War II.

In the United States, Canada, and western Europe, many negative effects of soil erosion on crop yields have been masked by improved crop varieties, heavy use of fertilizers, better pest and disease control, and improved tillage and planting methods. All are technologies that are becoming more and more expensive, at least in many developing countries.

The focus of this volume is on soil and water conservation on steep lands. Many important technical and socioeconomic issues from throughout the world are discussed and analyzed in detail. One major conclusion from the case studies cited is this: While understanding the physical causes of soil degradation helps in identifying corrective measures, purely engineering approaches that do not take into consideration the underlying socioeconomic factors have generally failed. This holds true as well for soil degradation problems on less steep land, for example, the problems associated with rainfed agriculture, irrigated agriculture, and the farming of arid land.

While soil degradation problems are widespread and could have significant impacts on the world's ability to meet future food demands, opportunities exist in both the technical and policy arenas for promoting better resource utilization and management. Many known technologies and practices for conserving soil and water resources enhance crop productivity, at least in the short term. However, long-term actions, such as policy reform and institutional adjustments, coupled with long-term funding commitments, are the key to resolving many of the world's problems of resource management and agricultural productivity. Such policies include the promotion of small-holder agriculture through the provision of producer incentives, rural credit, reasonable food crop prices, adequate market and transport systems, strong agricultural research and extension programs, and the promotion of farming systems that do not degrade land and water resources. These far-sighted goals, however, require continuity within national governments and international assistance agencies. There have been too many five-year plans that did not last more than a year or two and too many shifts in the direction and emphasis of development plans and programs.

Just as many techniques for soil and water conservation can only be successful if they are site-specific, so too policies must be devised with the ultimate beneficiaries in mind. As catchments and watersheds are often the planning units for soil and water conservation programs, countries and large geographic regions within countries must be viewed as the planning units for policy analysis and recommendations. For example, studies producing long, comprehensive lists of methods and policies that can be successful on global, continental, or even ecosystem bases are only important first steps. Policies and institutional adjustments must be devised to fit the social and economic climate of a given country. In many cases, governments do not have the capabilities or the political will to choose from long menus of good actions. They need to know what specific policies might work better in their countries, what economic benefits will result, and what institutional adjustments will be needed to carry out successfully these policy recommendations.

Efficient resource use is key to the long-term sustainability of agricultural production. Policies initiated now to achieve these goals will go a long way toward narrowing the growing gap between supply and demand for food and other agricultural products and will have lasting benefits for the future health and welfare of mankind. In addition, progress in managing the world's natural resources can be made through better management of the interaction between development and environmental interests, despite the gap that still exists in our information base and knowledge. Fortunately, this volume is an important contribution toward closing that gap.

Mohamed T. El-Ashry

Preface

Material for this book was originally presented at a workshop, "Soil and Water Conservation on Steep Lands," held in San Juan, Puerto Rico, March 22-27, 1987. That workshop was organized by the World Association of Soil and Water Conservation and the Soil Conservation Society of America (now the Soil and Water Conservation Society). Workshop sponsors included the United States Soil Conservation Service, the United States Agency for International Development, and the World Resources Institute, with considerable help from the United Nations Food and Agriculture Organization and the Swedish International Development Authority. A total of 132 persons from 27 countries participated in the workshop. Forty-one presentations were given by individuals from the Caribbean region; North, South, and Central America; Africa; Australia; Thailand; Indonesia; and Taiwan.

The workshop had three objectives: (1) to compare experiences from successful soil and water conservation projects on steep lands as a means of determining the common principles involved that might be applied worldwide, (2) to publish the invited papers as a record of the magnitude of soil erosion worldwide and what accounts for the success or failure of efforts to deal with the erosion problem, and (3) to develop a manual that can be used by field technicians to integrate soil and water conservation measures with improved agricultural production systems.

After examining the manuscripts presented at the workshop, it was decided that instead of a proceedings containing these verbatim a more useful book would result from editing these manuscripts to adhere rigidly to the theme. This resulted in fewer and shorter manuscripts, but the editorial committee finds the result a more useful book.

The second publication resulting from the workshop and considerable work afterward by N. W. Hudson, David Sanders, Eric Roose, Jerome

Arledge, Max Schnepf, myself, and especially T. F. Shaxson developed much differently than expected. It was found that there are a great many guidelines available for field technicians. What was needed were guidelines of much broader application. The result is a manual that can be used by a broad spectrum of interests, from soil conservationists attempting to raise the awareness level of policymakers, to project leaders attempting to explain problems and solutions to their administrators or funding groups, to nonconservationists charged with establishing conservation measures while producing agronomic and forest crops.

Aside from the tangible contribution to the two publications, the workshop resulted in many contacts among soil conservationists from widespread geographic and climatic areas of the world. Efforts are being made by the World Association of Soil and Water Conservation and the Soil and Water Conservation Society to ensure that these contacts can be maintained.

W. C. Moldenhauer

I

INTRODUCTION

1

Tilting at windmills or fighting real battles

N. W. Hudson

Don Quixote was famous for his inclination to tilt at windmills, imagining them to be enemies that had to be attacked. In my keynote address at the start of the workshop, I suggested that participants should not waste time fighting imaginary problems. I did so for two reasons: because in recent years there have been major changes in thinking about soil conservation and because there are new principles that are now generally accepted, even though there may be a delay in them being applied in practice. At the end of the workshop, we used the information that came out of the papers and the discussions to refine my assessment of which problems are real and which are only windmills.

What emphasis "soil conservation"?

I suggested that we no longer need to argue that soil conservation is of little value alone. It must be an integral part of general agricultural development and not an isolated discipline run by specialists who do nothing else. The workshop reinforced this approach, even to the point of suggesting that "soil conservation" is no longer the most appropriate name. An alternative was "conservation farming," which changes the emphasis from "conservation" to the real subject, which is "farming." Another strong contender for the title was "land husbandry," with its implications of stewardship and caring management of the land resource.

We can also take for granted that mechanical protection works, such as ditches, drains, and earthworks, may have a part to play, but they are of no use in isolation. What conservation farming is looking for today are packages that start with improved farming and only include mechanical protection work as a component when it cannot be avoided. This concept was also strongly supported in many of the country case studies and during the field trips, where the theme came out clearly that improved production should lead to better erosion control instead of the other way round. One delegate put this neatly saying, "We have spent too much time on the terraces and not enough on what happens between the terraces."

Ironically, this shift in emphasis—playing down the concept of soil conservation as a separate discipline needing a special service to handle it—is today moving most slowly in countries that in the past led in the establishment of successful soil conservation services. It is they who will be trying to catch up during the next decade. After 50 years of the soil conservation movement pressing hard for the establishment of soil conservation services, it will not be easy to put the machine into reverse and say, "We got it wrong. We want a different approach now." Countries in the process of developing a national policy for the use of their natural resources are more likely to choose to follow the model of countries like Brazil or Zimbabwe, where soil conservation is absorbed within extension, than countries that in the past led the world in soil conservation. An example of forward thinking is provided by G. Robertson, the commissioner for soil conservation in Western Australia, who asks, "Are soil conservationists going to be dinosaurs? Or can they adapt to the changing conditions?"

Bottom-up planning

The next issue that I identified only as a windmill was the thought that all soil conservation activities must be planned with the full knowledge and cooperation of the farmers. They must be bottom-up programs, not top-down. It would be an exaggeration to suggest that every case study showed that this principle has been adopted, but it was definitely accepted by the majority of speakers and is likely to be soon accepted by the others. Some of the farsighted papers on planning conservation policies pointed out that when we talk about getting the cooperation of farmers to operate the project we are still only part of the way toward full farmer involvement. We should be going farther back in the planning process and getting the assistance of farmers to define the problem and to be involved from the beginning in considering how improvements could be made. Another good quote was this: "We have to stop thinking of farmers as part of the problem, and make them part of the solution."

The matter of timing

The time scale of soil conservation was another important topic. I suggested that evidence is mounting that technical assistance from aid organizations is more successful when applied through long-term programs than through short, fixed-term projects. Also, it is better to operate through existing government ministries and departments rather than to set up a separate project organization. The country case studies confirmed this, but we should not dismiss this as a battle already won while the entire operation of most of the large multinational and bilateral aid organizations is entirely structured around limited-term projects. Between the Puerto Rico workshop and the publication of this volume, there have been several important discussions of development assistance—the publication of the Brundtland Report, "Our Common Future"; the International Institute of Economic Development Conference on Sustainable Development, and the Nordic Conference on Environment and Development. All of these showed that there is a general acceptance that the changes required in the developing world, toward more effective use of their natural resources, depend heavily upon the idea summed up in the new buzz-word "sustainability," which is another way of saying that a steady, sustained pressure is better than throwing large amounts of money at the problem for a short time. The message coming from the aid agencies is that they appreciate the need for major changes in their policies and operations, but they are like the oil supertankers—so large and ponderous that after a decision on the bridge to change direction the vessel continues for miles before the change is noticeable.

Another aspect of timing is that, to gain acceptance by farmers, any proposed soil conservation activity must offer short-term benefits to farmers. Peasant farmers work to a short time scale. It is no good talking about the effect of degradation 10 years in the future when the immediate problem is how to keep the family fed during the next six months. When defining benefits, the issue is what the farmer perceives to be a benefit. For most peasant farmers the question of cash profitability per hectare is irrelevant. An increase in yield is usually desirable, but sometimes improving the reliability of yield may be more important than the quantity. A desirable benefit might be to improve the production per unit of labor. This might be by increasing production with existing labor, or by maintaining present production with less labor. It is becoming increasingly unrealistic to assume that in developing countries there is a large pool of unused labor available for agricultural tasks. Case studies have shown that the amount of labor that can be invested is a critical constraint on conservation farming.

Prevention versus mitigation

Another windmill is the need for pictures of gullies and land devastated by erosion. At one time this was necessary to catch the attention of political leaders and the general public, in the same way that the famine in Ethiopia was only realized by the public after the pictures of starving children were seen on television screens. In the case of the two related problems of soil degradation and insufficient food production, we must take emergency measures, like gully control in the first case or famine relief in the second, but the main thrust should surely be on the positive side, preventing the problem before it arises instead of trying to cure it afterwards.

In my keynote address I suggested that these principles are sufficiently well accepted, that we did not need to pursue them at length during the workshop. But after hearing the country case studies, this assessment needed some modification. Instead of slides of gullies and devastation, we had a horrific sequence of examples of attempts to cultivate land of ever-increasing steepness. It is a considerable improvement in conservation thinking that we have moved away from the concept of capability classification and the idea that land steeper than "x" percent should not be cultivated. However, I think the workshop showed a swing too far in the other direction, toward the thought that if steep lands are going to be cultivated then our only duty and obligation is to work out how they can be farmed to minimize the damage.

I believe that as advisors on the use of land we have to strike a balance between realism and idealism. We saw many examples of cultivation on land steeper than 45 degrees that can never be made sustainable by physical solutions. There is no way of avoiding or defeating gravity, and on steep slopes with high rainfall, cultivation will inevitably cause much more erosion than there would be in the undisturbed state. It was clear from the country studies that there are too few governments that have accepted the need for a national strategy on the use and development of their land resources. There is really no excuse for this when there are today so many methodologies for systems of land evaluation or classification and the techniques for gathering the necessary information are becoming more efficient with each new development in satellite imagery. There must be some trade-off between the duty of specialists to devise means to overcome the degradation problems that exist and their role to press for better policies to try to avoid the problem arising in the first place. In accepting the concept that steep lands are going to be farmed, therefore we must find solutions, there is danger of forgetting that prevention is better than cure.

This is particularly the case when many of the factors leading to degradation on steep lands have a root cause outside of agriculture. If the problem is an unreasonable pressure of cattle and human populations on the land, soil conservation is not going to solve the problem. Nor is soil conservation going to solve the problem when the causes stem from political and social issues of land ownership and land tenure. Sometimes the solutions to inappropriate land use lie outside agronomy, for example, when the alternatives depend upon creating different cropping patterns and markets, or manipulating the price of agricultural products.

The money and manpower factor

The other main land use problem was beyond the reach of the workshop, but we should keep drawing attention to it. That is the fact that many developing countries are not prepared to devote enough manpower and money to developing their agriculture. Too often these resources are allocated to national prestige projects, sometimes quite unnecessarily. Even worse are the examples of countries that spend an absurd proportion of their budget on armaments while their people are starving. It is becoming difficult for the famine-relief agencies to attract support when the problem is compounded by the intransigent policies of repressive governments.

The real problems

Turning to what we as technicians should see as the windmills and the real problems, I think that after the workshop I can safely repeat two suggestions I made in my keynote address. First, we should stop thinking that we must only make recommendations to achieve the ideal solution and eliminate erosion. Instead, we should be thinking in terms of tactics to minimize damage in the real circumstances. For example, to solve degradation of the Sahel, some suggest that the numbers of livestock be reduced. But since that is not going to happen in the near future, the pragmatic tactic is to look for ways of reducing the damage, like better management of the grazing and the water supplies. The second point is that we should be careful not to try to reinvent the wheel. What one of us sees as a new and unsolved problem may have already been solved somewhere else. The wide range of country reports showed that this is true of many conservation practices, although unanswered questions about erosion processes on steep lands remain.

The objective of the workshop was to share experience in practical soil conservation on steep lands and to make this experience available to others. Speaking for those who instigated and planned the workshop, it was very successful, particularly because it provided a forum where many new thoughts and ideas could be hammered out in argument and debate. This volume presents the more formal part of the results of the workshop, a record of the proceedings. The companion volume embodies the recommendations and will hopefully provide guidelines or signposts for the way ahead. The workshop confirmed our thought that there have been important changes in thinking about land use and soil degradation in recent years, and it provided the opportunity for a definition of how the new approach to conservation farming can be put into practice.

2

Conserving soil by stealth

T. F. Shaxson

Experience suggests at least three reasons why frontal attacks on soil erosion have not always resulted in soil conservation: (1) We have not always paid attention to how farmers or other land users feel about erosion or about our recommendations for dealing with it. (2) We have tended to attack erosion by itself when the problem is inappropriate land use and management. (3) We have recommended inappropriate practices.

Farmers, graziers, and foresters are primarily interested in plant production, not conservation per se. Therefore, recommendations must fit the agronomics and economics of what they are trying to achieve (Figure 1). It is necessary to get soil conservation integrated with plant production rather than vice versa. Improving soil conditions for rooting and improving soil structure and infiltration capacity will achieve both purposes.

Some social aspects

Farmers, graziers, and foresters are the final arbiters of what will be done in fields, pastures, and forests from day to day. Their perceptions of how recommendations fit in with the agronomics and economics of what they are trying to achieve will affect whether or not they decide to implement the recommendations and maintain them.

In situations where things have not gone well, it is important to find out why land users did not adopt, implement, and maintain recommended practices. Possible reasons might include: (1) Ignorance of what is recommended. Is there contact with Extension agents? Do the Extension agents know what the recommendations are? Are there options for action that can be offered? (2) Lack of resources to implement recommendations in an acceptable time-frame. If so, can the individuals costs be subsidized in cash or in kind by the local or wider community? Does the present land use system produce enough output to bear the expected costs? Can costs be reduced by changing the recommendations? (3) The land user is unwilling to implement the recommendations. Is this because he or she judges the expected results to be unworkable or uneconomic in terms of costs and benefits or social consequences?

Given these possible reasons for nonadoption of soil conservation recommendations, it could be said that projects whose chief objective is only to conserve soil are, in fact, the least successful in doing so.

The types and sequences of plants that land users grow are dictated by considerations of profit and/or subsistence. The types and sequences of plants that conservationists may recommend are often dictated by a primary concern for soil conservation. Plants used to achieve the two goals may or may not be different. Emphasizing activities that improve soil conditions for rooting favors the farmer's aim of more vegetative production per hectare. Crop cover and plant residue assist the farmer's goal of good

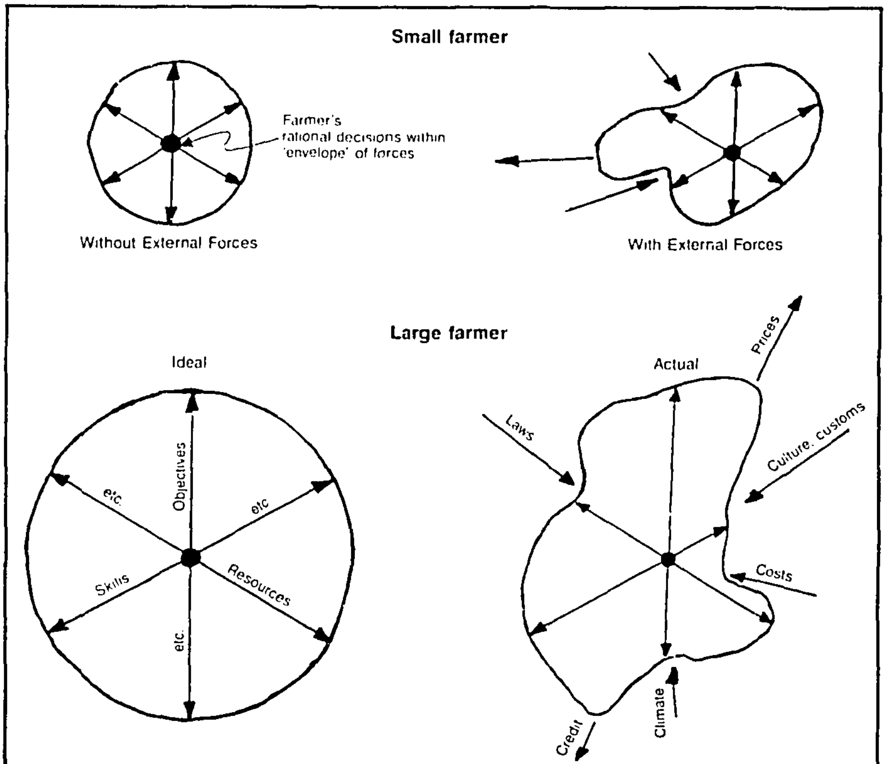

Figure 1. "Distortion" of the farmer, with and without external forces.

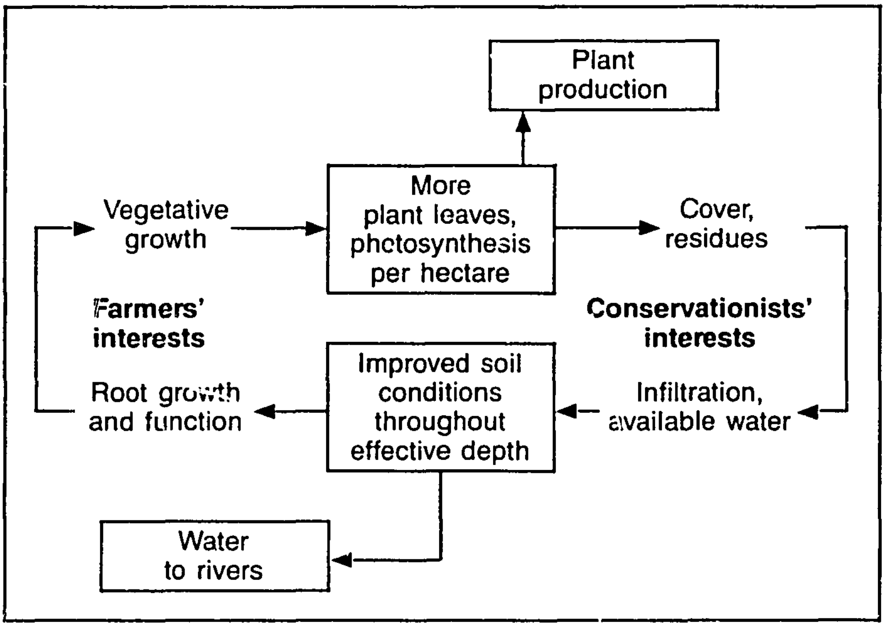

Figure 2. Integrating water and soil conservation with agriculture (3).

infiltration capacity and soil structure, which are also the conservationist's aim (Figure 2).

Some technical aspects

A major challenge we have is that of increasing plant production per hectare per year without degrading or destroying the soil in the process. We have not been very successful so far in achieving both aims simultaneously, chiefly because intensifying plant production often has meant more tillage. This degrades both soil structure and rooting conditions and makes the soil more susceptible to erosive forces. In this context, all forms of reduced-, minimum-, or no-tillage offer advantages both for plant production and soil conservation.

A lack of distinction between "conservation" and "reclamation" has often resulted in too much emphasis on programs for repairing spectacular damage and too little on the preservation of productive lands not yet seriously damaged. To emphasize reclamation where there is inadequate social or economic justification can waste scarce resources. Encouragement of the growth of recolonizing vegetation may be the most economic means of stabilizing seriously degraded land.

Following a similar line of thought: If erosion has been occurring because there is too much bare ground exposed to erosive rainfall, the construction of banks across the slope to reduce runoff effects will have little impact on the real problem.

In defining the possible options for solving any problem of erosion by water, we must consider how to maintain appropriate overall combinations of the following key features: (1) effective depth for rooting, (2) structural soil conditions in this effective depth, (3) duration plus density plus frequency plus above-ground location of plant and residue cover, (4) steepness of slope, and (5) length of slope. Most commonly, slope steepness and soil depth are relatively unchangeable. Slope length often can be modified. But the most critical variables under control of the land user are those of cover and soil structure. Changing one of the above factors without making compensatory adjustments in the others usually proves insufficient to stabilize an unstable situation.

Soil productivity is a matter not only of fertility but of organic matter and physical conditions, such as aeration and water relations generally. The national centers for soya research and for wheat research in Brazil recently stated that many farmers are unable to achieve expected yields because the soil environment for rooting of plants has been severely degraded by pulverization of the surface and compaction of the subsoil (*2, 3, 4*).

Erosion is not an invisible disease stalking the land in search of soils to destroy, but is, in fact, a foreseeable ecological response to inappropriate land use and management. Because it happens as a consequence of altered interactions between various factors of the environment—climate, soil, vegetation, water, topography, and others—it behooves us to try and identify the root causes of any land degradation problem and thus avoid the "knee-jerk" reaction of recommending terraces and land use change in every situation, which has happened all too often in the past. Identification of real causes allows much more reasonable recommendations of appropriate action. The answers may be social or economic rather than purely technical.

Another major cause of farmers' disaffection with conservationists' recommendations for land use is the rigidity with which we interpret and map erosion hazard, particularly with reference to "nonarable" classes. All too often the broad type of use—pasture, rough grazing, plantation forestry—are automatically attached to classes VI and VII. It may be unrealistic to make this link automatically. Small farmers confined to steep land have no option but to cultivate that land. However, government authorities may be unwilling or unable to move them in the interests of better land use.

To solve this serious problem, it is necessary to define type of land use and management in terms of the combinations of cover, soil structure, soil depth, slope length, and steepness that a farmer's preferred type of use—even annual planting of crops on steep slopes—must achieve if it is to remain stable. Annual cropping with minimum tillage and retained residue cover may be a better alternative on a steep slope than overgrazed, poorly managed pasture. The important thing in determining whether or not a particular land use and management scheme is acceptable is the effect it has had on the land over time.

Three criteria suggest themselves as measures of adequacy for any chosen type of land use: (1) Is production sufficient? (2) Does the preferred use provide and maintain sufficient cover and good soil structure conditions? (3) Is the soil eroding at an excessive rate?

Examples of failures

Where schemes and projects aimed primarily at soil conservation have not put the satisfaction of farmers' requirements at the head of the list of goals, farmers have been lukewarm, if not downright antagonistic. On the other hand, where projects have paid due attention to farmers' aims, using conservation as one criterion of success, enthusiasm and involvement have been markedly greater and overall success more frequent.

Following are several examples of failure in soil conservation efforts because the people became disillusioned:

In some central African countries, well-meant programs requiring villagers to construct contour banks on cultivated land provoked severe resentment of government officials (*4*). The programs also provoked widespread mistrust of the departments of agriculture when villagers who refused to undertake the task were fined or imprisoned for noncompliance. People were especially embittered when they saw that even where banks were constructed the problem of erosion did not end.

In India, construction of level contour banks by government personnel over wide areas of vertisols led to waterlogging for significant portions of the rainy season, which reduced crop production. The antagonism this generated toward government personnel effectively halted, for several years, the work of soil conservation as well as other forms of extension concerning crop and animal husbandry.

In a large-scale land development program in central Africa, with significant loan funding from the World Bank, the method adopted to prevent channels from becoming choked with eroded soil from interbank areas was to increase runoff flow velocity by increasing the gradients. The government remained responsible for repayment of the loan even though the portion used for bank construction may well have been of little or no net benefit. Because the villagers, across whose lands the banks were constructed, perceived no particular benefit from most of the banks (except those providing all-weather road access), they were unwilling to undertake maintenance (clean-out) of the channels, which would have maintained their effectiveness in preventing erosion and possible gullying. The government then had to decide whether to abandon the banks once the channels were choked, or to spend further resources on undertaking maintenance.

Again, in central Africa, an attempt was made to implant a textbook demonstration of planned land use in accordance with the erosion-hazard classification of several hundred hectares of village lands. The government fenced off areas deemed suitable only for grazing, constructed an integrated network of gradient banks, protected waterways and crest roads, and built dams that provided stock-watering points and key road crossings. However, driving heavy earth-moving machinery across the large number of densely cultivated plots of village farmland generated so much resentment that within a few months of completion of construction works little could be seen, even from the air, save a few tracks and some of the dams, none in a reasonable state of repair.

Examples of successes

On a happier note, some examples of success counterbalance the above gloomy picture:

The approach taken to conservation on tea estates in Malawi was to tell managers that a significant reduction in the costs of producing tea could be achieved by reorganizing the road system to allow uninterrupted access to the tea gardens during the rains, the main production and harvest period. The challenge was accepted, and a system was devised for areas of new plantings and replantings. Earth roads were aligned wherever possible along topographic crestlines and integrated with lateral roads and conservation banks along contoured lines on controlled gradients. The contoured layout promoted the alignment of tea rows relative to the contour, rather than in straight rows, which had been the practice. This assured that weeding and harvest practices tended to impede downslope movement of any runoff water. Agronomic research had shown that mulching benefited the growth of young tea. This was undertaken also along the contour, which not only benefited the young plants but simultaneously provided protective cover to the soil. Roads along crests were not subject to damaging cross-flows, and roads on or immediately below controlled-gradient conservation banks were satisfactorily drained and remained passable at any time. Many managers who implemented the layouts said that while the costs of putting the layout on the ground were somewhat higher than those of the conventional system annual maintenance costs were very much reduced. This was because of the reduction in runoff, which had damaged roads, and of erosion, which carried off soil and fertilizers and choked the channels of the conservation banks. The attraction was the reduced cost of production; a stealthy result was the reduction of land degradation.

At Indore, in central India, a village development project was originally designed with strong emphasis on the installation of a conventional system of soil and water conservation. Because insensitive government action in previous attempts to control erosion had severely antagonized the villagers, it was quickly seen as inappropriate to insist that, true to textbook recommendations, conservation activities should begin at the top of the catchment and work progressively downslope. In fact, it was initially inappropriate to suggest soil conservation measures per se. The strategy adopted was to first investigate the factors that farmers felt were limiting their efforts to achieve a better life and gain farmers' confidence with various agreeable improvements. These included the introduction of better varieties of sorghum and encouraging the use of fertilizers, promoting the use of irrigated Berseem clover, demonstrating that maize could be grown with fertilizers on parts of the village land never before used for the purpose, helping to sort out problems of electricity supply to village irrigation pumps, and helping to alleviate other common problems. Farmers' confidence both in themselves and in their extension advisers greatly increased. Improved productivity provided more surplus crops for sale; protective storm drains reduced temporary waterlogging and loss of seeds and fertilizers; soil damage by high-energy rainfall declined as a result of better crop cover; extra cash income enabled farmers to haul themselves out of debt to the local moneylenders; and a generally cooperative spirit developed between villagers and their advisers. After three years, the villagers decided to restrict the previously uncontrolled communal grazing on a poorly grassed hill to allow the planting of trees for use as firewood and timber. The grass growing between the saplings had opportunity to seed, and the density of herbage increased quickly on what had been a severely overgrazed area. Soon there was a good bulk of fodder for cutting and carrying. A noticeable result was a reduction in runoff affecting the pasture and cultivated lands at the foot of the hill. In the end, farmers said that they were now ready to do whatever might be necessary to tackle the problem of gully erosion, which, after the removal of more pressing problems, was the next difficulty to be faced.

At the western end of the state of Santa Catarina in southern Brazil, there are small farmers growing annual crops in large areas with average slopes over 20 percent. The combination of soil types (reddish clays derived from basalts) and rainfall regime (some rain in most months of the year, but often very erosive) has allowed the development of minimum-tillage systems for annual crops, such as beans, maize, and soya. These systems are characterized by the maintenance of 100 percent cover practically throughout the year with living and dead mulches of vetches and other low-growing legumes. Annuals are contour-planted through these mulches either in narrow furrows or using punch planters. The farmers describe the soils as being "fatter" in terms of organic matter content and soil structure, and they are able to maintain yields with less fertilizer and reduced pesticide use. In passing, they also mention that runoff and erosion is significantly less than before.

Across the state border, in Parana, on somewhat similar soils but lesser slopes, excessive use of disk equipment in growing soya and wheat in rotation had caused serious problems of compaction at the bottom of the disk layer. This results in large volumes of runoff and removal of eroded soil and requires municipal authorities to spend large sums annually on rural road maintenance, to the detriment of financing other more positive social programs. Crops often suffered from mid-season moisture stress in dry periods during the summer rainy season because of shallow root systems. Winter wheat suffered similarly from moisture stress within its restricted root range. The local rivers and streams were choked with sediment and polluted with pesticides and fertilizers brought down by the runoff and erosion. After extension agents promoted deep tillage to break up the compacted layer and encouraged farmers not to burn crop residues, road damage declined to a startling degree, springs that had dried up early in the dry season started to flow more strongly and longer, possibilities for fish-farming and irrigation have increased, and water quality in streams and rivers is greatly improved.

Through programs aimed at improving water management and making cropping more secure, conservation of the soil has been achieved as a consequence of improved land use.

Satisfying land user aims

Because erosion is a consequence of inappropriate land use, conservation of the soil in situ will be a consequence of appropriate land use. Our challenge is to devise ways in which the land users' aims can be satisfied with systems that are also conservation-effective.

Using this line of thought, we might invert the wording in the notice of this workshop. It now reads: "There are numerous examples around the world of successful systems for controlling soil erosion while increasing crop production..." Should it not read: "There are numerous examples around the world of successful systems for increasing plant production while controlling soil erosion"?

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3

Soil conservation on steep lands in the tropics

Maurice G. Cook

The tropics constitute the world's major battleground between efforts to attain food self-sufficiency and to preserve fragile ecosystems. During the last decade, real increases in food production per capita were achieved in Asia and Latin America that virtually prevented a worldwide food crisis (*2*). Estimates for the next decades, however, are less positive, partly because most of the food production increases have been achieved on land with fertile soils, irrigation, and adequate infrastructure. Worldwide estimates indicate that, in addition to increasing crop yields on this favored land, an additional 200 million hectares of new land must be in production by the year 2000 to maintain the present, but largely inadequate, levels of world per-capita food production (*1*).

Limitations to production

Most of the land that is currently not farmed and that has sufficient rainfall and temperature for productive agriculture is in the tropics. Much of that land is marginal. though, because the prime land is essentially fully occupied. Steep lands constitute about 400 million hectares of that marginal land in tropical Latin America and the Caribbean. This is more than 25 percent of the total land area in these two regions. In addition, the carrying capacity of most tropical steep lands is already exceeding its limits. Potential and actual misuses of these steep lands have caused worldwide concern about widespread deforestation, erosion, and silting of reservoirs downstream.

The most extensive limitation on steep lands is severe soil erosion. Because of the extreme slopes often encountered, the stability of the soils after clearing is often low. Calculations using the universal soil loss equation indicate soil losses of 500 tons per hectare or more. Actual rates may not be that high. Nevertheless, erosion rates of 100 tons per hectare will remove the topsoil completely in about 20 years. Many examples can be seen of soils that are abandoned after a couple of decades of abuse.

A second major concern on steep lands is a pronounced dry season in about two-thirds of the steep land area. Many steep lands are in semiarid climates and, therefore, combine some of the worst attributes of the fragile land. During the long dry season, plant cover is either sparse or nil, leaving the soil exposed to the first intense rains of the wet season, a perfect setting for erosion. On the remaining one-third of steep lands, which have a udic soil moisture regime and no long dry season, the soil is protected by a plant canopy that dramatically minimizes the erosion hazard. Rainfall distribution patterns, therefore, help explain differences between places such as the relatively prosperous steep lands of Pasto, Colombia, with no strong dry season, and the Choata Valley in nearby northern Ecuador, which has a strong dry season, and the hills are literally sliding down.

Steep lands also have soil fertility problems in addition to their erodibility and the semiarid climate. Low nutrient reserves and aluminum toxicity are significant problems on at least a third of all steep land areas.

Socioeconomic consequences

The danger of massive land deterioration on steep lands also poses serious socioeconomic concerns. Level, fertile land is the obvious choice of any farmer. The fortunate land settlers occupied such land in the tropics. With time, these settlers became more powerful, and the less powerful were gradually displaced to the adjacent steep lands. Traditional technologies developed by the initial settlers of steep lands allowed for sustained production systems, although at very low yield and income levels. Thus, most steep lands had relatively stable, sustained production systems with minimum environmental damage up to the first half of this century.

However, increased population growth during the last few decades has resulted in further fragmentation of small holdings on steep lands and an increasing number of landless, rural families. Many of these families chose to migrate either to the urban centers or to the sparsely populated humid tropics. Attracted by prospects of industrialization that did not materialize, migrants settled in slum areas, swelling the population of cities that already were large. Lima, Peru, for example, had a population of about 2 million people in 1960, but the city has grown to nearly 6 million today. Half of Lima's population lives without electricity, sewer systems, or running water. There is massive poverty in the cities, and this is one of the main causes for widespread civil unrest common in many countries.

What happens to those left behind on steep lands? Family growth forces further fragmentation of land into very small parcels. Women are increasingly in charge of farming because many migrants leave their families behind. Many men commute between their traditional homes on steep lands and their outposts in other areas every few months. As farms decline in size, another serious consequence is that farmers are forced to use destructive farming practices. For example, in the Dominican Republic highlands, female farmers are now plowing old pastures on 100 percent slopes in order to plant corn and beans. When interviewed, the women state candidly that they are aware the land will likely erode to bedrock in three to five years. But they do not have any other place to grow food. After a few years, they will probably migrate to a city, thus making the urban problems even worse.

Deforestation is severe on steep lands, and trees are seldom replaced either naturally or by reseeding. They are first used for building construction, which tends to use the best timber. The remaining trees are used for fuelwood. A landholder who wishes to maintain his land in trees is seldom able to do so because his neighbors stage continuous invasions of his land to gather firewood.

Off-site effects of soil erosion

Not to be overlooked are the off-site effects of soil erosion on steep lands. The off-site effects are variable and not well quantified. Nevertheless, it is known that the eroded soil moves into rivers or reservoirs in many cases, and this problem can only become worse unless erosion on steep lands can be reduced.

Steep land problems are more severe in some countries than others. Countries with the combination of steep lands and a long dry season face the greatest peril. Obvious examples are Haiti and El Salvador. There is little doubt that steep lands with all their ramifications are a major factor causing civil unrest in both countries. Other potential powder kegs are Peru, Jamaica, Guatemala, and Mexico.

Unfortunately, there are numerous constraints to improving these fragile steep lands. These constraints may be divided into three broad groups: (1) information and awareness, (2) institutional and policy, and (3) technological. These three areas must be tackled simultaneously in order for progress to be made.

The main information and awareness constraints are twofold: (1) A majority of the public is generally not aware of fragile steep land issues. This ignorance is widespread on erosion and flooding and the eventual social impacts, such as reduced agricultural profitability, increased cost of agricultural commodities, social costs of human relocation, and increased cost to public work facilities and transportation systems due to sedimentation and flooding. (2) Because of general public ignorance, politicians and interest groups assign little importance to steep land issues. Steep land dwellers do not have a clientele that is influential in social, economic, and political circles. These people are a low priority for budget outlays.

The main institutional and policy constraints include the following: (1) Lack of continuity in government development policies, resulting in frequent reorganization with little, if any, improvement. (2) Policies designed to placate the urban population with low food prices that discourage farmers and result in disinvestments in lands. For example, in an extreme case, a government may import a key commodity, such as rice, near harvest time to lower the price paid by consumers. This, in turn, depresses the price paid to farmers. The net result of these policies is more migration into the cities. (3) Lack of an effective agricultural credit system, coupled with insufficient transportation infrastructure. This inhibits the delivery of farm outputs and farm products in a timely fashion. Countries such as Ecuador have placed special emphasis on this issue, and they clearly have a higher potential for improving the management of their steep lands.

The main technological constraints are (1) lack of a sufficiently detailed land resource database where land constraints are systematically identified and interpreted according to up-to-date technology, (2) lack of adequately trained specialists to live and work in steep land areas, and (3) lack of well-coordinated technology transfer networks for steep land areas with similar technological constraints.

A plan of action

Much more could be said about the problems of and the constraints to improving steep lands, but the critical question is this: What can and should be done? One important next step is to establish a mechanism to address the problems and constraints that have been described.

This organization should be established (or an existing one identified) that would have a major coordinating role in networking the myriad of organizations involved in conservation. It could carry out such activities as preparing and distributing a newsletter and conducting technical workshops and conferences in relevant countries. These and other efforts would allow individuals to stay in touch with each other and to keep updated on what is working successfully and what is not. It could also serve as a resource base for organizations trying to strengthen their efforts in conservation.

A major need and something that an organization such as this could address is the matter of economic incentives to local farmers. All of our best technical efforts will come to nought unless they prove to be helpful to those who depend upon the land for their livelihood. One such area where progress can be made is in the marketing and transport of produce from fragile lands. In general, farmers on steep lands are isolated from markets, which makes their access to buyers expensive and often impractical. There needs to be developed better marketing alternatives, such as improved handling of agricultural products or cooperative transportation. The conservation alternatives should improve the economic viability of farm systems on fragile lands. They should provide farmers with a better cash flow, increase the value of their land, and, thus, provide a real incentive for soil conservation.

Obviously, financial resources are needed to enable this organization to succeed in this worldwide endeavor. It is proposed that a donor support group for steep land problems be formed. It could include representatives from such well-known organizations as the U.S. Agency for International Development, World Bank, InterAmerican Development Bank, U.N. Food and Agriculture Organization, and many others. The Soil and Water Conservation Society and the World Association of Soil and Water Conservation stand ready to support further initiatives on this subject to the extent available technical and financial resources will permit. We need to act quickly. At stake is the quantity and quality of the soil resource in steep land regions. But even more critical for the millions of people who live and work in steep land regions, the issue at stake is life itself.

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II

PRINCIPLES AND PROGRAMS

4

Planning and implementing soil conservation projects

Ted C. Sheng and James R. Meiman

Soil conservation projects are difficult to sell because results from them often require a long time to materialize, benefits are widely dispersed and not easy to identify, and individual farmers must invest heavily in the projects. Individuals and nations both are looking for quick, direct returns on their investment. However, if planned and implemented properly, it is often possible to encounter fewer problems and achieve both short-term and long-term benefits. Each country has its own unique set of circumstances. The factors mentioned here are generally applicable, but they should be examined closely in each case.

As scientists, many of us tend to look at conservation problems in terms of soil-plant-animal-water relationships. We neglect the roots of the problems in social, economic, and political terms. Technical and socioeconomic solutions are equally important.

Soil conservation projects are people- or process-oriented. By people-oriented we mean that the biophysical treatments proposed begin and end with the people living on the land. The approach is becoming well-known through experience with on-farm water management in irrigation systems, community forestry, and farming systems techniques (*3*).

A process-oriented approach means that we should not start with all the answers and draw up a plan as we would in designing a bridge. Rather, we start by looking at the environment in the way the people living in the area see it. From this starting point, a learning-by-doing process is begun, and adaptations are made as necessary. One can start small and demonstrate what can be done for a particular problem area before moving to larger areas. This allows enough time for successful solutions to evolve. The small start should show some tangible results quickly. At the same time, external factors that affect people living in the area, such as laws, policies, incentives, services, and markets, should be addressed. The purpose is to bring bottom-up and top-down approaches together.

An effective, interdisciplinary approach is needed for any soil conservation project. Teamwork must be stressed. Experience has shown that if the project is designed from the start as a team effort there is a better chance of success.

Planning considerations

Single or multipurpose project. One of the questions facing the planner at the beginning of any proposed soil conservation project is whether the project should be solely for erosion control or for more than one purpose. Experience has shown that in developed countries or economically advanced developing countries both the government and the people are usually concerned with conservation and environmental protection. In these countries, projects with the single purpose of erosion control or land conservation will likely get public support.

In less developed countries, "production" or "development" is often emphasized. Conservation becomes secondary because it slows down the rate of resource use, spreads benefits over a longer period, or simply cannot earn foreign currency. While a nation is struggling for survival, any project aiming only at conservation or environmental protection will hardly get government and farmers' support. In these countries, soil conservation projects should be designed to achieve multiple purposes. The usual strategies are to include in the conservation projects some production goals, such as crop production, water production, or power production, and to integrate soil conservation with other development projects, for example, rural development, watershed development, land settlement, or irrigation development (*4*). So long as conservation work will be carried out to benefit the land and the people, the name of a project is not important.

The planner should, however, be concerned about the adequacy and effectiveness of such integration. Inefficiently involving too many other activities or inadequately introducing conservation work will defeat the purpose.

Targets against capabilities. Targets should not be too ambitious, bearing in mind that a small success is better than a big failure (*5*). They should match the capabilities of the nation's institutions and of the farmers in the project area. This is quite obvious, but many conservation or watershed management projects repeat this mistake over and over. The reasons are not difficult to understand.

Governments take the opportunity to seek as much foreign aid as possible, while the international agencies tend to inflate the targets and benefits in order to make justifications. For example, a conservation agency proposes 1,000 hectares to be treated in a year. The ministry in charge then alters the target to 2,000 hectares. The government planner or the international agency later increases it to 5,000 hectares. Without understanding the working conditions, many people mistakenly think that if only the necessary funds are provided the work will be carried out.

People must realize that institutional strengthening has limits (5). A conservation agency may not be permitted to outgrow similar government agencies. Temporarily employed technicians in a conservation project may be dismissed once the project is terminated. This will cause frustration and a waste of time, training, and human resources.

Personnel training requires time. A conservation project cannot rely mainly on new recruits, giving them some training and sending them out to do a successful job. Experience shows that a college graduate in soil conservation may need several years of field experience to be able to do independent work. Less qualified persons may need even more time and require more supervision. Yet in many developing countries there are not enough professionals in this field who can do independent work as well as supervision.

Institutional coordination is also a problem in developing countries. Qualified professionals are scarce in every agency, especially the engineers, hydrologists, soil scientists, and economists needed in soil conservation projects. Often, only after an agency's own business is taken care of, may they lend their hands to others.

It is most important to consider the acceptance of farmers and their capabilities. Farmer acceptance is always gradual. We know of some projects where, after several years of intensive extension and incentives, farmer acceptance in a watershed or project area was still less than 50 percent. Even when farmers accept the project, their capability should still be considered. For instance, if terracing a hectare requires 450 man-days, the project should not expect each family to accomplish that much a year.

Resources and schedule conflicts. After a realistic overall target is planned, the next consideration is to set a time schedule based on the flow of resources. Critical stages and bottlenecks should be identified and solutions sought. Realizing that it takes time to get human and other resources in place to carry out the planned activities, thorough consideration and preparation are necessary. A comprehensive network analysis is usually needed.

Alternative courses should be adopted in case there are conflicts. Regulating resources flow, modifying technology, and adjusting progress are some of the techniques to overcome the conflicts.

When farmers' acceptance is slow and the project is process-oriented, a progressive work schedule is desirable. At the beginning, work can involve pilot farmers and grow gradually as trained staff are available for assisting them. As lessons are learned and the confidence of farmers and technicians increases, the project can accelerate. This is why projects often require a long duration.

Appropriate planning approaches and techniques. Planning is a dynamic and iterative process, and all conservationists should realize that plans are points of departure rather than rigid fiats. Any plan should allow for continuous refinement as experience is gained during the project life.

A major problem usually confronting the planner is how to reconcile "what should be done" and "what can be done." What *should* be done can be found by physical surveys of topography, soils, present land use, and erosion hazards so that a rank of priority areas can be set. What *can* be done is limited by socioeconomic conditions and the capabilities and interests of individual farmers. Success will occur only if soil conservation practices are integrated into the farming system by the farmer. This takes time and effort. An effective plan will show how resources will be used to bring together what should and can be done.

Eventually, farm planning for each farm or for groups of farms in a project area will provide the necessary bottom-up information. But at the stage of planning and before project approval and implementation, it is too time-consuming to complete such work on individual farms. Instead, some simplified bottom-up planning techniques can sometimes be used, such as conducting sample surveys of farmers' needs, developing farm models, or carrying out reconnaissance-type socioeconomic surveys in the project area. Whatever it is, the design of questionnaires and survey forms should be done carefully, and farmers should be well informed about the objectives.

Technical criteria used for classifying land capability and for estimating conservation needs should be practical and reliable. If not, it will cause difficulties in the later implementation stage. The conservation practices to be introduced must be effective in erosion control. Otherwise, the main objective of the project will not be fulfilled.

Implementation considerations

Effective mechanisms for assisting farmers. An effective mechanism for assisting farmers is the key to successful implementation of such projects. The problems always are which organizations should be involved and how will they be organized? Emphasis should first be put on establishing field offices that can offer effective assistance to farmers. Many top-heavy, traditional institutions in developing countries should alter their structure and shift more resources to the field, delegating more authority to the regional and field offices (*4*).

The effective delivery of soil conservation techniques to farmers involves an understanding of a farmer's system. This requires an interdisciplinary team to work with the farmer. The team may be led by one agency, such as a soil conservation service, a forestry department, or an extension agency. There is no single answer; circumstance vary from country to country. The problem for extension services is that their field agents usually have been overloaded with too many other duties. In other agencies the problem is that staff normally lacks experience, resources, and a network to deal with farmers.

Experience shows that a joint approach and teamwork among the field officers of the agencies can serve the farmers better. At the beginning of conservation projects, time should be spent in organizing and developing field teams fully supported by subject-matter specialists.

Incentive needs. The need for incentives to encourage farmers to adopt conservation practices has been well documented (*1*, *2*). The reasons are twofold: Many farmers have few resources to invest in conservation, and many soil conservation benefits accrue in the future and to others.

The popular and most direct incentive is to give cash subsidies for work performance or as partial wages. Food and other items are also used as incentives. There are advantages and disadvantages in using cash as a subsidy. Cash is easy to handle, but it can be misused by farmers. On the other hand, giving commodities increases management problems, such as transportation and storage, and also involves farmer preference.

Indirect incentives, except technical assistance, are used far less in developing countries. Some, like tax exemption or deduction and security in land tenure, may require exhaustive discussions and years of planning with land and tax authorities. Such proposals often need legislative support. Others, like farm credits and marketing service, can be effective if a project takes an interdisciplinary approach.

Effective use of incentives requires a detailed knowledge of the farming system as well as a thorough understanding of the farmer. A good incentive will promote the farmer's goals, will encourage eventual self-reliance on the part of the farmer and the community, and will fit into both short-term and long-range plans. A special consideration in conservation work is to provide incentives for proper maintenance.

Incentives should also be given to government staff who work in the field. The working conditions in rural areas, especially in uplands, are mostly rough and inconvenient. Without proper incentives, such as adequate per diem, priorities for promotion, and opportunities for advanced training, the project will have difficulty in attracting and maintaining competent, dedicated personnel.

Adequate administrative support. Good administrative support is essential but often neglected. Administrators tend to pay more attention to headquarters than to the field offices. Services to field offices in many countries are poor, and staff assigned there have a sense of being downgraded. Sufficient vehicles need to be provided to them for field use. Necessary equipment should be available in the field. These are essentials because soil and water conservation work is field-oriented. In many countries there is no delegation of authority in the field regardless of the difficulty in communication. Another serious problem is frequent changes in project leaders and key personnel, without concern for continuity.

In the real world it is not uncommon for field staff to be bogged down because of a lack of transportation, equipment, funds, leadership, and/or authority.

Training and research needs. Staff training is an element vital to the success of conservation projects. A project can only grow as fast as trained persons are available to implement the plan (5), but professional training in soil conservation or watershed management is rather rare in the Third World. Although young people can get trained abroad, the physical and socioeconomic conditions are so different that they need to be re-oriented when they return home. What really is needed is a well-designed and continuous in-service training program tailored to local needs. Such in-service training programs should offer to involve young professionals of various disciplines, along with technical officers and field assistants. Experience shows that four to five weeks should be an appropriate duration for the initial, basic training of professionals and sub-professionals, including substantial time for field practices. For field assistants and extension officers, the duration can be shortened.

In addition to staff training, farmer training should also be carried out as early as possible. Usually, awareness campaigns and project introduction meetings can be employed at the beginning of a project and carried on as long as needed. Special training for farm leaders and contact farmers should follow as soon as technicians and extension officers are properly trained and demonstration plots start to show tangible results.

Problem-solving and practical research should be included in the project. Adaptation trials for new species and for transferred technologies are also needed (2). These are short-term, applied experiments that governments and international aid agencies should agree to include as a part of the project. Many applied, on-farm field studies provide a most effective mechanism for linking together technicians, farmers, and extension workers, as well as for developing an interdisciplinary approach.

Monitoring and evaluation systems. Lack of basic data and evaluation results are common short-comings of many soil conservation projects in developing countries. With competition for resources, these are necessary to continue to attract investment in conservation projects. Final evaluation results should be made known and should include physical accomplishments, economic benefits, and social and environmental impacts.

Using an inexpensive personal computer and existing software, a project's data base can be established gradually. During the project's life, continuous monitoring should compare the planned targets with actual achievements. Such internal and continuous self-monitoring becomes a strong building force and ensures that a learning process approach is put into practice.

Evaluation mechanisms should be built into a project with the methodology clearly defined. Establishing an independent unit for evaluation, partly involving outside experts, is an ideal approach. Because the benefits of soil conservation are difficult to assess, only the most important benefits need to be taken into consideration. For instance, evaluation can be centered on major land use changes, farmers' income, sedimentation rates, water quality, etc., as required. Once the items are determined, the methodology should be spelled out and necessary equipment installed. Too often evaluation is a last-minute endeavor, without proper data, that proves ineffective.

Soil conservation work takes time. A project should be given a sufficient period to show results. Often, when a project is barely started, groups of outside evaluators are at the doorstep disrupting the project and its staff. Outside interference should be kept to a minimum, especially in the early phases of a project.

In conclusion

There are many more considerations in planning and implementing successful projects, but the most important of those we have identified here are as follows:

► Projects must be looked at as complicated systems, requiring an interdisciplinary approach that combines biophysical and socioeconomic elements.

► A process or learning approach must be used that involves the farmers or land users in each step. In such an approach, the land users and technicians learn from each other.

► Project activity takes place in the field; therefore, legislative, technical, and administrative support should focus on field operations. This support should be accompanied by delegation of authority to field officers.

► A project's duration is usually a brief part of the long-term horizon needed for successful conservation programs, and this should be realized in the planning and implementation of a specific project. It is each country's responsibility to develop and control this overall conservation program, no matter how much project help it may obtain.

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5

Options for conservation of steep lands in subsistence agricultural systems

Hans Hurni

About eight percent of the world population are farmers living in subsistence agricultural systems on steep lands. Many of these farmers are threatened by land degradation, mainly soil erosion or problems associated with steep land irrigation. Because of various limitations, few conservation options remain for these farmers on specific fields when all economic, sociocultural, ecological, technological, and political factors are applied. The Ethiopian case demonstrates why this is so.

Options in soil conservation

Soil conservation always means change. "Traditional" ways of using the soil resource have failed to conserve it and call for a different way of agriculture. If soil conservation as a goal has been accepted, change must be accepted as well. The key questions, however, are these: What type of change is needed? What type of change is possible?

While the first question usually can be answered with a list of measures, the second eliminates many of them. Following are six groups of potential changes, which are discussed in the context of steep land subsistence agricultural systems and the two aforementioned questions.

Land use. There exists severe economic constraints to land use change. Subsistence agricultural systems normally are organized in a very refined way and provide many internal options to common hazards. If, for example, rains are late or crops are destroyed by hailstorms, reseeding or replanting is done immediately. A variety of crops is grown on a field to cope with selective occurrence of diseases or pests. Livestock is an integral part of the farm and can be used as financial stock, draft power, and a source of food products.

In such systems any change in land use means reorganization of the whole farm, or even the neighboring community. Even slight changes affect the whole community much more than in nonsubsistence systems. Moreover, land use changes may not be feasible ecologically, as in drier zones where a dense cover on the ground can hardly be attained, especially if livestock grazing is involved.

The most effective measures to reduce soil erosion are changes in land use leading to a more dense vegetative cover. For example, the conversion of cultivated land to grassland will reduce erosion to at least one-tenth, if not one-hundredth, of current rates. Changes in land use, however, can only be justified if no other options for soil conservation exist. For example, cultivation on steep lands with a very short future use due to already shallow soils must be changed to land use systems with a much more dense vegetative cover, such as permanent grass, even if this poses problems for the farmer and the community he lives in. Therefore, if major changes of land use are inevitable, farmers must change their subsistence system, in most cases to "modern" farming with economic interdependence.

Ground cover. Changes in ground cover offer a promising alternative within present agricultural systems, especially if no change in land use is required. Potential soil conservation measures improving ground cover include dry seeding, intercropping, agroforestry, alley farming, grass strips, grass development on bare ground, and grassland improvement. While some techniques, such as dry seeding, are appropriate only in areas where the onset of the rainy season is reliable, and while intercropping is already applied in traditional systems in many parts of the Third World, the remainder of the measures aimed at increasing ground cover offer good opportunities for both conservation and development. Furthermore, gully borders, earth bunds, waterways, and cutoff drains can best be protected against erosion by establishment of a dense vegetative cover.

Many constraints to changes in ground cover are ecological. For fodder and fruit trees in agroforestry systems, there is an altitudinal limit at about 2,500 meters above sea level and a second limit toward drier zones. In combination with cereal crops, trees are generally not esteemed by farmers, especially at higher altitudes, where subsistence farmers are concentrated due to more favorable environmental parameters, such as lower temperatures, reduced diseases (except pneumonial diseases), and higher reliability of rainfall. Grass strips are only useful on cultivated land if grazing is avoided throughout the year, a difficult option in subsistence systems. Intercropping cannot be practiced for every crop, especially not for wheat and barley. If these crops are applied solely, that will not reduce erosion to tolerable levels on slopes steeper than about 15 percent, especially if at the onset of the rainy season there is no vegetative cover.

Land management. Options for change in land management include contour plowing and minimum or zero tillage for cultivated land and controlled grazing, cut and carry, and area closure for grassland. However, the tillage options require weed control beyond the capacity or possibility of a subsistence community, and contour plowing alone will reduce erosion on cultivated land by only about 10 percent, an amount insufficient to ensure sustainable production. The grassland options, on the other hand, offer much better possibilities with fewer constraints.

Slope length. Slope length can be reduced with all types of physical structures that either retain or divert surplus surface runoff. Furthermore, measures such as agroforestry techniques designed along the contour contribute much to reduced slope length. However, agroforestry requires sufficient moisture and temperatures high enough to grow leguminous trees, thereby limiting its ecological applicability in many situations.

On steeper slopes, shortened slope length alone does not reduce erosion sufficiently. Drainage systems to divert runoff to a adjoining river or artificial waterway are critical elements in any conservation system designed to shorten slope length. Moreover, biological measures are only effective so long as they provide dense ground cover to reduce the speed of overland flow. Livestock grazing cannot be allowed.

Soil properties. Higher humus content, better infiltration, and increased water storage capacity of the soil all reduce soil erodibility (*8*). Mulching, natural and artificial fertilization, and zero or minimum tillage may all contribute to more favorable soil properties.

The main constraint in subsistence agricultural systems, however, is the fact that all materials to be used for increasing organic matter in the soil are used for other purposes. Crop residues are fed to cattle or burned for cooking. Dung is also burned because of the shortage of firewood and for its excellent heating qualities. The option of improving soil properties cannot be applied without solving the firewood problem and the necessity for using animal wastes for fuel. Reduced tillage practices pose the problems previously mentioned.

Slope gradient. In traditional subsistence agricultural systems, the option of changing slope gradients is the one most frequently used, even without irrigation. Terraces in Yemen, Nepal, localized areas in Ethiopia, Kamerun, Peru, and many other countries, testify to the popularity of structures to reduce slope gradients (*3*).

The main constraint in the construction of terraces is the high labor input required to attain reduced slope gradients. Recent research has focused on developments whereby natural erosion, land management, and/or animal power are used to build terraces over longer periods of time, rather than direct construction. Furthermore, it has been shown that many of the techniques applied in direct construction are not suitable to local ecological and sociocultural situations. Level structures in high rainfall areas cannot retain maximum runoff during heavy storms, especially on cultivated land. Livestock must be excluded from areas where terrace-forming practices are applied, be they physical or biological. Also, there may be a limit to terrace formation because of insufficient soil depth and excessive slope gradient. These factors must be considered at the design stage of conservation activities.

However, the options of terrace formation or construction probably remain the best means of soil conservation on cultivated land—if proper care is taken in consideration of the site-specific agroclimatic and ecological conditions and if the technologies are adapted to the sociocultural and economic environment.

The Ethiopian case

In Ethiopia, about 20 million people, half the population, are subsistence farmers on steep lands; another 35 percent have better environmental conditions on flatter land. Only 15 percent of the population live outside the subsistence agricultural sector in towns.

Environmental degradation. The Ethiopian Highlands, situated in the eastern Sahel belt, are favored by their altitude with much more rainfall than the surrounding lowlands. As a result, they have been a center of civilization for many millenia. Major deforestation started 2,000 years ago (*4*), and ox-plow agricultural systems developed first in the northern parts of the country and later in the South and West. Studies of an early civilization, the Aksumite Kingdom, famous since the third century A.D., revealed that soil degradation probably was the cause of its decline in the seventh century A.D. (*1*). Thereafter, response to degradation was by expansion into new areas with better soil. Lalibela, between the 11th and 14th centuries, and Gonder and Menz, between the 16th and 17th centuries, probably are locations of developed civilizations further south with a subsistence agricultural system and a later decline due to soil degradation.

From an original 40 percent tree cover, natural forests have been reduced in Ethiopia to barely 3 percent at present. Much of the reduction has come during the last 100 years. Soil degradation is extreme in the areas of early agriculture, namely in the northern regions of Eritrea, Tigray, Wello, Gonder, and northern Shewa. Not by chance, these areas coincide with famine areas in the last two major famines, in 1973-1974 and in 1984-1985. Without directly correlating famine to soil erosion, the latter certainly undermined sustainable production. The human perception of the seriousness of soil erosion seems to be a major obstacle to soil conservation (*2, 5*).

Activities of rehabilitation. The organization of the Ethiopian peasants into about 20,000 associations since the 1974 revolution provided favorable conditions for rehabilitation activities. In addition, external support through "food-for-work" programs, bilateral support, and technical assistance were initiated in 1974 and continuously expanded over the past 13 years. Today, annual inputs into soil conservation, afforestation, and community forests amount to about US $50 million. The program, administered through the Ethiopian Ministry of Agriculture and carried out with labor-intensive works organized within the peasant associations, concentrates its activities in about 100 selected watersheds. These watersheds are situated along the most degraded parts of the Ethiopian highlands.

So far, through these activities, about 600,000 kilometers of earth and stone bunds have been constructed on cultivated land, about 300,000 kilometers of hillside terraces have been built up for afforestation of steep-lands, about 100,000 hectares of hilly land have been closed for natural regeneration, thousands of checkdams have been constructed in gullies, and millions of tree seedlings have been raised in nurseries and transplanted on the afforestation sites. The main problems with the program have been the food-for-work approach, which diverts the interest of a farmer from conservation to grain; the uniform application of contour bunds, despite ecological problems; overintensive application of physical structures in places where no measures of this kind would have been needed; and insufficient training to promote the conservation idea in schools, among technicians, and, most importantly, among farmers.

The main advantage of the program is the creation of awareness of soil erosion and promotion of conservation in many parts of Ethiopia, the improvement of the food situation through the distribution of grain and oil, and the incorporation of soil conservation as an integral part of agriculture on steep lands. In the last 10 years, about 15 percent of the land in need of soil conservation has received a first treatment with the above program. An increase in activities is still required if the country is to achieve a stable

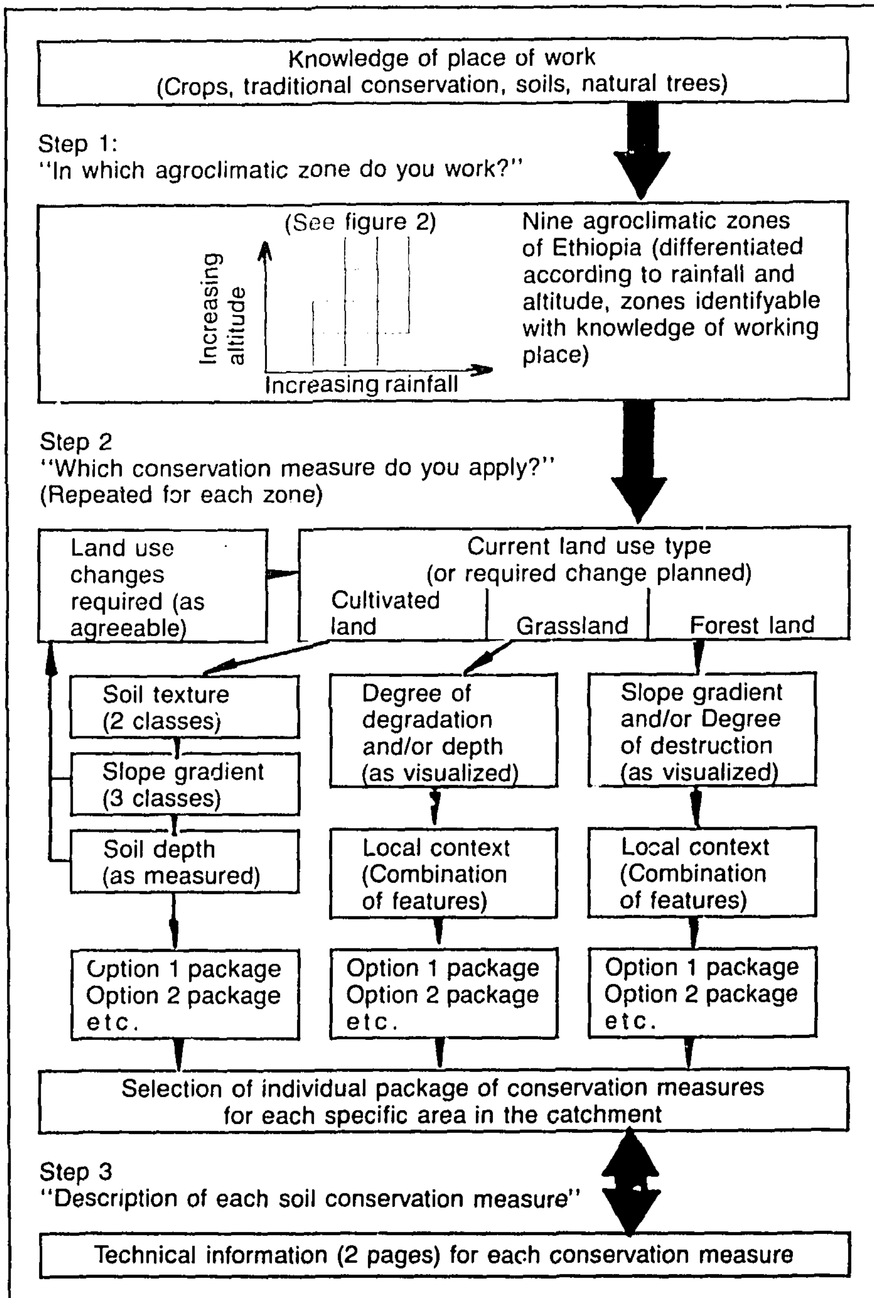

Figure 1: Flow chart for a stepwise approach to arrive at recommended options on conservation measures for local selection (6).

situation within the next generation.

In view of these considerations, it became necessary to improve design and planning of soil conservation, to include measures recommended by evaluators and experts but not yet applied, to group measures according to local conditions, and to prepare a technical manual for use by farmers and field technicians. Guidelines in the form of optional measures for local situations were discussed and prepared in a first phase for development agents of the Ministry of Agriculture. These agents are active in most peasant associations of the country and number about 5,000 people. In a later phase, the plan is to prepare further technical materials at the farmer's level based on the guidelines described below.

Guidelines on soil conservation. The process of creating a technical manual for development agents consisted of three major phases: (1) individual soil conservation measures either in use in Ethiopia at present or strongly recommended and of proven applicability were compiled, defined, and described; (2) agroclimatic and ecological parameters influencing the applicability of the conservation measures were defined and the measures grouped according to this classification; and (3) the first draft of a handbook written at the level of a 12th grade student with some agricultural experience was designed and prepared. A first edition of 5,000 copies was printed in English (*6*). The book was also translated into the local language, and a synchroneous print of 5,000 copies in Amharic was prepared to facilitate communication at all levels.

Figure 1 is an overview of the design process that a development agent will follow when using the document for conservation implementation. The following example demonstrates how the process is implemented in the field.

In step 1 of the approach, the development agent, with the help of figure 2, identifies the agroclimatic zone in which he is active. Assuming that he identifies the "Moist Weyna Dega," this will lead him to pages 24-25 in the manual where he will find a description of his zone as well as recommended soil conservation measures, according to land use and ecological parameters (Figures 3-6).

In step 2 of the approach, the development agent will start planning on a selected slope, say with cultivated land. Soil texture is identified there with the finger test described in the book. Because the soil is sandy to silty, he will generally look for *level* structures to apply in combination with *cutoff drains* for this specific agroclimatic zone. Next, the development agent measures the slope gradient. The slope is about 25 percent graded, so he must measure soil depth as well. It is 0.8 meter deep.

Option 1 package, according to the manual, is *level bunds* at 2-meter

Legend:
A: Main crops
C: Traditional conservation
S: Soils on slopes
T: Natural trees

Altitude in meters above sea level	Less than 900	900 to 1,400	More than 1,400
More than 3,700			HIGH WURCH (No conservation) A: None (frost limit) C: None S: Black soils, little disturbed T: Mountain grassland
3,700 to 3,200		MOIST WURCH *(See page 16)* A: Only barley; one cropping season per year C: Drainage rare S: Black soils, degraded T: Erica, Hypericum	WET WURCH *(See page 14)* A: Only barley; two cropping seasons per year C: Widespread drainage ditches S: Black soils, highly degraded T: Erica, Hypericum
3,200 to 2,300		MOIST DEGA *(See page 20)* A: Barley, wheat and pulses, one cropping season per year C: Some traditional terracing S: Brown clay soils T: Juniperus, Hagenia, Podocarpus	WET DEGA *(See page 18)* A: Barley, wheat, nug, pulses, two cropping seasons per year C: Drainage ditches widespread S: Dark brown clay soils T: Juniperus, Hagenia, Podocarpus, Bamboo
2,300 to 1,500	DRY WEYNA DEGA *(See page 26)* A: Wheat, tef, rarely maize C: Terracing widespread S: Light brown to yellow soils T: Acacia trees	MOIST WEYNA DEGA *(See page 24)* A: Maize, sorghum, tef, inset rare, wheat, nug, dagussa, barley C. Traditional terracing S: Red-brown soils T: Acacia, Cordia, Ficus	WET WEYNA DEGA *(See page 22)* A: Tef, maize, inset in W parts, nug, barley C: Drainage widespread S: Red clay soils, deeply weathered, gullies frequent T: Many varieties, Ficus, Cordia, Acacia, Bamboo
1,500 to 500	DRY KOLLA *(See page 30)* A: Sorghum rare, tef C: Water retention terraces S: Yellow sandy soils T: Acacia bushes and trees	MOIST KOLLA *(See page 28)* A: Sorghum, rarely tef, nug, dagussa, groundnut C: Terracing widespread S: Yellow silty soils T: Acacia, Erythrina, Cordia, Ficus	
Below 500	BERHA *(No conservation)* A: None except irrigation areas C: None S: Yellow sandy soils T: Acacia bushes		

Annual rainfall (millimeters)

NOTE: Later in the book this figure will be repeated in such small form:

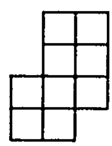

Figure 2: Agroclimatic zones of Ethiopia. On the vertical is altitude, increasing upward. On the lateral is annual rainfall, increasing toward the right side. Each box represents one agroclimatic zone for which sets of conservation measures are recommended, according to ecological and socio-cultural parameters (6).

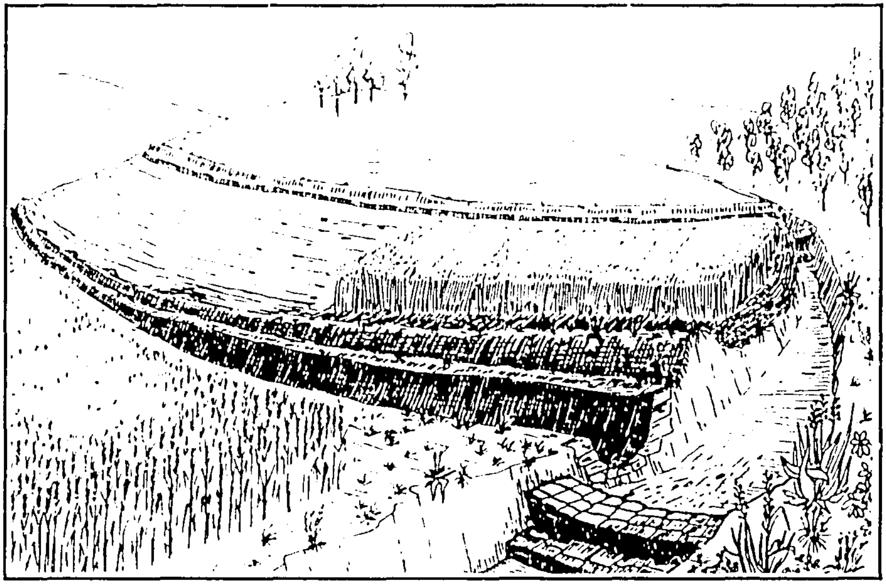

Figure 3: Graded fanya juu physical structures on cultivated land. These structures are designed to retain some runoff while allowing excess runoff from heavy storms to be drained through the lower ditch. Drawings like this are used for training and extension in Ethiopia.

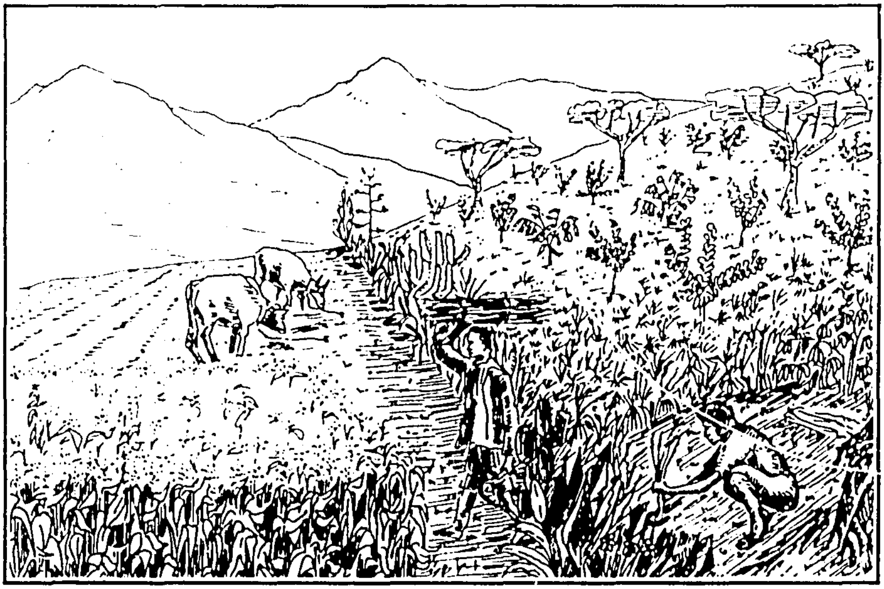

Figure 4. Cut and carry is a recommended practice for managing degraded grassland. Free grazing of livestock is prohibited, but the grass may be cut and brought to the animals for feed.

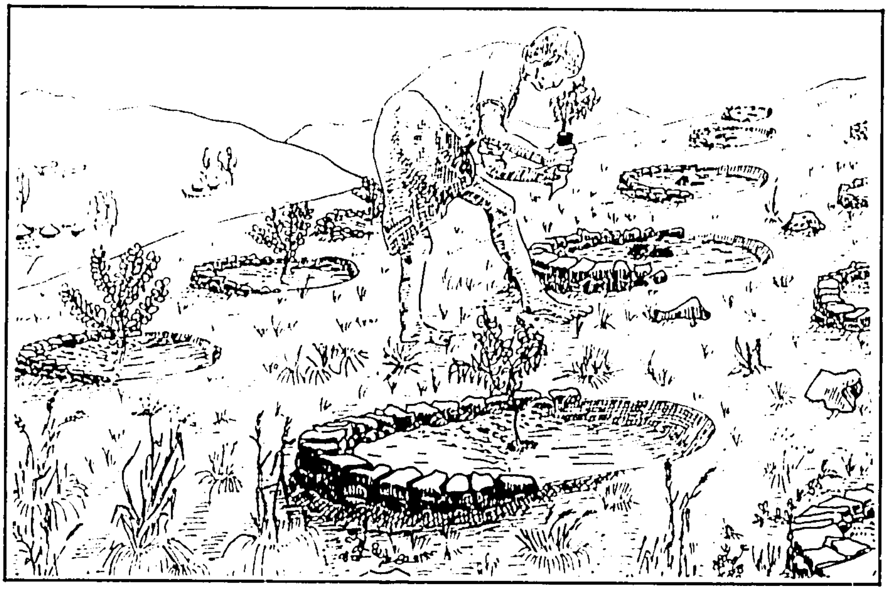

Figure 5. Microbasins are used for tree planting in afforestation sites in dry and moist agroclimatic zones. This small physical structure assists in the preservation of surface runoff while leaving the soil at the planting spot virtually undisturbed.

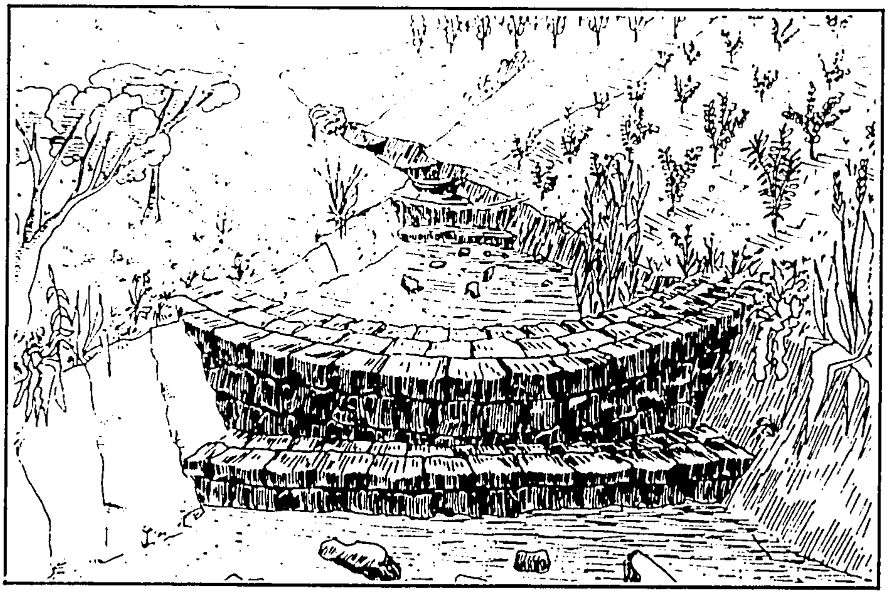

Figure 6. Brushwood or stone checkdams are applied for gully control. Local material available in the vicinity of the gully is used to reduce the velocity of flow. Simple structures need to be densely spaced if they are to remain functional for a longer period of time.

vertical intervals with *cutoff drains* in between. The bunds have to be developed into *bench terraces* in the course of some years of continuous maintenance.

Option 2 package is as option 1, but with *level fanya juu* instead of *level bunds* for faster terrace development, but higher maintenance inputs.

Option 3 package is recommended if options 1 and 2 are too narrow in spacing for the farmer. Here, *alley cropping* is recommended, but part of the cultivated land must be converted to grassland.

All options are discussed with the farmers involved until an agreement is reached. Implementation follows after careful design of the structures on the ground. The main contribution of the manual is presented in step 3, where 18 conservation measures used in the Ethiopian context are described in detail.

The future. At the speed of soil conservation implementation in Ethiopia over the last 10 years, it will take another 70 years to cover the essential parts of the country. During this time, the population may increase from 42 million people to some 200 million if present trends continue. Motivation of the rural masses for population control and environmental rehabilitation will be key issues.

However, activities can only be launched if they are properly guided. The technical guideline presented here is merely a beginning for a more refined system of conservation planning and application. Its broad distribution in Ethiopia is supported through the design of training materials based partly on the drawings of the manual. Development agents have the possibility to use posters with similar drawings or photos of the measures as in the book, thereby synchronizing what they use and what they teach. Certainly, much more must be done in the future, not only in Ethiopia, but on all land threatened by degradation, especially steep lands used by subsistence farmers who are extremely vulnerable to the consequences of reduced agricultural yields (*7*).

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6

Soil erosion research on steep lands

R. Lal

Most research on soil erosion and its control has been on flat or rolling land with a maximum slope of about 20 percent. Such research on steep lands, with slopes exceeding 20 percent, has been neglected because steep lands traditionally have been considered marginal for farming. Therefore, little research information is available to help plan effective resource management strategies on such land or to develop sustainable land use systems.

This does not imply that steep lands are not being used or cultivated. Some countries, with high human and animal populations, have no choice but to expand their land bases to include steep lands for food production. Countries in this situation include those in the Himalayan-Tibetan ecosystem, the Andean region, eastern Africa, and the Pacific and Caribbean regions.

People in the most densely populated regions, where land pressure is too great, have no choice but to exploit steep lands. For example, in Nepal, hill slopes up to about 45 percent are cultivated. In Ethiopia, 54 percent of the total land area has a slope gradient exceeding 8 percent, and 29 percent has a slope gradient exceeding 30 percent. In comparison, only 6 percent of Sudan's land area exceeds a slope gradient of 30 percent (*3*).

Extremely steep slopes also are being used in the Andes and the Caribbean, and steep lands are cultivated in temperate regions. In North America, Purnell (*3*) estimated percentages of land area in different slope classes as follows: 36 percent in the 0-8 percent class, 50 percent in the 8-30 percent class, and 14 percent exceeding 30 percent. The corresponding percentages for land areas in Europe and North Asia are 43, 38, and 19, respectively.

Magnitude and extent of the problem

To adopt a "cry wolf" attitude would be counter-productive. It is important to be objective, to define the magnitude and severity of the problem more precisely. It is difficult to develop effective solutions to soil erosion and erosion-caused degradation on steep lands if we do not precisely know the problem's extent and the regional and geographical distributions of the different slope classes. It is equally important to know the major soils being cultivated, or likely to be cultivated, in different slope classes, along with their physical, nutritional, and biological properties as well as their productive potentials and major limitations.

What are the current or existing land uses or farming systems? What are the likely trends in farming systems due to changing needs within the next 20, 50, or 100 years? What are the productivities of existing farming systems? What are soil, climate, and sociopolitical constraints to increasing production of the existing farming systems?

Some relevant information appears in this book, and additional data are available from the Food and Agriculture Organization. For example, Purnell (*3*), using a soil map of the world, estimated percentages of areas of sloping land for different regions/continents (Table 1). This is useful information indeed. However, the information derived from soil and topographic maps based on reconnaissance surveys at 1:5,000,000 scale has limited utility for detail and effective land use planning. Attempts should be made to produce topographic and soil maps using semi-detailed surveys at 1:25,000 to 1:100,000 scale. Most information now available is scanty, sketchy, often unreliable, obtained with nonstandardized methodology, and difficult to use in comparisons, so valid generalizations and conclusions are not possible.

It will be an important step forward if reliable estimates are obtained (a) of the soil types in different slope classes, (b) of current and projected farming systems, and (c) of important limitations to increasing production. Available information must be collated and new data obtained to build and strengthen the needed data base. The desired land resource inventory information needed for a region based on a semi-detailed soil and topographical survey includes the percentage of land in each soil order (Soil Taxonomy, USA) on slopes of 0-8 percent, 8-30 percent, and greater than 30 percent. This information should be complemented with surveys of the vegetation and land resources.

Research needs in soil erosion and its control

Soil and water loss. Quantitative, reliable measurements of soil erosion in relation to different factors and causes of erosion are few. Research information is needed for the following:

Soil erosion and land use. It is important to quantify soil erosion and

Table 1. Area of sloping lands in tropical regions (3)

	Percentage of Land Area by Slope Class						
Slope (%)	Africa	Southwest Asia	South America	Central America	Southeast Asia	Total Area 10^6ha	Total Area (%)
0-8	56	45	52	35	40	3,340	51
8-30	34	31	30	40	31	2,107	33
>30	8	24	18	25	29	1,048	16

runoff in relation to existing and new farming systems for different slope gradients and slope length and for different soils and rainfall regimes. Although the literature on soil erosion is voluminous, accurate, reproducible, and reliable field data are still needed. Such data can provide the basis for developing conservation-effective land use systems.

"Conservation-effective" needs further clarification. Attempts have been made to estimate erosion potential using empirical models, such as the USLE (universal soil loss equation), MUSLE (modified universal loss equation), and other variations of parametric models. Simulation model results, however, are useful only when they can be validated against actual field data. The field data must be obtained by uniform, standardized methodologies so that results from different soils and ecological regions are comparable. The data published in tables with an added footnote "the storage tank overflowed for x percent of rains" is useless because it is the heavy rains that cause the most damage. Runoff and soil-loss equipment must, therefore, be properly designed, installed, and operated.

Erosion can be measured on hillslopes using field runoff plots, in agricultural watersheds, or in small river catchments. Although sediment yields from river catchments can provide useful information on denudation rates over the catchment, knowing the "delivery ratio" for different parent materials, land uses, and topographics is a major bottleneck. To know erosion potential from agricultural land, it is important that soil losses are measured on field runoff plots and/or small agricultural watersheds.

Erosion-induced productivity decline. Erosion-caused alterations in soil properties and crop yields should be assessed to establish levels of tolerable soil losses for different soils, crops, and management systems. For many shallow soils in the tropics and subtropics, the presumed levels of tolerable soil loss, based on U.S. experience, are too high. Tolerable levels of soil loss should be evaluated on the basis of the erosion-caused productivity decline and the rate that new soil is formed. The magnitude of each of these factors is unknown in most regions where steep lands are intensively used. Also not known are the short- and long-term economic losses caused by on-site and off-site effects of accelerated erosion.

Erosion processes. It is not known whether the physical processes governing erosion on steep lands are the same as on flat or gently sloping lands. Subtle differences are likely.

Slope gradient and length: The effects of slope gradient and slope length on steep slopes presumably differ from those on gentle slopes. Some researchers believe that these effects can be easily computed from physical principles. That may be the case for regular slopes with uniform soil characteristics. In nature, however, regular slopes are the exception rather than the rule. The effects of slope gradient on soil erosion and runoff should, therefore, be assessed for different shapes, lengths, and slope aspects. How does overland flow originate? What are the threshold slopes for different soil types at which a rill is transformed into a gully?

Directional rainstorms: There is another important but less understood aspect of slopes—the interaction between directional rainfall and aspect in relation to soil detachment and splash downslope for different slope gradients. Researchable questions include the following: What is the *maximum effective* rainfall on a given steep slope? What effects does a directional storm have on interrill erosion? Is interrill erosion as important on steep lands as on gentle to rolling landscapes? Some researchers argue that it is not (*1*).

Rain splash and overland flow: What is the interaction between sheetwash and rainsplash at high slope angles? Some researchers argue that this interaction differs drastically from that on gentle slopes (*1*). However, the interaction has not been widely studied for different soils, rainfall regimes, slope angles.

Highly erodible: Where are the highly erodible areas in catchments with steep terrain, and what are the factors that determine the critical areas? How does the run-on of a steep slope compare with that of a gentle slope?

Mass movement: Mass movement is a common problem on steep lands, both cultivated and uncultivated, but the process is not yet adequately understood. It should be assessed in relation to surface soil thickness and the hydrological, pedological, and edaphic properties of the subsoil (*6*). What is the critical shear strength below which mass wasting is common? What effect does antecedent moisture index have on mass movement? Can mass movement be predicted with some index of antecedent precipitation and soil profile characteristics?

Land capability evaluation. One approach to developing appropriate land use systems for conserving soil and water resources is to use the land for whatever it is capable of under management that is not ecologically undesirable. In this regard, land evaluation is an important step for conservation and land use planning. The FAO framework for land evaluation (*2*) is a system of land evaluation that can be applied to sloping lands.

Erosion is caused by bad farm practices. Packages of cultural practices and management systems that have proven successful under similar conditions elsewhere should be validated and adapted for different soils and environments. The "Sloping Agricultural Land Technologies" (SALT) should be assessed and adapted in different regions (*5*). Appropriate SALT technologies to be evaluated include conservation tillage, stripcropping, cover crops, contour terraces, alley cropping and agroforestry, and mixed cropping. Suitable combinations of different technological components may differ for different soils and climatic regimes.

Erosion control. Some countries and regions have no choice but to use marginal land for the production of food, fuel, fodder, and fiber. The scientific community cannot say no to the use of lands with a slope exceeding, say, 8 percent. We must test and evaluate land uses and soil and crop management systems that permit sustainable production on these lands. Even on flat land, soil and water conservation is a continuous, never-ending endeavor. On steep lands, one must be extra careful.

Soil and water conservation systems are not restricted to engineering techniques designed to alter slope length or gradient. Biological measures that provide an effective cover close to the ground surface are likely to be more effective, more ecologically compatible, and more durable.

Erosion-induced soil degradation. The term "soil degradation" is used to describe qualitatively a decline in soil quality. Erosion-caused degradation includes reductions in effective rooting depth, plant-available water, nutrient reserves, organic matter content, and structural properties. Research data should be obtained to establish critical limits for these soil properties that affect crop production. The limits may differ with soil, prevailing climate, land use, crops, and ecological regions. If the critical limits of organic matter content, water and nutrient status, porosity, and compaction are not known for major soils and crops, it is difficult to judge whether a soil is degraded and, if so, to what degree.

There is a lack of basic information about the physical processes of erosion-caused soil degradation, for example, compaction, porosity, critical rooting depth, and plant-available water reserves. The amount and kind of soil organic matter necessary to maintain adequate structural condition varies by soil type and environment, and neither amount or kind is known in many circumstances.

Restoration of degraded land. Currently, there are an estimated 1.5 billion hectares of land cultivated in the world. An additional 2 billion hectares of land that were once biologically productive have gone out of production. It is also feared that some 5 to 7 million hectares of cultivated land are now lost for agricultural production every year through soil degradation (*4*).

One wonders how reliable these estimates are. Because we do not know either the critical levels of degradation or the responses of different crops to different soils under different management conditions, are we crying wolf with regard to the magnitude and trends in soil degradation? Or is soil degradation a genuine threat to mankind? If the estimates are anywhere near correct, the consequences are alarming indeed and are the basis for one of the greatest challenges facing the scientific community.

Regardless of the reliability of the data on degraded land, it is apparent that the world is running out of good, arable land. As population increases, the greatest opportunity for increasing world food supply lies in restoring productivity where it has been lost by misuse. To improve world food security, we must develop systems for continuously recharging our soil and water resources. Soil restoration involves more than just physically saving the fragile soil. It involves restoring or even enhancing its productive capacity by improving its organic matter content, porosity, infiltration rate, available water capacity, and biotic activity.

Systematic, long-term research aimed at restoring degraded steep lands should be initiated on different soils in various ecological regions. Degraded ecosystems can be restored through judicious land use and by adopting management systems that do not cause gross imbalances in the soil-water-climate equilibrium. Because soil is a finite, nonrenewable resource, there is no choice but to restore the productivity of degraded land. Through technological innovations, we have the capacity to do it.

The network approach

Networking is a likely approach to accomplish the mammoth research task outlined in the previous two sections. For example, if the World Association of Soil and Water Conservation were to undertake the task, it could develop a series of regional networks. A functional structure of such regional networks is shown in figure 1. Regional networks, coordinated by the WASWC secretariat, would be organized for each of the eight regions through a network coordinating committee. In addition to coordinating research, the WASWC secretariat could establish a central data bank. The data would be centrally analyzed to compare results obtained from different regions and the information shared with all regional networks. The WASWC secretariat would develop strong linkages with international organizations

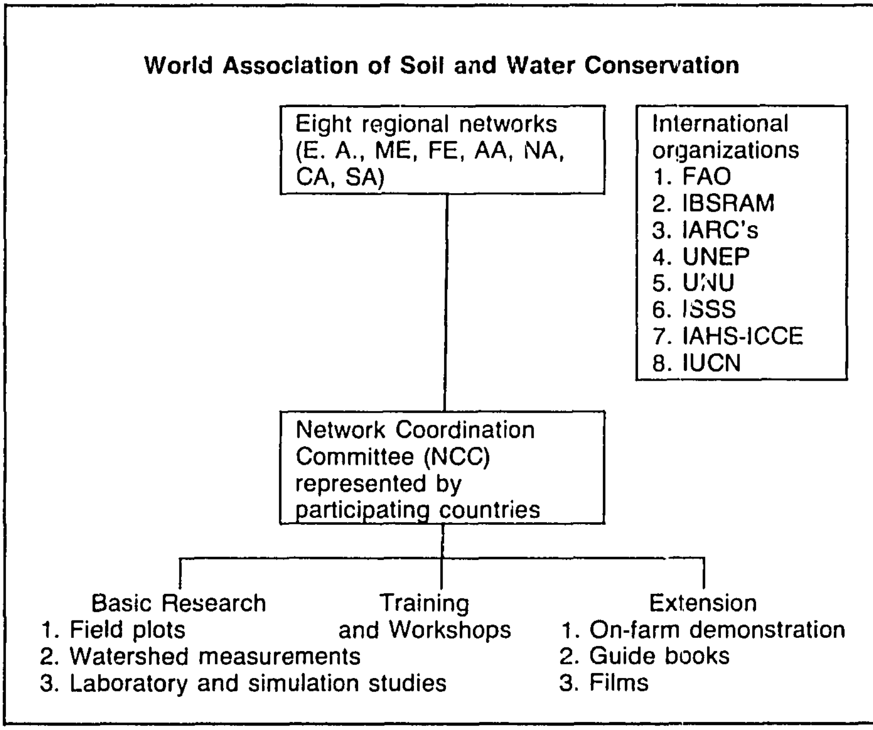

Figure 1. A functional structure of SALT networks. (E-Europe, A-Africa, ME-Middle East, FE-Far East, AA-Australasia, NA-North America, CA-Central America, SA-South America).

having similar interests in research, extension, and training activities. Some important international organizations that WASWC would seek support from include: FAO, International Agricultural Research Centres, United Nations University, United Nations Environmental Programme, International Society of Soil Science, International Association of Hydrologic Sciences, International Union for Conservation of Nature and Natural Resources, and others. The network coordinating committee would be comprised of members from the participating countries, and the committee would work closely with the national institutions. In addition to research projects, the committee would conduct regional training courses and workshops and perform extension duties. In collaboration with the regional coordinators, the network coordinating committee would also develop strong linkages with national programs.

The program outlined in figure 1 could function only with adequate financial support for WASWC or any other organization that takes on the task. Even if WASWC functioned closely with other international organizations having similar interests and had their full support, it would need its own financial resources. In addition to financial, logistic, and personnel support from international organizations and regional networks, the WASWC secretariat would need to seek independent financial support from such donors as the U.S. Agency for International Development, several foundations, Canadian Agency for International Development, International Development Research Council, International Federation of Institutes for Advanced Studies, Australian Centre for International Agricultural Research, and other financial organizations representing each of the eight regions listed.

It will require complete dedication from all involved to make a networking system work. The success of such an endeavor depends upon the enthusiasm and dedication of all participants from the headquarter's secretariat to field hands overseeing day-to-day field work. And, of course, farmers will provide the acid test of SALT's applicability.

Conclusions

Sloping lands, which account for a substantial portion of the land resources in the world, are intensively cultivated in many of the world's regions. However, a precise resource inventory based on semi-detailed soil and topographic survey is not available for many regions. Sloping lands are components of fragile ecosystems that are susceptible to rapid soil degradation due to physical, chemical, and biological processes.

Research needs on soil erosion include reliable measurements of soil and water losses under different land use systems. It is also important to evaluate the economic consequences of soil erosion, including knowledge of erosion-caused productivity declines. Basic research is also needed on the relative importance of different processes involved in sediment origin and transport in relation to slope gradient and length, direction of rainstorms and effective rains, rainsplash and its interactions with overland flow, critical areas contributing to sediments and water runoff, and mass movement. Assessing the degree of soil degradation and developing methods of restoring the productivity of degraded lands are important research priorities. Proven agricultural technologies for sloping lands are needed so these lands can be properly managed.

Networking is a likely approach to accomplish this task of important research and development priorities. The research and training activities should be organized at the regional level. Overall coordination of the networks, performed by the WASWC, should involve active participation of such other international organizations as FAO, IARCs, IUCN, IAHS, ISSS, and others.

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7

Food and Agriculture Organization activities in soil conservation

D. W. Sanders

Until recently, soil conservation received relatively low priority in the plans of most developing countries. Priority was generally given to programs of a more spectacular nature or to those that produce quick, obvious returns for the time and money invested. Generally, there was a feeling that land was plentiful and soil erosion was not a serious problem.

Over the past decade, this attitude has changed rapidly, and there is now far more awareness of soil degradation and interest in soil conservation. There are a number of reasons for this change in attitude:

► Soil erosion and other forms of land degradation are now so far advanced in many countries that their effects are obvious to even a casual, untrained observer.

► Population numbers have grown rapidly in most developing countries, and this is resulting in an acute shortage of land in all countries not well endowed with reserves of unused land.

► Many of the large dams built in the 1960s and 1970s, such as the Mangla and Tarbella dams in Pakistan, are silting up much more quickly than expected because of the high rates of soil erosion in the catchment areas.

► The effects of drought in Africa over the last decade are now being closely linked with soil degradation.

► The worldwide interest and publicity given to environmental matters over the last 10 to 20 years are now having their effect, and the public at-large is now much more aware and interested in the protection of the environment than ever before.

Turning this interest into effective programs is not an easy task, however. No one is sure how much land is lost annually because of soil erosion, soil salinity, and other forms of soil degradation, but a number of estimates have been made. One of the more conservative of these suggests that 5 to 7 million hectares of land are lost annually through soil degradation (*1*).

This is an extremely large area and gives rise to the thought that an even greater area must be losing its productive capacity as the various processes of degradation take place.

To compound this problem, many countries are now fast running out of new land that is suitable for agricultural production, and farmers are turning more and more to the steeper slopes, poorer soils, and other areas that are not only difficult to farm but also prone to soil erosion.

The United Nations Food and Agriculture Organization has responded to this changing and challenging situation in a number of ways. One step has been to produce the World Soil Charter. This short document, unanimously adopted by the FAO conference in 1981, outlines a number of principles and guidelines that, if followed, should allow any country to develop its land resources without the problems of land degradation.

As a follow up to the adoption of the World Soil Charter, FAO has intensified its work in soil conservation. Efforts have been made to increase awareness of the subject, not only to let people know that there is a problem, but also to inform them that land degradation can be prevented and controlled. To do this, a number of publications and filmstrips have been produced on the subject and widely distributed. In addition, visits have been made to countries, when requested, to assess soil erosion problems and to advise on solutions.

Under its field program, FAO now operates 16 soil conservation projects in 15 different countries. In addition, assistance is being given to additional countries on the formulation of policies, programs, and projects and, where necessary, help in finding external sources of funding.

FAO's projects in soil conservation are located in Africa, Asia and the Pacific, South America, Europe, and the Middle East. They vary greatly in size, cost, and objectives. Included are schemes aimed at assessing and mapping soil erosion, training programs for conservation staff, policy development and planning of national soil conservation programs, developing conservation services, pilot demonstration schemes, and watershed management activities. The projects may run from a few weeks to several years in duration and vary in cost from less than US $100,000 to several million dollars.

Few of FAO's projects are aimed entirely at soil conservation. Most of the agency's work in this field is integrated with other activities. For example, there may be projects that have as their primary objective general rural development, dryland farming, or livestock production, but with a soil conservation component.

Because they are multidisciplinary, it is sometimes difficult to analyze the projects in terms of how effective they have been from the soil conservation standpoint. Following are three examples of the types of soil conservation projects in which FAO has been involved and some comments on what can be learned from them. Two of the projects, in Jordan and Lesotho, are examples of general agricultural projects with soil conservation included. The third, in Ethiopia, was established primarily for soil conservation.

Examples of FAO projects in soil conservation

The Jordanian project. From 1964 to 1981, FAO was involved in a succession of related projects in the dryland farming areas of Jordan. The general objectives of these projects were to increase agricultural productivity in the dryland farming areas and, at the same time, to prevent and control soil erosion.

Over the years, cultivation in Jordan had extended onto steep hillsides. Where animals were used as the source of draught power, this was not too serious; cultivation was shallow and carried out across the slope with simple plows that did not invert the soil. In the 1960s and 1970s, however, large numbers of tractors were introduced and deep moldboard plowing became fashionable. On the steep hillsides, tractors could only operate up and down the slope. This proved disastrous and resulted in a serious increase in soil erosion. At the same time, only poor crops of wheat, barley, and legumes could be grown on the steep, shallow soils. The answer, clearly, was to change to a different, stable form of land use for these steeper slopes.

The solution developed was to build stone walls on the contour, interplanted with perennial crops. The walls slowed runoff, increased infiltration of rainwater into the soil, trapped silt, and gradually built bench terraces. Between the contour walls, farmers planted olive trees, fruit trees, and grapes.

As an incentive, farmers were paid food rations provided by the World Food Program, while budded olives, fruit trees, and grapes were provided by the government at nominal prices. Teams of government technicians, who had been trained by the project, marked out the position of the terraces, ensured that a reasonable standard of work was maintained, measured up the completed work, and arranged for farmers to be paid the food rations.

Since this work began, more than 30,000 hectares of land have been treated, the rate of soil erosion has been slowed, and a relatively stable, profitable form of land use has been introduced. The government, by itself, is continuing this program of stonewall terracing and planting.

Reasons for the program's success include the following:

- ► Use of stonewall terraces was not new—this type of conservation structure had been used in the region for at least 2,000 years—and the technique of constructing terraces on the contour was merely a refinement of an already known and accepted practice.

► Once constructed, the terraces require little maintenance, and this maintenance does not require particular skills.

► Use of food aid, although not fully covering the cost of construction, and the provision of good quality, inexpensive seedlings proved to be adequate incentives for the farmers to undertake the necessary work.

► Farmers were generally prepared to accept the change in land use from annual to perennial crops. This can be attributed to (1) the farmers perceiving a clear economic advantage in the change; (2) olives, fruit trees, and grapes were well-known crops in this region and their husbandry was well understood by the farmers; and (3) adequate supervision and technical advice was provided by the government.

The Ethiopian experience. Over the past 15 years, the highlands of Ethiopia have been subject to two devastating famines. While both have been due largely to drought, another cause has been the severe soil erosion and land degradation that has occurred over the centuries.

Depleted, shallow soils, stripped of most of their natural vegetation, have not been able to respond when rainfall has been low. Whereas in the past farmers may have been able to harvest poor crops after years of low rainfall, now they frequently harvest nothing, and there are insufficient reserves of vegetation to carry livestock through poor seasons.

Appreciating these facts, the government embarked on a large-scale soil conservation program in the mid-1970s. Faced with the problems of limited resources, few trained staff, and a large, eroded area to deal with (an estimated 270,000 square kilometers of the highlands of Ethiopia are significantly eroded), the government based its conservation strategy on the widespread use of a few simple measures. These consisted of:

► Construction of earthen and stone contour banks on the gently sloping land. These structures are closely spaced and aim at the total interception and retention of runoff.

► Construction of stone contour walls and tree planting on steeper slopes.

► Building of earth and stone silt traps in gullies.

► Closure of other areas to grazing to allow natural revegetation.

To support this program, food aid was supplied through the World Food Program and other donor organizations. This food was distributed to the farming communities in payment for the conservation works undertaken. All work was organized through the country's peasant associations—farmer associations established in the early 1970s.

In practice, this program has proved effective insofar as it has allowed a large number of people to be mobilized quickly and resulted in the construction of many physical works in a short time. In fact, the results of the program are spectacular. Since 1979, some 836,000 kilometers of soil banks and hill terraces have been built on some 650,000 hectares, while approximately 500 million trees have been planted, providing cover on about 120,000 hectares. In addition, about 313,000 kilometers of farm roads have been constructed. Other works include the development of springs, construction of small earth dams, establishment of nurseries, and gully and streambank protection works (*3*).

While the sheer volume of the work done is impressive, the problem is vast, and a recent assessment (*2*) shows that even if the present program continues to expand as fast as it has in recent years (about 20 percent per annum in real terms), it will take more than 50 years to cover the erosion-susceptible areas, which, in turn, are increasing in size with population growth. The cost would be enormous (more than US $4 billion at 1985 prices). Even then, the impact may fall short of requirements.

A number of other evaluations of the conservation program in Ethiopia have been undertaken, and while all of these have recognized the efforts that have gone into the program to date, all have shown some concern for two reasons. First, with the incentive of food rations, farmers have been willing to work on the program and to help build various works on their land. Unfortunately, to date there is little indication that the farmers believe these works to be worthwhile or will be prepared to maintain them. Some works built only five or six years ago already are in need of repair. This raises the question of the long-term effectiveness of the works and how they will be maintained.

Second, physical erosion control works cannot be expected to solve the problems by themselves. If erosion is to be controlled, other conservation practices will also have to be applied, such as improved agronomic practices, better tillage techniques, and, in many cases, a complete change in land use.

With problems of limited resources and few trained staff, the government requested assistance from FAO. A small project was started in 1979 that concentrated on providing basic training for local staff. In 1981 this was enlarged to a second-phase project that ran until the end of 1986. In these two phases, much has been done in the way of training local technicians, technical staff, and farmer representatives.

A third, four-year phase to the project started in early 1987. In this new phase, the project will continue to help train government staff. In addition, more time will be spent helping to develop and introduce systems of conservation farming, which will supplement the work already underway on the construction of physical conservation structures.

The Lesotho project. Lesotho is a small, mountainous country in southern Africa with about 400,000 hectares of land suitable for cultivation. Erodible soils and intense rainfall, coupled with heavy overgrazing and poor systems of cultivation, have led to severe soil erosion in much of the country.

From the time Lesotho was granted independence in 1966, until the late 1970s, government agricultural development activities centered on a number of "area-based" projects. Because erosion is such an important problem in Lesotho, all of these projects included a soil conservation component. One of these was the FAO-assisted Khomokhoana project, situated in northwestern Lesotho and encompassing the 15,000-hectare catchment of the Khomokhoana River. About 9,500 hectares in the catchment were cultivated; the remaining 5,500 hectares were comprised of steep, rocky hills, roads, streams, and villages.

Some 40,000 people—8,000 families—lived in the area, which was intensively cultivated and heavily overgrazed. Most of the catchment was badly gullied and otherwise eroded. The cultivated land was divided into small plots, with the average holding between 1.5 and 2 hectares. Grazing land was open for anyone's animals to graze upon, as was the cultivated land once crops had been harvested.

The project, which ran from 1975 to 1980, was financed by a US $2.8 million grant from the Swedish government. Basically, it was a general agricultural development project designed to tackle problems in agronomy, livestock production, farm mechanization, farm management, marketing and credit, extension, and soil conservation.

Erosion has long been recognized as a problem in Lesotho, and the project area, together with the rest of the arable land in the country, had been treated in the 1940s and 1950s. Treatment consisted of the construction of earthen contour banks on the flatter land and the laying out of permanent grass strips on the steeper cultivated land. Small earth dams were built in many water courses, and limited tree planting was done on badly eroded areas.

Over the years, most of these works had been neglected and had fallen into disrepair. But they had served a useful purpose. They forced farmers to cultivate on the contour so that, in time, this became the established practice for the country.

Briefly, the Khomokhoana project's soil conservation program consisted of repairing and rebuilding the old contour works where possible, tree planting in gullies, on streambanks, and in badly eroded areas; and constructing simple gully control structures. Some works were done mechanically. Where possible, however, they were done by hand, and the village people were compensated in food rations for their labor. At the same time, the project actively tried to introduce better cropping practices that would not only increase farmers' incomes but also provide better ground cover and reduce erosion.

Meanwhile, assistance was given to farmers as well for improving the quality and productivity of their livestock.

The end of the project coincided with a change in the government's agricultural development policy. Emphasis shifted away from area-based activities, toward traditional district agricultural offices and the establishment of a network of depots and stores aimed at providing basic agricultural supplies and marketing services to all farmers. This, in effect, meant that the project team was dispersed to different duty stations, and the remaining work was not completed on a catchment basis.

To its credit, the project resulted in the successful training of a group of young, enthusiastic officers. It also demonstrated how an entire catchment could be planned as a unit and how the farming community could be effectively involved in the planning and implementation of the necessary work.

The experience gained from this and similar projects in the country pointed to the need for an overall policy or long-term plan for soil conservation. The need is for well-thought-out, long-term government programs and strategies if soil erosion is to be controlled. Once a sound, long-term program has been developed, projects of various types and sizes can be designed and used like building blocks to fit into the overall plan. In this way there could be reasonable assurance that the contribution of individual projects will be lasting.

Requirements for successful soil conservation schemes

There seems to be no one factor that can be singled out as the key to successful soil conservation programs. Success generally can be attributed to a combination of factors that have led land users to adopt and then continue to use conservation practices. Among these factors are the following:

► The adoption of conservation practices appears to depend at least as much on socioeconomic factors as on the physical effectiveness of the practices.

► Farmers and other land users need to be involved from the start in planning conservation schemes. This involvement must be genuine, including full explanations of what is possible, consultations, and negotiation of agreements.

► Farmers will only adopt and continue to use conservation methods if they can see some direct benefit in doing so for themselves and their families in the short-term. These benefits are most likely to be in the form of increased yields, higher incomes, or the reduced need for some input, such as labor. Farmers in the Kitui area of Kenya are now terracing fields at their own expense and without the need for much encouragement by the government. The terraces effectively prevent soil erosion, but they also lead to yield increases on the order of 40 to 90 percent. Appeals to land users to adopt conservation programs for such reasons as national interest, the protection of downstream dams, or the need to save soil for future generations are not likely to have lasting effects.

► Land tenure systems also have a bearing on which, if any, conservation practices land users will accept. Farmers see no point in investing in conservation works on land to which they have no assured long term rights or control. Many farmers in the Machahos district of Kenya have been building terraces on their fields in recent years—at the same time that they are being granted legal title to the land. On the other hand, it is understandable that farmers in Lesotho have shown little interest in leaving protective crop residues on their fields when they know that anyone can bring animals to graze them once the grain has been harvested.

► The conservation practices and techniques advocated must be practical and appropriate to local conditions. In Kenya, the fanya juu terrace, a modified form of contour terracing, has been developed to suit local conditions.

The conservation practices advocated must be within the technical capabilities of field staff and farmers to apply. Therefore, systems that require complex engineering designs and layouts are not practical in circumstances where large areas must be treated and where field staff are few and their training limited.

► Implementing soil conservation programs can be expensive in time and labor. A combination of incentives, subsidies, and disincentives are required to induce land users to take up soil conservation on the necessary scale. In recent years, food aid has been extensively used in a number of developing countries to encourage farmers to install physical erosion control structures. However, the use of incentives or subsidies must be carefully thought out, planned, and implemented, or the inducements may become counterproductive. Farmers can easily become dependent upon subsidies or refuse to do even maintenance work if they are not paid.

► Experience indicates that conservation can only be achieved if governments are committed to seeing through long-term programs. Short-term project approaches have met with little success. It has only been through long-term programs, supported by the necessary legislation, staff, finances, and facilities, that worthwhile achievements in conservation have been made.

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8

The USAID approach to soil conservation assistance programs

Raymond E. Meyer

Activities of the U.S. Agency for International Development cover a wide range of topics. USAID works with host governmental institutions and implements projects through contractors, so projects with similar goals or purposes may be quite different, depending upon the country and local situation. The USAID information base includes approximately 100 projects related to soil conservation. Few of these were called soil conservation projects, but many had a component relating to conservation. Many of the types of activities discussed in this book may be sponsored or assisted by USAID.

USAID works at several levels of organization. The most common is at the host-country level through the USAID mission in the country. These bilateral projects are country-specific and generally have no provision for dissemination of lessons learned. There are few geographically regional projects, although the Africa Bureau has just completed a natural resource plan for the region. There is no unified or overall focus on soil and water conservation within the agency.

Some project considerations

There are several considerations that a donor should take into account when deciding upon projects. As soil conservationists, for example, we have an important role to play in providing the best possible information so that investment decisions and interventions can be made with the most likelihood of success. We should insist that decisions be based on scientific fact rather than rhetoric. If data are not available, research should be supported to obtain the necessary data.

How does a donor decide whether to support activities addressing degradation in dryland regions or on steep lands, to address soil conservation in an agricultural project or in a forestry project, to support conservation or hunger relief, to support conservation or irrigation, to train human resources or build institutions? What are some of the trade-offs? What are the long-term versus short-term costs and benefits? How do we measure intangible benefits and relate them to tangible needs? How can we best distribute a very limited budget?

These are important questions if we want to give countries or donors advice on investment opportunities in sometimes difficult political and economic climates. Can we really recommend governmental spending on conservation practices when the country has problems with balance-of-payments, food production, health, and employment? What is the role of governmental versus nongovernmental involvement in food production versus quality of life or long-term sustainability?

What is the information base for making decisions? Decisions are not made by soil scientists, but by generalists or politicians. We *must speak their language.* We must learn how to present scientific information in a way that the information is usable by national planners. We should not present our personal preferences and opinions as facts.

We must develop new partnerships and alliances to get the job done. How can we better involve the nongovernmental sector in the stewardship of soil and water conservation and at the same time provide a better information base so we can make decisions concerning interventions and investments on economic and financial criteria? How can we involve professional societies and organizations with their tremendous reservoir of talent and expertise? How do we get environmental concerns into agricultural projects and activities and get agricultural concerns into regional environmental projects? Some of this is taking place now, but more is needed. Environmental interests have a constituency, and we need their help.

A viable agriculture

It seems almost axiomatic that solving conservation problems at the field level is not sustainable if the farm unit involved is not financially viable. Neither can environmental concerns at the regional or watershed level be addressed without financially viable farm units. Someone has to pay. We have not learned how to solve this problem in the United States, let alone in developing countries.

If we look at the beautiful setting of Machu Picchu in Peru, we can understand that the Incas had a stable ecological relationship in their culture. Agricultural terraces require upkeep—they had the type of society that allowed for terraces. Where do we have those types of societies today? Do we know what policies or incentives allow for development and maintenance of such terraces?

If we look at the relationship between runoff and maize yield, based on data of 20 or more years ago, we see that if yields are extremely high runoff is kept to a minimum. Good agronomic practices are the best solution to reducing runoff and erosion; they certainly are not mutually exclusive. Moreover, good agronomic practices are essential to any long-term solution for soil erosion control. Good agriculture should not be considered the culprit in environmental degradation.

We must get the farmer on an income stream—the number one reason for changing agronomic practices is *profitability*. We must express consequences of erosion in terms understood by politicians, decision-makers, and financiers—*money*—crop yields link money to erosion. Do we have the data necessary to predict the costs and effects of poor agronomic practices and/or erosion or runoff on financial or economic systems at the farm level, or at a more aggregated level?

Some data would indicate that annual erosion only costs 30 kilograms of grain. Who will pay for reducing erosion at that sort of charge? What is the incentive? What are offsite effects? What are the costs of not taking action? Who puts up the capital for present value versus future costs? We must have more basis than just intrinsic value. In the developing world, we must also have subsistence for farmers, but, in addition, we need to feed urban populations. How do we program for increasing future needs on a sustainable basis?

Poor management of natural resources on agricultural land is a major cause of environmental degradation. What is driving this poor management? Population pressure perhaps? This may be the indirect cause, but there are probably more direct causes. There are many examples of poor management in areas with low population densities. Frequently, we use population pressures as an excuse for not addressing the real issues of research investments, economic investments, and nonviable economic and social systems in current politico-economic climates. It often seems easier to change the issues rather than to change the politico-economic conditions.

Agriculturalists do not degrade land resources as an objective; there are other underlying causes—alternative investment opportunity, employment, income, a lack of understanding of the biophysical system, or just hunger. There seems to be evidence to support the thesis that mining the soil fertility is a major causal factor of land degradation. Reduced fertility results in less return, which results in less time invested in management, which again results in reduced return. How do we break this cycle in a cost-effective way? Is anyone really doing the research to answer in a definitive way whether fertility is a major causal factor so we can address it as a resource need and implementation question?

Anyone who has worked in tropical areas has seen many very turbulent streams, for example, on the eastern Andean slopes in Peru. These generally have a very heavy sediment load. This implies that serious erosion is taking place, which is bad. But from whose perspective? Certainly, the downstream farmer in the floodplain who depends upon the sediment deposit for renewing his soil fertility does not necessarily think so. It is doubtful that if the river were clear downstream farmers' income would be any higher. What are the other offsite costs? In many cases in isolated areas there is little activity downstream, so offsite costs per capita would be low regardless.

To evaluate properly and to propose interventions, we should know what part of the catchment area contributes most of the sediment and what are the offsite benefits and costs—difficult and costly information to obtain. Is it justified? We can go 2,000 to 3,000 miles downstream from the previously mentioned river in Peru to where the Amazon and Negro Rivers converge at Manaus and see the tremendous sediment carried by the Amazon. But as one of my superiors frequently asks, "So what?" Who is making the investments and doing the research to provide the necessary information and analyses to answer questions of cause and effect, costs and benefits?

If we look at some isolated fields on high, steep slopes, as in Peru, we must ask: How much investment is necessary to maintain these fields? Is it feasible to maintain them? Who pays? The individual or society?

We can also look at a beautiful, well-maintained valley with much of what might be considered intrinsic value as well as agricultural value and ask what sort of economic/social system is needed to maintain it in the future? Are we obtaining the information now that will be necessary to answer those questions?

We can look at some terraces in Yemen that are currently eroding. The country lacks the institutional, economic, and human resources necessary to address the problem properly. Just because the terraces are 1,000 years old and should be maintained does not change the basic economic and financial questions. Ten years ago during the oil boom, most of the labor in Yemen was in other Gulf States, and there was not sufficient labor available at a reasonable cost to maintain the terraces. The cost of labor has changed, but so has the society, and maintenance still is not being done.

This situation indicates the complexity of the problem, the international linkages. Farmers in most isolated areas are affected by the international economy and do not have the ability to respond in a reasonable manner. We can no longer think of solutions in isolation.

Some trade-offs

A continuing problem in developing countries is migration to urban areas, which results in tremendous social costs. Do we have the data or methods of analyses to compare current rural investment in conservation practices against future welfare or urban costs? What basis can we use—increased income, improved subsistence, or simply future welfare costs? How can we acknowledge the international linkages for isolated rural economies? Can we consider terrace construction as a public work, even though on private land, as a productive use of national human resource balanced against food aid in the capital city?

Another example of land degradation exists in arid or semiarid regions. Sand dunes in many cases can be very destructive, but in other cases arid regions can be developed through irrigation. Do we have the necessary information and analyses to advise donors on whether investment is more productive in alleviating conservation problems on steep lands than in developing new areas through irrigation? Or does investment go to whichever area has the most political support at the moment? Do we know what the potential production is in the different situations? Is public investment to protect private land against sand dune encroachment more beneficial, from a national perspective, than assisting subsistence farmers in the highlands? Public financial resources are generally limiting. How do we answer urban food needs versus rural income and social needs?

Decisions should be made on the best data available. However, they are frequently made on the best presentation of data and not infrequently, by default, on the lack of data for alternatives. Who has the best data to show return or need for assistance and on what basis? Which types of degradation are irreversible? Which involve more people? As scientists, we should be concerned about obtaining the necessary data and information to make the case for conservation.

There are examples of good conservation practices in many places. How do we extract the principles of why they work in some cases so we can extrapolate and transfer these principles to other situations and develop a practice or system that is within farmers' financial and technical reach?

There are many examples of contoured fields and terrace systems in Ecuador, Peru, India, and other countries that are financially and technically viable. In many cases, it is improved water management that seems to provide the return and best illustrate that good agronomic management is the preferred solution to conservation problems. We need to have a good understanding of the soil system in order to make proper recommendations.

Should we forget about erosion and just try to improve agronomic and soil management? There are examples in this book where farmers did this on their own, without incentives, if it was to their financial advantage to do so.

Establishing a sound information base

What sort of research is needed most? We cannot afford to reinvent the wheel, but we must understand the constraints and operational characteristics affecting use of "the wheel." It is not necessary to relearn the basic erosion processes; but we need to quantify the erosivity of the climate; we need to quantify the erodibility of the soils; we need to quantify the landforms; and we need to quantify the effects of indigenous and alternative land management practices. We do not need 40,000 plot years of research, like went into the universal soil loss equation (USLE), but we need enough to verify, to modify, to predict, and to use a similar erosion estimation relationship. It is essential for planning purposes. Resource inventories are needed, and research sites must be characterized better so research results can be extrapolated and transferred with a greater probability of success. Researchers need to be linked together in networks for more cost-effective and efficient information development and transfer.

A strategy of research, education, training, extension, and implementation is needed. We need to look at implementation from the farmer's viewpoint. Technologies and conservation practices should be built into farm-level models that also include information on soil. water balance, and agroclimate so farmers can choose their own alternatives.

As a society, we have decided that we will not do many things. Therefore, those of us who feel that soil and water conservation is important have to find new means of becoming more efficient and effective. We must look for ways of leveraging our minimal input. There is a need to cooperate and work in a multidisciplinary and interdisciplinary fashion. Economists and social scientists must be part of the approach so that we have the language necessary to present the case—they cannot be on the outside, after the fact, or doing their own thing.

USAID has a new initiative in resource conservation and management—fragile lands. This is a joint effort by several bureaus and offices. It involves eight projects from different offices that address different aspects of the problem. I don't think I need to tell you the administrative problems in trying to make something like this work in a governmental bureaucracy.

I do feel, however, that if we can make it work it may well be a model for addressing many other problems more effectively with our current financial constraints.

More questions than answers

I have raised many more questions than answers herein. But this is the reality. There are many more questions than answers. A solid information base is needed for improving decisions on conservation investments. These decisions must not be based solely on the best presentations or rhetoric. USAID is assisting in the development of the information base in developing nations.

9

International activities of the Soil Conservation Service

Jerry Hammond

Many developing nations are faced with low production of food and fiber during a period of rapid population growth or overpopulation. The earth's population reached 5 billion in July 1986 (*2*). Most of these nations have limited resources available to trade in the international markets for necessary food products. They have a labor-intensive society, little capital, and few technical resources. To the detriment of world society, these problems often lead to national instability and turmoil. The nations are faced with problems of hunger and famine unless they receive help.

Recently, U.S. policy has been moving more positively to help developing countries solve their food and income problems. The U.S. Department of Agriculture is playing an increasingly important role in the international arena through the U.S. Agency for International Development and other international organizations. USDA, the largest single source of agricultural expertise in the United States, has unique capabilities of particular importance to developing nations. The goal is to help developing countries become more self-reliant in producing food and fiber from limited resources in order to improve the quality of life for their people.

The Soil Conservation Service, a USDA agency, has a long history of international involvement. The agency's first chief, Hugh Hammond Bennett, and his assistant, Dr. Walter Lowdermilk, traveled throughout the world in the 1930s and 1940s to view soil and water conservation problems. Dr. Lowdermilk documented his observations in a bulletin, "Conquest of the Land Through 7,000 Years" (*4*). During this same period also, SCS hosted many visitors from other countries to show them what was being done in the United States to combat serious soil erosion and land use problems (*1*). Not only did early SCS leaders share their conservation knowledge with other countries, but they also learned what other nations were doing that would be applicable in the United States.

Objectives of present international programs (in cooperation with USAID and other international organizations) are to (1) help farmers and livestock producers in developing countries use their natural resources without depleting them; (2) exchange scientific and technological information with countries that have soil and water resource conservation problems similar to those in the United States; (3) contribute to the overall achievement of U.S. foreign policy that seeks to promote economic stability, reduce poverty, and solve world food problems; and (4) increase the technical knowledge and professional capability of SCS personnel.

International Activities Division

The International Activities Division of SCS is, of course, responsible for international activities. Specifically, the division must do the following: (1) develop policy and procedures for SCS involvement in providing assistance to foreign governments; (2) develop and coordinate plans for implementing technical assistance to foreign governments, including identifying qualified personnel and arranging for staffing assignments; (3) plan and schedule short courses and on-the-job training programs for foreign nationals; (4) represent SCS in planning foreign assistance programs with officials from USDA, from universities, and from other government agencies; (5) serve as a contact for foreign visitors seeking assistance from SCS; and (6) develop and maintain cooperative relationships with organizations and individuals engaged in international activities.

SCS participates in international conservation assistance by assigning technical specialists for international assistance or by exchanging scientific teams with countries that have agricultural science and technology that can benefit the United States. SCS also provides training for foreign visitors, giving them the opportunity to observe SCS activities throughout the United States. Furthermore, SCS participates in meetings of international technical and professional societies and plans conferences with other agencies involved in international programs. USDA's Office of International Cooperation and Development is responsible for coordinating the department's international policy and programs related to technical assistance, participant training, and scientific technical exchanges.

Technical assistance

SCS provides technical assistance through OICD-administered agreements with foreign governments, international organizations, and other U.S. government agencies. Employee assignments that provide technical assistance to foreign countries may be long-term resident assignments or short-term temporary assignments. SCS has employees on long-term assignments in five countries—Egypt, Indonesia, Pakistan, Mexico, and the Gambia. Projects have been recently completed in Peru and Saudi Arabia.

An SCS agricultural engineer who specializes in irrigation is helping to analyze the technical, social, and economic factors that influence the development of improved irrigation systems in Egypt. The assignment includes helping to design and carry out projects that are aimed at properly developing Egypt's Ministry of Irrigation.

A team of five SCS conservationists will investigate conditions, determine needs, and provide recommendations for strengthening Indonesia's institutional and technical capability in upper watershed development, which includes many steep lands.

SCS has been assisting the government of Pakistan in its federally administered Tribal Areas Development Project. The project is designed to improve irrigation efficiency and explore the use of groundwater in this generally dry, mountainous region. Project activities include the construction and maintenance of irrigation systems, test wells, and small well-fields.

SCS and the World Bank are carrying out a long-term soil conservation project in Mexico. The overall goal of the project is to increase productivity by improving the technological and managerial capability of Mexican technicians and farmers in the hilly areas of the humid tropics.

An SCS soil conservationist is assisting the Soil and Water Management Unit of the Gambian Department of Agriculture to plan and carry out a soil and water management program. A more complete description of the project can be found in the December 1985 edition of *Soil and Water Conservation News* (*3*).

SCS provided long-term technical assistance to the Government of Peru in establishing a national soil and water conservation system within the Directorate of Water and Soil in the Ministry of Agriculture. This assistance included instruction in the kinds of soil conservation practices to use, as well as how to use the practices, especially on steep lands.

Nine SCS soil scientists were assigned to work with the Saudi Arabian Ministry of Agriculture and Water on the general soil map of the Kingdom of Saudi Arabia. The general soil map with map unit descriptions and interpretive data has been published in English and Arabic. The five-year project was completed at a cost of $5.5 million and will enable Saudi Arabia to identify and plan the use of its arable land.

During fiscal year 1986, SCS sent a total of 94 employees on both short- and long-term technical assistance assignments to 33 countries. Those traveling on short-term assignments assisted individuals working on resident projects, in addition to their specific short-term activities. SCS employees carried out 40 assignments in 23 countries under the Soil Management Support Services, a USAID project implemented by SCS to provide technical assistance in soil survey, soil classification and use, and management of soils to developing countries.

International training

USDA's Office of International Cooperation and Development is also responsible for coordinating training of foreign nationals brought to the United States under the auspices of USAID, for the Food and Agriculture Organization of the United Nations, the World Bank, or joint commissions. SCS training is confined mainly to the principles and techniques used by the agency in carrying out its soil and water conservation programs.

SCS is heavily involved with training assistance for officials, scientists, and technicians from other countries. During fiscal year 1986, 435 visitors from 55 countries observed conservation practices at many locations throughout the United States in order to carry adaptable methods back to their own countries. In an average year, SCS works with about 240 participants from approximately 45 countries.

Scientific and technical exchanges

Scientific and technical exchanges in USDA moved from a scientist-to-scientist approach to a more formal government-to-government orientation with the advent of a direct appropriation of funds for this activity in 1979. A fundamental goal of scientific cooperation and technical exchanges is to broaden the capacity of the agricultural community to respond to changing economic and ecological patterns in a world in which natural resources are becoming scarce.

SCS has been especially active with the People's Republic of China. It has sent 11 different teams to China to investigate various aspects of soil and water conservation.

SCS participated in a roundtable discussion and field trip on soil conservation technologies held in Budapest, Hungary. During 1986, exchanges were also held with Mexico, Bulgaria, China, Romania, and Venezuela.

International meetings

Each year, many SCS employees participate in international meetings. Last fiscal year, for example, 35 employees traveled to 11 countries to present professional papers or attend meetings of interest to SCS.

Examples of the types of meetings that SCS employees attended included the Agricultural Land Drainage Forum, Canada; Auto-Cartography Conference, England; XIII International Soil Science Meeting, Germany; International Conference on Rural Landscape Management, Poland; IV International Conference on Soil Conservation, Venezuela; and International Society of Remote Sensing, Scotland.

In summary

SCS can point to many success stories as a result of implementing international projects sponsored by USAID and other international organizations. Some noteworthy projects are the Helmand Drainage Program in Afghanistan, the On-Farm Water Management Project in Pakistan, the Soil and Water Conservation Unit in The Gambia, the Soil Conservation Project in Guatemala, the Soil and Water Conservation Project in Peru, and the Upland Agriculture and Conservation Project in Indonesia. Unquestionably, the Soil Management Support Services Project has gained worldwide attention.

Less developed countries need the kind of technical assistance SCS offers to help them get the most from their available resources while protecting those resources for future use. SCS is interested in knowing about worldwide resource development, utilization, and protection in order to better address problems in the United States. International activities make these goals possible.

SCS willingly shares its technical expertise with other nations. Its international programs focus on sharing knowledge through both development assistance and cooperation with other countries. SCS has served as a cooperating agency with international programs in the past, is doing so now, and expects to continue to do so in the future.

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III

SOCIAL AND ECONOMIC ISSUES

10

Sustainable agricultural development in North Thailand: Conservation as a component of success in assistance projects

David E. Harper and Samir A. El-Swaify

North Thailand is an excellent laboratory for the study of soil erosion and conservation. Almost 90 percent of the Upper North is sloping upland or highland, and the erosion problem is widespread yet potentially manageable. Many agricultural assistance projects have been active in the region for more than a decade.

Demand for sloping lands has increased dramatically in recent years because of increased population pressure and growing lowland demand for forest, water, and recreational resources (7). These changes are increasing pressures on traditional swidden farmers to adopt permanent, settled, sustainable forms of agriculture. The success of settled farming systems is contingent upon effective conservation of soil through erosion control.

The research project described here was designed to evaluate the relative success of international assistance projects in fostering soil conservation among participating farmers and to test the relationships among soil conservation, erosion, crop yields, and sustainability of production at the farm scale.

Study methodology

Site and sample selection. This study compared conditions on two non-project "control" villages with conditions on three project sites: the Thai-Australia Land Development Project, the World Bank's Mae Sa Project, and the U.S. Agency for International Development's Mae Chaem Project. These projects met the criteria of (1) having a soil conservation component, (2) having completed field activities so that sustainability could be studied, (3) being active on sloping lands, and (4) dealing primarily with ethnic Thais rather than hilltribes (to reduce cultural variation in the sample).

Table 1 summarizes the characteristics of the project sites. Site locations are shown in figure 1. The TALD site and its Ban Du Tai control are in Nan Province on rolling uplands (usually defined as under 500 meters elevation, with slopes less than 30 percent). The other two projects and their control are in the higher, steeper highlands of Chiang Mai Province.

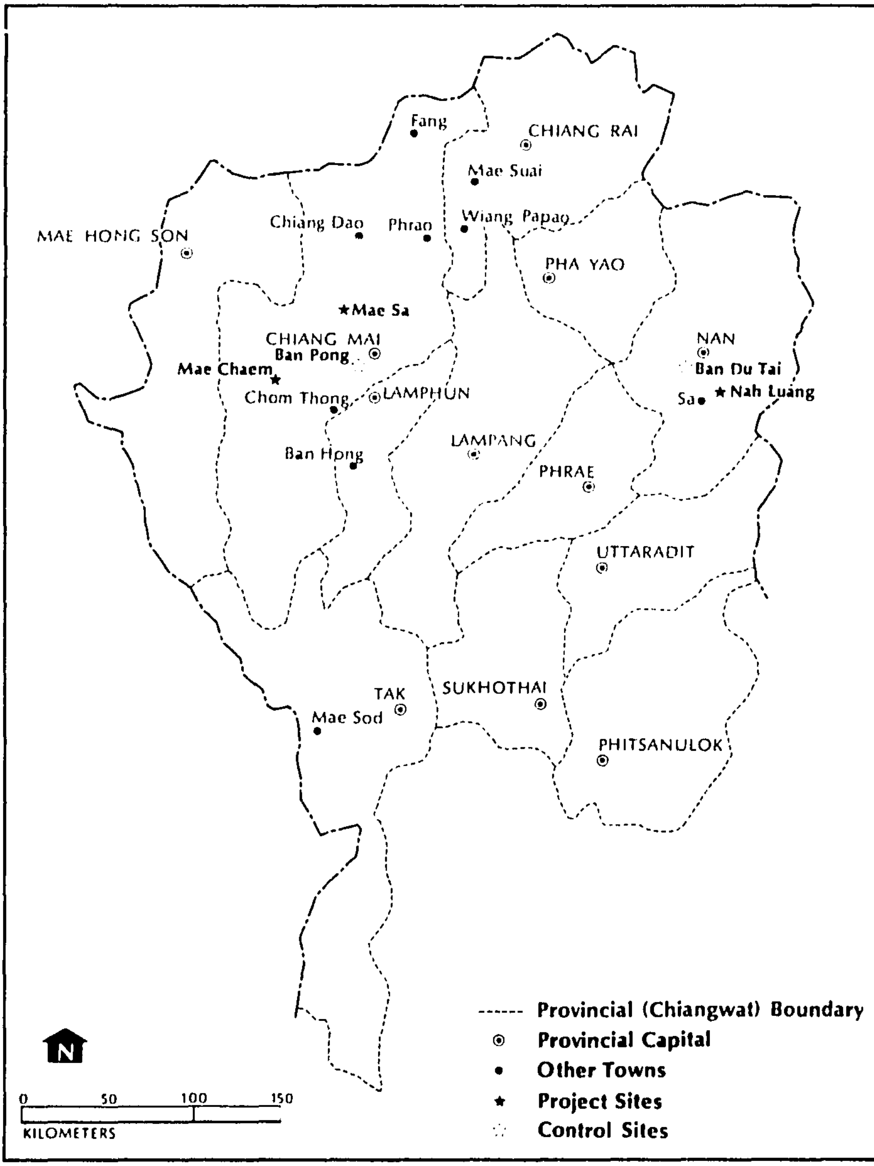

Figure 1. North Thailand, showing study areas.

Table 1. Summary of sample projects.

Descriptor	Projects TALD	Mae Sa	Mae Chaem
Province	Nan	Chiang Mai	Chiang Mai
Goals	Settle swiddeners, raise yields	Settle swiddeners, protect forest	Settle swiddeners, raise incomes
Conservation techniques	Contour banks	Terraces, banks, contour ridges, hillside ditches	Bench terraces
Construction methods	Heavy equipment	By hand, using Forest Department employees	By hand, hiring local farmers
Slope limits	20%	35%	35%
Landcscape class	Upland	Highland	Highland
Control village	Ban Du Tai	Ban Pong	Ban Pong
Main crops	Maize/mungbean relay	Rice, vegetables, maize	Maize, rice, soybeans

Stratified random samples of farm plots were selected. Sample plots had to be (1) owned by the same person since the development project was active; (2) used for growing food crops, rather than flowers, tobacco, etc.; (3) sloping, with an average steepness of 9 percent or more; and (4) accessible for site measurements and owner interviews.

Sample plots were selected by means of randomized map coordinates if reliable maps were available. Otherwise, lists of project participants were used. In control villages, samples were selected by examining tilled areas in the field and picking sites that represented the range of conditions and farming methods in the area.

Project/village description. *The TALD project.* The TALD project began in 1967. Involved initially were the Thai Department of Land Development and the Australian Development Assistance Bureau. Twelve years later, in 1979, the World Bank began providing loan support for the project, and its name was changed to the Thai-Australia World Bank Land Development (TAWLD) Project. The TALD project originally focused its efforts in Nan, Phrae, and Lampang Provinces. This research project selected sample villages of Ban Huai Muang and Ban Nah Luang, which were included in the TALD project in 1977.

The objective of the TALD project was "the development and stabilization of areas of rainfed agriculture which are currently being farmed on an intensive slash and burn or 'swidden' system of shifting cultivation" (*17*). Contour banks were constructed by heavy equipment on slopes of 20 to 70 percent in areas of high population pressure. The project claims to have increased crop production per unit area up to six-fold, mainly by intensification of land use.

Soil conservation was a primary concern in the TALD project. Conservation was to be achieved by building "graded banks to direct water into existing waterways; absorption banks to hold water and allow dispersal by means of seepage" (*17*). The project favored permanent contour banks, which were big enough so they could not be plowed out by farmers.

Mae Sa project. The Mae Sa Integrated Watershed and Forest Land Use Project began operation in 1973. The first phase of the Mae Sa project entailed socioeconomic and physical surveys as well as construction of a research and demonstration area. Various structural soil conservation techniques were tested at Pong Khrai, including bench terraces, intermittent terraces, hillside ditches, contour banks, and orchard terraces. During the eight second-phase years, the project selected control structures based on Pong Khrai results and installed them on about 700 hectares of farmers' fields.

Mae Chaem project. The USAID-sponsored Mae Chaem Watershed Development Project seeks to bring about significant changes in the 420,000-hectare Mae Chaem watershed, traditionally one of the poorest and more isolated areas in North Thailand. Until recently, "security incidents" were frequent and opium was a common crop.

The sweeping goal of the Mae Chaem project is "to raise the quality of life of the occupants of the watersheds in Northern Thailand in ways which support increasing environmental stability and which are self-sustaining."

Indicators of goal achievement include increasing size and productivity of agricultural areas, increased income from cash cropping, improved literacy and health, local participation in decision-making, stable or decreasing runoff and sediment yields, and stable or increasing rates of forest growth. The Mae Chaem project is the only one of the three projects under study to state clearly indicators of success in its design.

The Mae Chaem project attempts to solve problems of poorly built and maintained roads, swiddening, and forest fires (often escaped swidden fires) that contribute to high erosion rates. The project includes such components as land development (primarily building rainfed and irrigated bench terraces), irrigation facilities, road improvements, and public health and education. The project hires local farmers to build their own bench terraces by hand during the dry season. In this way, the project terraced 1,568 hectares in its first four years, at a cost of about $650 per hectare, more than 90 percent of which was for wages. Extension is conducted by "interface teams" that live in project villages.

Control villages. Control areas were chosen that had not been served by assistance projects and that displayed types of agriculture similar to project sites. Two control areas were selected: one for the upland TALD project, and another for the highland Mae Sa and Mae Chaem projects.

Ban Du Tai is the upland control. Most farmers rely upon mulch and canopy coverage to protect their soils. As in the TALD fields, most Ban Du Tai farms grow a main crop of maize followed by mungbean.

The highland control is Ban Pong. Most Ban Pong farmers till swiddens in the hills above their padi fields. Although most slopes are moderate, some fields are very steep. The steepest sample field had a slope of 74 percent. Farming practices are roughly analogous to those that would have been found on Mae Sa and Mae Chaem fields before the arrival of assistance projects.

Data collection and processing. Results were compared among projects, and between projects and controls. Field data were gathered by seven researchers, including five hired and trained Thai university graduates. Physical data were recorded on site dimensions, visible evidence of erosion, crop vigor, conservation methods [using a form modelled on the *Soil Data Card Hardbook* (*10*)]. Soil samples and bulk density samples were analyzed at the Chiang Mai University Soils Laboratory. Researchers also conducted individual half-hour interviews with each sample farmer on farming methods, perception of erosion, yield changes, and project participation. Results were compiled and statistically analyzed at the University of Hawaii.

Methods of estimating erosion rates. The universal soil loss equation (*18*) was calibrated against runoff plot data from research done by the TALD project, Department of Land Development, and Royal Forest Department. Although many assumptions are needed to make the model operable, the USLE nonetheless probably provides the best estimate of erosion on a large number of field sites when time and funding preclude actual measurement. The following procedures and assumptions were employed:

Rainfall erosivity (R factor). The study adapted the regression equation of Lo and associates (*8*), which calculates erosivity from annual rainfall distributions in Hawaii. Annual rainfall was calculated for various elevations in North Thailand and refined to include slope aspect to reflect the dominance of the southwest monsoon and the paucity of storms from the North. The resulting mean EI_{30} R values were 394, 404, 457, 464, and 563 meter-tons per hectare per year for Ban Du Tai, TALD. Mae Chaem, Ban Pong, and Mae Sa, respectively.

Soil erodibility (K factor). Most K-factor values published in North Thailand have been calculated from Wischmeier and Smith's nomograph (*18*). Therefore, we began by calculating Wischmeier and Smith's K nomograph values from field and laboratory data. The only reliable bare-plot K data are from the TALD project (*14*). These measured results were consistently lower than nomograph values by a factor of 0.73. Therefore, the nomograph-calculated K values were multiplied by 0.73 for all groups except Mae Sa, where an adjustment factor of 0.50 was used.

Crop management (C factor). The empirical relationships published by Wischmeier and Smith (*18*) for cropland and Dissmeyer (*2*) for forest and rangeland were modified for use in North Thailand. The C factor for each crop was calculated using erosivity, mulch, and canopy cover for each crop stage. A C-factor calculation model was developed for the major upland crops: maize, mungbean, rice, soybean, potato, peanut, cabbage, and chilies, as well as forest and bush fallow.

Land management (P factor). Surface treatment is important with respect to soil erosion rates in North Thailand, but practices and conditions are often quite different from those described in Agriculture Handbook 537 (*18*). Contour and bed-and-furrow tillage effects were calculated using Soil Conservation Service recommendations for Hawaii and bench terrace limits based on Wischmeier and Smith (*18*). Surface roughness effects were estimated using Dissmeyer's approach to forest and range areas (*2*). A permeability subfactor was calculated by amending Dissmeyer's equation for use with bulk-density-based permeability classes.

Topography (LS factor). Slope factor values were calculated using the Wischmeier and Smith (*18*) equation. Sheng (*16*), however, stated that the rate of increase in LS declines on slopes over 20 degrees, falling to zero as slopes approach 90 degrees. To reduce the effect of unreasonable LS values on erosion estimates for sample sites, a maximum LS value of 20.0 was applied.

Project results and discussion

The calculated erosion rates for each group are presented in table 2; these are for conditions "with" and "without" conservation structures.

Table 2. Erosion rates (mean erosion values within groups, in tons/hectare/year, "without" and "with" conservation structures).

Group	Without Conservation Structures		With Conservation Structures		
	Mean	Standard Deviation	Mean	Standard Deviation	Range
TALD (N = 40)	74	60	26	16	5-65
Ban Du Tai* (N = 41)	39	24	39	24	8-98
Mae Chaem (N = 40)	155	158	34	33	7-183
Mae Sa (N = 54)	136	99	89	80	5-148
Ban Pong* (N = 41)	284	193	281	195	50-931
Project (N = 134)	123	116	54	62	5-418
*Control (N = 82)	162	184	160	184	8-931

Control sites had both the highest and lowest erosion rates without structures (Ban Pong, 284 tons/hectare and Ban Du Tai, 39 tons/hectare), which highlights the range of farming techniques and physical conditions found in North Thailand. The mean erosion rate for project sites without structures was 76 percent of rates on controls. With structural conservation, erosion rates on project sites fell to only one-third of the rate on controls. Hence, the structural measures generated a 56 percent reduction in soil loss on project sites. Although the mean rates of soil erosion after projects were still much higher than probable soil generation rates, the projects nonetheless have greatly reduced erosion from former levels.

In the uplands, annual erosion rates on TALD sites fell from 74 tons per hectare before the project to 26 tons per hectare in 1985, a 65 percent reduction. Interestingly, farmers in the Ban Du Tai upland control, relying primarily on agronomic conservation methods, maintain a mean erosion rate of only 39 tons per hectare, and 34 percent achieve rates lower than the TALD mean of 26 tons per hectare. In addition, soil fertility, crop yields, sustainability, and farmer perception of soil quality were generally higher on Ban Du Tai control fields than on TALD sites.

The most striking reduction in erosion occurred in the highlands, on the Mae Chaem sites, where bench terracing reduced annual erosion rates by 78 percent, from 155 to 34 tons per hectare. However, the wide range of values (7 to 183 tons/hectare) suggests that many plots have terraces of questionable performance. Terracing in Mae Sa reduced mean erosion by 35 percent, from 136 tons per hectare to 89 tons per hectare. Here, even more than at Mae Chaem, the range of erosion rates (5 to 418 tons/hectare) was unexplained by topographic variability and indicated inconsistent implementation of project works. Some Mae Sa farmers, unhappy with yield declines and reduced cultivable area on their newly terraced fields, destroyed the terraces. Their lack of involvement in the project and poor understanding of reasons for conservation contributed to this destruction.

Because agronomic practices are critical to effective soil conservation, particularly in nonproject areas without structural measures, an index of agronomic conservation was used to compare groups. The index is simply the product of two USLE variables that best reflect the agronomic practices of a farmer: C, the cropping factor, and P, surface treatment (Table 3). These index values stratify the sites into two groups: upland and highland. The uplands have the lower or more conservative value of 0.17.

This similarity belies the difference in practices between the areas. On TALD sites, surface roughness from disk plowing generates low P values, whereas in Ban Du Tai, heavy use of mulch and heavy canopy cover generates low C values. Index values in the highlands are substantially higher than in the uplands. Mae Sa sites have the lowest mean score, 0.23, followed by Mae Chaem, 0.25, and Ban Pong, 0.28. This narrow range of values suggests that the projects generate relatively little improvement in agronomic conservation effectiveness.

Questionnaire results and discussion

Farmers' understanding of erosion processes was probed by asking, "What things do you think cause soil erosion?" Their responses, in categories relating to USLE variables, are presented in table 4. Nearly every respondent named rainfall as an erosive factor; slope steepness was identified by 60 percent. Bare soil or lack of plant cover was named by more than half of the farmers in Ban Du Tai, Mae Chaem, and Mae Sa; one-third in Ban Pong; but only one-quarter of TALD farmers. Cutting trees and plants was identified by a large majority in Mae Chaem (70 percent), where the proj-

Table 3. Index of agronomic (nonstructural) conservation (mean value of C × P, by group).

Group	*Mean*	*Standard Deviation*
TALD (N = 40)	0.174	0.057
[illegible] Du Tai* (N = 41)	0.171	0.053
Mae Chaem (N = 40)	0.258	0.110
Mae Sa (N = 54)	0.232	0.084
Ban Pong* (N = 41)	0.279	0.094
Project (N = 134)	0.223	0.092
*Control (N = 82)	0.225	0.094

Table 4. Perceived causes of soil erosion (by percentage of cases).

	TALD (N=36)	*Du Tai (N=37)*	*Mae Chaem (N=33)*	*Mae Sa (N=47)*	*Ban Pong (N=32)*	*Project (115)*	*Control (68)*
Heavy rainfall	92	100	100	100	100	97	100
Bare soil or lack of cover	25	59	58	51	34	45	47
Steep slopes	56	57	70	51	63	59	60
Soil types	22	19	24	32	34	26	27
Farming methods	8	11	33	28	13	23	12
Cutting trees and plants	25	51	70	38	47	44	49
Other	8	0	0	0	9	2	4
Causes mentioned	2.4	3.0	3.6	2.8	3.0	2.9	3.0

Table 5. Source of soil erosion knowledge (by percentage of cases).

	How Did You Learn About Erosion?				
Group	*Direct Observation*	*From Neighbors*	*From TV or Radio*	*Project or Government*	*Other Source*
TALD	81	19	3	58	0
Di Tai*	97	8	8	3	0
Mae Chaem	100	21	0	61	3
Mae Sa	100	10	4	39	0
Ban Pong*	94	19	6	3	6
Project	94	16	3	51	1
*Control	96	13	7	4	3

ect has attempted to educate farmers against forest cutting and burning. Table 4 also shows that only a minority of farmers recognize that soil type or farming methods affect erosion, with highland groups having slightly better scores. The last two columns of table 4 show that project and control scores were almost identical, indicating that knowledge of soil erosion causes was not improved substantially by project participation.

To identify how best to disseminate information on soil erosion, farmers were asked: "Where did you learn about soil erosion?" (Table 5). By far the leading source of knowledge about erosion was direct observation: 9 of 10 farmers reported seeing soil moving in their fields. Only one respondent in six gained erosion information from friends and neighbors. A significant proportion of project participants cited project or government sources of erosion information. In contrast, this proportion was nearly nil in control groups. Radio and television provided limited erosion information in all locations.

It is commonly proposed that farmers must experience improved crop yields and household welfare if they are to adopt conservation. Perceived effects are often as important as real effects. Answers to the question "By how much have these soil conservation measures changed your crop yields?" are shown in table 6. Conservation could be interpreted by project or control farmers as any technique used on their fields. A minority of responses were in the "great improvement" category. The majority in all other villages, except Ban Pong, noted small to moderate improvements in yields. Control farmers were more likely than project farmers to perceive no improvement in yield due to conservation. Nearly one-third of TALD respondents perceived declining yields from soil conservation.

Reasons for not using conservation measures (or other measures if conservation was already practiced) were remarkably similar for project and control groups (Table 7). Lack of labor and money were noted as the two greatest impediments to soil conservation. Large groups of respondents in all villages were unaware of other conservation methods, or felt that erosion was not serious or operates too slowly to be of concern. This suggests a large role for education in future projects. Results from table 7 contradict claims in the conservation literature that land ownership is a necessary pre-condition for sound resource management. This reflects the continued availability of new lands, the security of some farmers' tenure, and the quasi-legal recognition of rights of swiddeners to clear and till land.

Table 8 summarizes responses to a follow-up question: "What type of government or other assistance would cause you to use soil conservation measures on your land?" Land assistance was the primary need mentioned. Labor assistance was needed on 80 percent or more of highland farms, but on half or less of cases in the uplands. The most commonly mentioned need in the uplands was for technical help or education, or for earth-moving equipment. Earth-moving equipment can be viewed as the upland equivalent of labor assistance in the highlands. Financial assistance was mentioned in 85 percent of Mae Chaem cases, where farmers were paid by the project to build their terraces, and mentioned much less frequently elsewhere. Overall, 11 percent or fewer of the respondents said that no form of assistance would cause them to use conservation measures. The inter-village differences in perceived needs for assistance suggest that projects should survey their prospective participants before selecting project elements for delivery.

Conclusions from project results

The study results indicate that the three projects have significantly reduced soil erosion rates on their respective sites, although erosion on most fields

Table 6. Perceived effectiveness of conservation methods for improving crop yields (by percentage of cases).

	Group						
Amount of Yield Improvement	*TALD (N=41)*	*Du Tai (N=37)*	*Mae Chaem (N=39)*	*Mae Sa (N=49)*	*Ban Pong (N=29)*	*Project (129)*	*Control (66)*
A great deal	2	22	21	16	14	13	18
Small/moderate improvement	56	60	64	67	28	63	46
No improvement	2	16	8	8	38	6	26
Yields declined	32	3	8	8	21	16	11
Yields vary	7	0	0	0	0	2	0

Table 7. What prevents use of (other) conservation measures (by percentage of cases)?

	Group*					
Reason for Not Using Measures	*Du Tai (N=41)*	*Mae Chaem (N=41)*	*Mae Sa (N=49)*	*Ban Pong (N=39)*	*Project (91)*	*Control (80)*
Lack of money	73	95	61	69	77	71
Lack of labor	66	90	80	79	85	73
Insecure land tenure	0	0	8	10	4	5
Can use swiddening	3	0	0	33	1	18
Methods do not work	8	3	15	3	9	5
Erosion is very slow	41	32	37	45	34	43
Erosion is not serious	32	42	33	42	37	37
Do not know methods	34	46	53	31	50	33
Other	15	6	4	9	5	12

*Due to unclear instructions to interviewers, no responses from TALD sites were obtained.

Table 8. What assistance is needed for farmers to use conservation methods (by percentage of cases)?

	Group						
Types of Assistance Needed	*TALD (N=41)*	*Du Tai (N=37)*	*Mae Chaem (N=41)*	*Mae Sa (N=51)*	*Ban Pong (N=39)*	*Project (133)*	*Control (76)*
Labor assistance	44	51	100	82	92	76	72
Money/pay me to build them	15	38	85	43	64	47	29
Technical help/ education	56	68	49	43	49	49	33
Earth-moving equipment	41	59	32	27	51	30	32
Would never use methods	0	11	2	10	3	5	7
Other	2	0	2	2	0	2	0

remains excessive. Most farmers feel that project-built structures have been a net benefit to their farms. A major point emerges from observation of the Ban Du Tai control farms: agronomic methods alone can be very effective in controlling erosion. Conscientiously used mulch and cover management not only controls raindrop impact and sediment transport but benefits soil structure and fertility as well. Indeed, soil degradation can proceed despite the presence of conservation structures if projects ignore agronomic conservation techniques. Unfortunately, agronomic conservation measures demand more persistent labor but are less visible and dramatic than are structures. They rely upon extension and education, the weak links in project delivery, and "target achievement" is difficult to measure. Development projects should emphasize agronomic methods if the benefits to farm production from expensive structures are to be realized and sustained. Ultimate project success in fostering permanent, settled farming in swidden areas depends upon the extent to which they generate stable soil fertility and crop yields.

The careful matching of conservation structures with site characteristics and cropping systems has not been emphasized by the projects. Even in Mae Sa, where several types of structures were used, the sole selection criterion was slope angle. A major design and construction flaw has been the exposure of subsoil during terrace construction on shallow soils. The resulting lower yields and fertility gradients understandably reduced farmers' acceptance of conservation methods. Lack of lateral drainage causes storm runoff to overtop the fronts of terraces, eroding risers, and shortening the useful life of the structures. This has dangerous implications in view of the fact that less than one-quarter of the sample farmers diligently maintain their conservation structures. This is particularly serious for projects in which structures and waterways serve the common needs of many farmers and the focus of responsibility may be diffuse. In addition, in the long term, projects will not achieve their objectives without placing significantly more emphasis on teaching farmers about soil erosion and conservation, acknowledging the necessity to provide labor or material assistance to participants and securing farmers' commitment to maintain fixed investments in conservation.

Although projects were cited as important sources of erosion information, they still reached only half of the project participants. Farmers understand the natural causes of erosion, such as rainfall and slope, but not the cultural causes. If farmers understand that erosion can be reduced by changing their farming practices, then they are more likely to accept—or develop—effective conservation strategies. Knowledge of erosion may be insufficient to initiate conservation, but it is an important element in sustaining and maintaining conservation action, and it can reduce the incidence of destruction of conservation structures by farmers who perceive only negative effects.

Labor assistance is the primary form of help that farmers need in order to use conservation methods. Hiring farmers to build their own structures has several benefits: farmers receive needed employment; they become committed to the structures; and soils are less likely to be damaged than if heavy equipment is used. Using heavy equipment makes little environmental, economic, or social sense in regions with surplus labor.

The results show that even if farmers understand and implement structural conservation there is no assurance that their yields will improve. Conservation packages for extension in less developed countries must focus not only upon reductions in soil movement but also—and even primarily—upon yield improvement or stabilization. These findings indicate that conservationists should work more closely with agronomists and other production-oriented agriculturalists if sustainable agriculture on slopes is to be achieved.

Elements of project success

The observations summarized above, detailed in the original study (*4*), and discussed by other authors (*3*) point to certain elements that successful conservation programs have in common. These elements relate to concept, design, implementation, maintenance, and monitoring.

Concept. Attaining effective conservation should be included and clearly stated among project goals. In so doing, project goals should acknowledge the following:

► Conservation is part of a larger social and environmental fabric, and conservation has little chance of succeeding unless it becomes part of the recipient culture. Decisions to change farming methods, to apply conservation techniques, and to adopt attitudes of stewardship rather than exploitation of the land are made by individuals in the context of their society.

► Projects should serve the needs of participants. A survey of the biophysical and social problems and opportunities of the target area can provide the basis for understanding these needs.

► Simple technological packages are more likely to gain farmer acceptance than those that are complex or exhaustive.

► Education is central to conservation. Farmers will support conservation only if they understand the economic, environmental, and social consequences of their actions.

► Conservation must be associated with clear productivity benefits to the farmers themselves, off-site impacts notwithstanding. Although governments and other off-site agencies must play their appropriate roles, the secret to successful management of soil resources is to devise systems of soil conservation with benefits so apparent and immediate that they will be adopted spontaneously by farmers throughout areas of high erosion hazard.

Design. To build upon conceptually sound principles, the design of a successful conservation program should display the following elements:

► Match site characteristics with conservation-effective and sustainable land uses. Many conservation approaches have been transferred directly from flat lands to slopes, techniques that "in the humid tropical uplands are inadequate and impractical when it comes to coping with erosion problems" (*16*).

► Balance both social and physical aspects of conservation by incorporating state-of-the-art findings from research, including local research and experience from pilot projects and demonstrations (*12*, *13*).

► Ensure that farmers are aware of the causes of erosion and how to control it, the reasons for conservation, and the necessity of long-term maintenance.

► Involve recipient farmers in identifying problems and potential solutions and in designing and implementing the project. A promising approach is the Australian technique of the "problem census" and "consensus budgeting" in which farmers help to identify farming problems and solutions with guidance from trained extension agents. When farmers help to develop the plan, they will understand it and become committed to it (*5*, *6*).

► Emphasize small, incremental improvements in farming systems, which are well-suited to conservative peasant cultures. If the project aims to replace completely rather than to improve indigenous agricultural technology, success is rare (*9*). "The smaller the change required and the more dependable the return from the technology, the more likely the change is to be acceptable to farmers" (*11*).

► Emphasize agronomic conservation measures, supplemented only as necessary with engineering structures. Such emphasis, combined with the items listed above, assures slope stability as well as enhanced crop productivity.

Implementation. Many well-conceived and carefully designed projects still fail during implementation. To improve the likelihood of successful implementation, projects should take the following actions:

► Share costs with farmers or facilitate financing. Assisting farmers with costs is a prudent means of securing their support and impressing upon them the administrators' strong commitment to conservation.

► Permit project flexibility, which will allow the project to adapt to new knowledge during implementation. Project managers should have the authority to amend projects. Flexibility requires local control of projects.

► Deliver information efficiently through extension. Successful implementation requires committed extension agents who win the respect and cooperation of the farmers. In Thailand, extension agents in the past came from urban backgrounds and had limited skills in extension. It was not unusual for farmers' knowledge of traditional food and cash crops to exceed that of the agents (*5*), so their advice was rarely taken seriously (*9*). The Mae Sa project in 1979 resorted to training village elites to extend conservation farming techniques because of a lack of qualified extension personnel (*15*).

► Try to reach poor farmers as well as "safe" farmers. To focus on safe farmers or the most productive lands because they are most likely to succeed will often increase rather than diminish gaps in productivity and income in poor villages (*1*).

Maintenance. Conservation methods sustain their effectiveness only if maintained and supported in the long term by recipient farmers. This might be secured through encouragement, education, and contractual agreements (as a condition of receiving project assistance), or through payment or project action.

Monitoring. Few agricultural assistance projects with conservation components actually quantify the performance of their activities. More commonly, projects assume that the conservation methods they implement will reduce erosion and improve yields; this is a deficient means of evaluating project success. Projects should:

► Carefully monitor and record the progress of the project.

► Monitor the effects of conservation activities on crop yields, soil fertility, runoff, and erosion. Results of this monitoring can be used to improve future projects or to correct weaknesses in existing projects.

► Correct harmful design or construction flaws in conservation structures and transmit improved agronomic advice to participating farmers.

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11

Assessing economic benefits of soil conservation: Indonesia's upland model farm program

Harold C. Cochrane and Paul C. Huszar

Intensive cultivation of steep slopes in the upland regions of Java results in high rates of soil erosion. This erosion poses a serious threat to the continued productivity of the upland regions. Moreover, eroded soil contributes to the siltation of downstream irrigation systems, which reduces their productive life, and to the siltation of riverbeds, which exacerbates the flooding threat. To address these problems, the Indonesian government formally began an uplands conservation program in 1976. This paper evaluates one component of this conservation program, the model farm program of the Citanduy II Project.

While the major goal of the Citanduy II Project is to reduce soil erosion, the project's planners realized that in order to induce farmers to particpate in the model farm program more direct benefits to the farmers were necessary. Therefore, the project was started in 1981 with the multiple goals of reducing erosion and increasing farmer incomes and employment.

The program, a five-year effort, involved establishment of 48 model farm units and impact areas. The model farm units and impact areas are located in the villages of Mekarsari and Cibahayu in West Java and the village of Sadabumi in Central Java; all are within the Citanduy watershed.

The model farm program consists of introducing a package of upland agricultural technologies. The package includes construction of bench terraces and use of new cropping patterns, seed varieties, and inputs of chemical fertilizers and insecticides on land with slopes up to 45 percent. Land with slopes of more than 45 percent get an agroforestry package. Subsidies and credit are provided for the construction of bench terraces and the purchase of new inputs.

Initially, a model farm is established. Because a farmer's land is typically fragmented into a number of relatively small parcels of less than 1 hectare each and because an area of approximately 10 hectares is needed to make bench terracing feasible, selection of the model farm site depends upon the cooperation of a number of farmers on 10 hectares of contiguous land. Moreover, implementors of the project seek sites with the worst erosion conditions in order to provide the most dramatic demonstration of the program's benefits and, presumably, produce the greatest soil conservation benefits.

After the model farm is established, extension agents try to persuade groups of nearby farmers, in what are called the impact areas, to adopt the model farm package. The extension activity focuses on those land areas with the worst erosion problems. The farmers adopting the model farm package also get some input subsidies for three years and financial credit for their activities.

Nature and significance of benefits

Data previously collected by the Unit Studi Dan Evalusai Sosial Ekonomi for 65 farms in each of the three villages of Mekarsari, Sadabumi, and Cibahayu were used to analyze the nature and significance of economic benefits of the model farm program. The data were collected two to three years after implementation of the project and represent the results of personal interviews with farmers on the performance of their farms before and after the project.

While the data were collected for the purpose of evaluating the project, no apparent evaluation plan was formulated. As a result, only a relatively small portion of the collected data proved useful for an economic evaluation. Moreover, important economic variables were not directly measured and must be inferred from the data. Finally, no data useful for assessing the effects of the project on soil erosion were collected. However, data exist for evaluating the benefits of the project in terms of incomes and employment.

Table 1 summarizes the descriptive analysis of land and labor productivity and the use of labor before and after the introduction of the model farm program. Table 2 summarizes the analysis of the statistical significance of the changes in the before and after values shown in table 1. Pecuniary values are measured in terms of Indonesian rupiah. For purposes of comparison, the current exchange rate is approximately Rp 1,640 = US $1.

Value of production. Table 1 indicates that the total value of production per hectare (rupiah/hectare), before adjusting for inflation, for both the model farm area and the impact area increased after terracing for the entire area and within each village. These changes are statistically signifi-

Table 1. Annual land and labor productivity and labor use, Citanduy II Project, Java.

	Model Farms						Impact Area Farms						Nonadopter Farms	
	Before		After				Before		After				Before	
	Mean	Std Dev	Mean	Std Dev	Diff	% Chg	Mean	Std Dev	Mean	Std Dev	Diff	% Chg	Mean	Std Dev
Mekarsari														
Total value per hectare*	300,882	103,969	1,119,015	498,498	818,133	272	234,357	423,554	933,391	1,178,133	699,034	298	799,076	1,611,050
Labor use†	1,418	974	2,619	867	1,201	85	1,204	1,701	2,147	2,115	943	78	799	591
Labor productivity‡	284	155	461	231	177	63	274	226	520	403	246	90	973	924
Sadabumi														
Total value per hectare*	251,339	155,459	403,182	385,768	151,842	60	158,247	102,148	217,770	183,773	59,523	38	173,788	152,313
Labor Use†	1,024	508	3,070	2,501	2,045	200	1,196	720	1,571	820	375	31	1,132	760
Labor Productivity‡	299	260	131	127	−168	−56	180	200	172	194	−8	−4	325	583
Cibahayu														
Total value per hectare*	161,595	97,413	424,429	146,019	262,833	163	174,655	154,165	430,537	215,751	263,882	151	517,989	781,546
Labor use†	1,553	837	2,589	791	1,037	67	2,056	1,153	3,228	1,622	1,170	57	1,950	1,474
Labor productivity‡	232	435	180	89	−52	−22	93	66	160	96	67	72	229	193
Total														
Total value per hectare*	232,066	129,732	631,610	478,314	399,544	172	190,086	270,395	539,504	766,876	349,418	184	496,951	1,044,889
Labor use†	1,349	801	2,746	1,495	1,398	104	1,497	1,308	2,334	1,740	837	56	1,302	1,104
Labor productivity‡	2669	307	251	207	−17	−6	180	190	279	306	99	55	492	695

*Rupiah per hectare.
†Hour per hectare.
‡Rupiah per hour.

Table 2. Calculated T values, degrees of freedom, and hypothesis test (.01 level) of equal before and after means.

	Calculated T Values	*Degrees of Freedom*	*Reject Hypothesis*	*Calculated T Values*	*Degrees of Freedom*	*Reject Hypothesis*
Mekarsari						
Total value per hectare*	4.711	7	Yes	5.435	36	Yes
Labor use†	3.615	7	Yes	7.506	32	Yes
Labor productivity‡	2.649	7	No	3.294	31	Yes
Sadabumi						
Total value per hectare*	1.314	7	No	1.921	33	No
Labor use†	2.316	7	No	2.341	32	No
Labor productivity‡	1.769	7	No	0.252	32	No
Cibahayu						
Total value per hectare*	5.011	9	Yes	9.474	35	Yes
Labor use†	3.830	9	Yes	5.494	34	Yes
Labor productivity‡	0.351	9	No	5.381	34	Yes
Total						
Total value per hectare*	4.667	25	Yes	6.606	106	Yes
Labor use†	4.547	25	Yes	8.047	100	Yes
Labor productivity‡	0.243	25	No	3.537	99	Yes

*Rupiah per hectare.
†Hour per hectare.
‡Rupiah per hour.

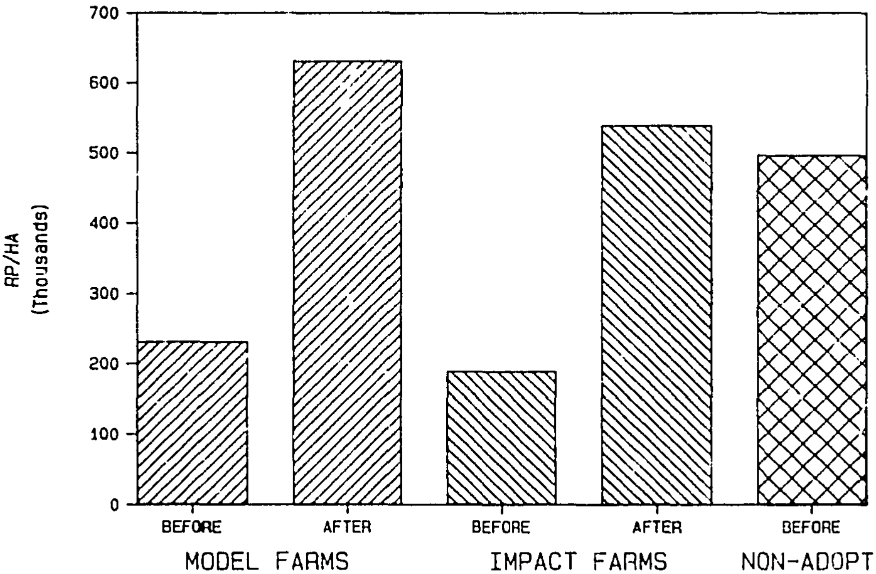

Figure 1. Land productivity, Citanduy project.

cant at the .01 level for all cases, except for the village of Sadabumi (Table 2). On average, the increased nominal value of annual output per hectare was 399,544 rupiah/hectare (172 percent) in the model farm areas and 349,418 rupiah/hectare (184 percent) in the impact areas (Figure 1).

On average, the group identified in the data as nonadopters of the model farm package had returns per hectare that were not significantly different from the returns on the model farm or the impact farms after adoption of the model farm package (Table 1). The nonadopters appear to be economically rational because they would not have gained by adoption.

This, however, is a spurious result because the "nonadopter" label in the data set turns out to mean farmers who did not accept subsidies, though they may adopt part or all of the model farm technology. Why they did not accept subsidies is not clear, though it may have been due to an aversion to government interference in their business or because they were not eligible for the subsidy program. But direct observation of the model farm areas indicates that many farmers in this group used the model farm technology in whole or part.

A better term for "nonadopters" is probably "nonparticipants." The fact that these nonparticipants had returns comparable to those of the participants in the program indicates that subsidies may not be necessary or at least were inefficient in the model farm program.

Labor use. Annual labor use per hectare (hours/hectare) increased after terracing on both the model farm areas and the impact areas (Table 1). On average, model farm use of labor increased 1,398 hours per hectare (104 percent) and impact area labor use increased by 837 hours per hectare (56 percent). Changes in labor use were significant at the .01 level for all cases except in the village of Sadabumi, where the change was not statistically significant (Table 2). The model farm areas used 2.1 times as much labor per hectare and the impact areas used 1.8 times as much labor per hectare as the nonadopters. The largest statistically significant increase in labor use was in Mekarsari, which had an 85 percent increase on the model farms and a 78 percent increase on the impact area farms. Labor use by nonadopters was significantly lower than by adopters of the model farm program. Figure 2 summarizes the results for the entire project.

Labor productivity. Changes in labor productivity (rupiah/hour) on the model farms were not statistically significant, while changes on the impact farms were statistically significant for the project as a whole and within the villages of Mekarsari and Cibahayu (Table 2). The largest increase in impact farm labor productivity occurred in Mekarsari. On the average, for all of the villages, labor productivity did not change significantly on the model farms, but increased 99 rupiah per hectare (55 percent) on the impact area farms. These results are summarized in figure 3.

Figure 3 also shows, however, that labor productivity for the nonadopters was, on average, 492 rupiah per hour or 1.8 times greater than for the adopters in the impact areas. That is, labor apparently was used more efficiently on the nonadopter farms. The reason for this difference is not clear, though the possibility exists that the subsidies in the model farm program reduced the effective wage rate of labor and resulted in labor with a declining marginal product and, thus, average product to be employed.

Adjusting for inflation. Reliable price indices do not exist in Indonesia and, for that matter, in most developing countries. The standard procedure for deflating pecuniary values of agricultural inputs and outputs in Indonesia and other developing countries where rice represents the major crop is to convert these values into rice equivalents. That is, pecuniary values are converted into the amount of rice that they could purchase. Using the price of rice to deflate pecuniary values, however, assumes that all commodity prices move together, which may not be the case.

Data for the model farm program do not contain prices, but prices can be inferred from the data on the value and quantity of production. Over the period examined, rice prices increased 19 percent, but corn prices fell

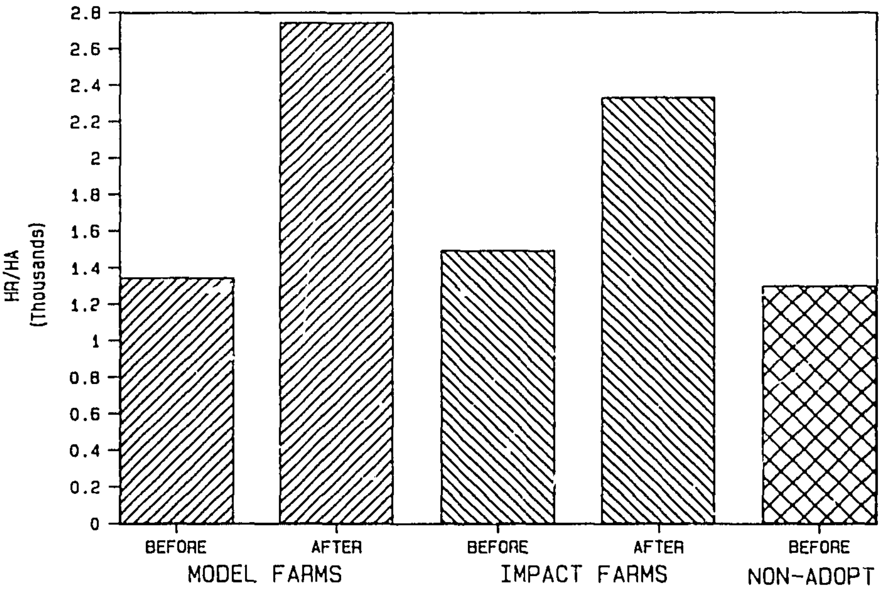

Figure 2. Labor use, Citanduy project.

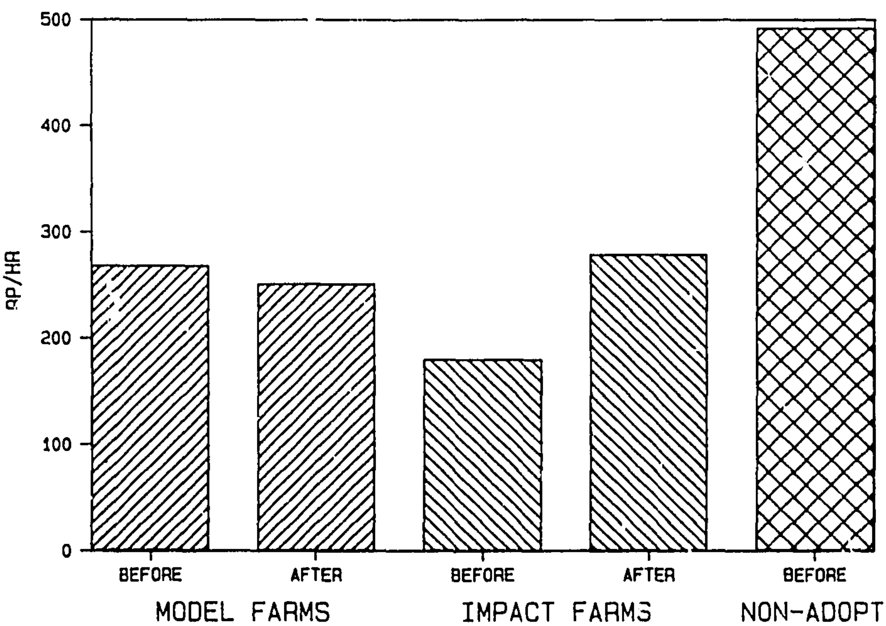

Figure 3. Labor productivity, Citanduy project.

41 percent, cassava prices increased 4 percent, peanut prices decreased 11 percent, coconut prices increased 60 percent, coffee prices increased 152 percent, and the prices of remaining crops fell 9 percent.

If the "before" prices are used to deflate the "after" value of production, then the effect is to deflate "after" values by approximately 11 percent. That is, real production increased 336,952 rupiah per hectare per year (145 percent) on model farms and 295,954 rupiah per hectare per year (156 percent) on the impact area farms, an average increase of 316,453 rupiah per hectare per year (150 percent).

On the other hand, use of rice equivalents would effectively deflate the "after" values by 19 percent. In terms of rice equivalents, the increase in production would be calculated as 298,699 rupiah per hectare per year (129 percent) on model farms and 263,279 rupiah per hectare per year (138 percent) on the impact area farms, an average increase of 280,989 rupiah per hectare per year (133 percent). Use of rice equivalents thus underestimates the impact of the model farm program by an average of 35,464 rupiah per hectare per year (11 percent).

Using a 12 percent discount rate over 15 years, the present value of the properly deflated 316,453 rupiah per hectare per year of production benefits is 2,155,361 rupiah per hectare. While program costs have not been computed, it seems likely that they are less than the present value of these production benefits alone. Additional employment and reduced erosion benefits resulting from the project simply increase the benefit/cost ratio of the project.

Finally, we have presented pecuniary values in both nominal and real terms because of uncertainty regarding whether or not the inferred prices reflect actual prices or prices implicit in the survey of farmers. Surveyors may have assumed price levels to convert "value of production" responses to measures of "quantity of production," and the statistical inferences here merely uncover these assumed prices. Until this issue is resolved, we feel it is best to deal with both nominal and real values.

Causes of changes

Production per hectare (rupiah/hectare), employment (hour/hectare), and labor productivity (rupiah/hour) all increased as a function of the model farm program. The model farm package consists of terracing, changing cropping patterns, and new input mixes. The following analysis attempts to determine the contribution of each part of the model farm package to the observed increase in land productivity. In particular, the analysis isolates the contribution of terracing from the other changes.

The methodology employed was shaped to a large extent by the data available. It would have been ideal if production functions could have been estimated for the individual crops and a model constructed to optimize the mix of labor, chemicals, seeds, and land prior to and after adoption of the model farm package. The data available, however, provided only the value of production by sample plot, hours of labor employed, and value of purchased inputs. At best, before and after revenue functions could be estimated from this information. Given these limitations, the optimum mix of chemical and labor inputs were computed before and after the program.

Estimation of the value functions. A Cobb-Douglas form of value function was used to estimate the value functions as follows:

$$VALUE = \exp(C)\ L^{a1}\ IN^{a2} \qquad [1]$$

where VALUE is the value of production in rupiah per hectare, C is the constant from the regression equation, a1 is the coefficient attached to labor, a2 is the coefficient attached to the other inputs, IN is the other inputs measured in rupiah per hectare, and L is labor hours divided by hectare.

The value of production, labor inputs, and chemical inputs were divided by plot area. This implies constant returns to scale for all three inputs, a restriction we were willing to tolerate because the sample plot areas proved to be less than a hectare in almost all instances. Generalizing from these data in order to extrapolate to larger farms was considered too risky.

Ordinary least square regressions were performed on the log transformations of value, labor, and chemical inputs for both before and after the program. The resulting two revenue functions were used to determine the optimal combination of inputs and outputs, before and after implementing the program. The difference in output value, given an economically efficient mix of labor and chemical inputs, should provide a consistent measure of the impact of the model farm program. This strategy is superior to simply comparing the before and after yields per hectare because it allows productivity changes to be disaggregated between the different components of the model farm package.

Determining efficient levels of inputs. The first derivatives of equation 1 with respect to L and IN provide the basis for determining how each additional labor hour per hectare or rupiah of chemical input per hectare influenced the value of production. The value of the marginal product of labor is calculated as:

$$VMP_L = a1\ \exp(C)\ L^{(a1-1)}\ IN^{a2} \qquad [2]$$

The value of the marginal product of chemical inputs is calculated as:

$$VMP_{IN} = a2 \exp(C) L^{a1} IN^{(a2-1)} \qquad [3]$$

The optimum combination of these ingredients is the one that equates these marginal values to the resource costs.

Wages for female and male workers were inferred from the available data by regressing the hired wage bill against the hired worker hours. The resulting wage rates and the fact the marginal resource cost of chemical inputs was 1 rupiah were used to solve equations 2 and 3 for the optimal mix of inputs. These were then used in conjunction with equation 1 to determine the optimum revenue for the average farm.

One problem inherent in this approach is the marginal resource cost to charge for family labor. Men, women, and children all have different chores that are likely to differ from those assigned to off-farm labor. The wage bills included in the available data provide information only about payments to off-farm help. It is questionable whether these rates should be applied to family members. No doubt the shadow price of on-farm labor should be tied to what one could earn off the farm. But in the absence of any better information, we assumed that this shadow price was equivalent to that which a hired female worker would earn. It was thought that the wages of hired males would reflect heavy work that might not conform to the activities of the farm family.

The private benefits received by both the farm families and hired labor were computed by multiplying the optimal labor hours on and off farm by the marginal wage rate. Rents to the landowner were derived by computing the value of production, via equation 1, and subtracting the wage bill and purchased inputs. We assumed that subsidies were not necessary and that farmers could pay for fertilizers, seeds, and chemicals. The benefits received by the landowners were, therefore, understated by the amount of the subsidy. In structuring the problem this way we were able to determine whether adopting the model farm package was worthwhile even without subsidies.

Optimum and actual input mix for all plots. Prior to adopting the model farm package, farmers employed labor up to the point where the value of an additional hour was 37.5 rupiahs. This implies significant over-employment of labor because the cost of an additional hired female and male worker was estimated to be 79 and 206 rupiahs, respectively. Assuming that the weighted average marginal cost of labor prior to adoption was 100 rupiahs per hour, then 286 labor hours per hectare would produce an economically efficient solution. This is admittedly a small number, and we know that, on average, farmers actually employed approximately 1,178 hours per hectare. The reason for this discrepancy between what is considered economically optimal and actual practice may lie in the shadow price attached to family labor; 100 rupiahs per hour is likely too high. It is likely that significant underemployment or unemployment exists, thereby decreasing opportunity costs.

It also appears that prior to implementation of the model farm package the value received from the application of chemical inputs was only 25 percent of their cost, with the subsidy. The efficient level of application is only 4,900 rupiahs per hectare. One can only speculate as to why this might be the case. Additional analyses reported below provide at least a partial explanation.

After adoption of the model farm package, the situation seems to have improved significantly. Farmers achieved close to an optimum input combination after adoption of the package. According to the estimated value function, the optimum input mix is 1,450 labor hours per hectare and 51,000 rupiahs of chemical inputs per hectare. The average farmer actually employed 1,774 labor hours per hectare and 57,400 rupiahs of chemical inputs per hectare. This is somewhat surprising because chemical inputs were subsidized and, normally, one would expect them to be overutilized. Perhaps the program limited the subsidies to a level that either by accident or by design produced an economically efficient solution.

Value of terracing. Given the efficient mixes of labor and chemical inputs, it is possible to compute the "best practice" solutions before and after terracing; the difference in the value of production represents the contribution of terracing. Terracing boosts on-farm income by 79,983 rupiahs per hectare per year. The present worth of this gain, using a 12 percent discount rate over 15 years, is 544,880 rupiahs per hectare.

While we do not have data on the cost of terracing, researchers in Indonesia have estimated that the cost of terracing is approximately 330,000 to 495,000 rupiahs per hectare. If this cost figure is accurate, then terracing alone has a net present value of 49,880 to 214,880 rupiahs per hectare. That is, subsidies for terracing do not appear necessary, though credit may be an important factor.

Other benefits. The magnitude of the potential gains attributable to terracing caused us to wonder whether the practice was enhancing the productivity of farm inputs, given the same cropping patterns, or whether it facilitated a change in the mix of outputs. By regressing physical production against farm revenue, we were able to obtain the price of each crop before and after the technology's introduction. Applying these estimated prices to the levels of production reported provided a breakdown of farm income by crop. Figure 4 reveals that terracing significantly altered the source of incomes. It induced farmers to shift from low-valued crops, such as cassava, to those that earn three to five times more per kilogram, particularly rice, peanuts, and coconuts.

Conclusions and lessons learned

The following conclusions can be drawn from the analysis:

► The nominal value of output within the model farm and impact areas increased by an average of 374,480 rupiahs per hectare per year. Eleven percent of this increase may have been due to inflation, so the deflated value of the increased output was 316,453 rupiahs per hectare per year. Using a discount rate of 12 percent over 15 years, the present value of the deflated value of increased production is 2,155,361 rupiahs per hectare. While costs of the program have not been computed, it seems likely that the present value of production benefits exceeds these costs, without considering the employment and erosion control benefits of the project.

► Labor inputs within the model farm and impact areas increased an average of 1,117 hours per hectare, and labor productivity increased an average of 45 rupiahs per hour. On the other hand, nonadopters used less labor per hectare and obtained a higher return per hour of labor used. The differences in labor use and returns to labor between the adopters and nonadopters may have been caused by subsidies.

► The actual farming input mix of labor and fertilizer went from being suboptimal before the model farm program to nearly optimal with the program.

► Terracing alone contributed an average of 80,000 rupiahs per hectare per year to the value of output. Discounting at 12 percent over 15 years yielded a present value of terracing equal to 544,880 rupiahs per hectare. Terracing likely costs between 330,000 and 495,000 rupiahs per hectare, so terracing alone has a net present value of 49,880 to 214,880 rupiahs per hectare. Erosion control benefits of terracing would increase this value.

► Increased returns from the program were largely associated with changing cropping patterns. Cassava production fell from 42.4 percent to 12.4 percent of the average value per plot, while rice production increased from 7.1 percent to 26.8 percent, and peanut production rose from 3.4 percent to 17.8 percent. Because cassava production is generally thought to contribute to soil erosion, the reduced production of cassava is expected to reduce erosion.

Lessons learned from the evaluation process include the following:

► Data collection should be guided by the evaluation to be conducted, rather than the other way around. While a relatively large data set had been gathered for the model farm program, most of the data were of little value for assessing the economic benefits of the program. The data collection effort could have been streamlined and the evaluation enhanced if well-

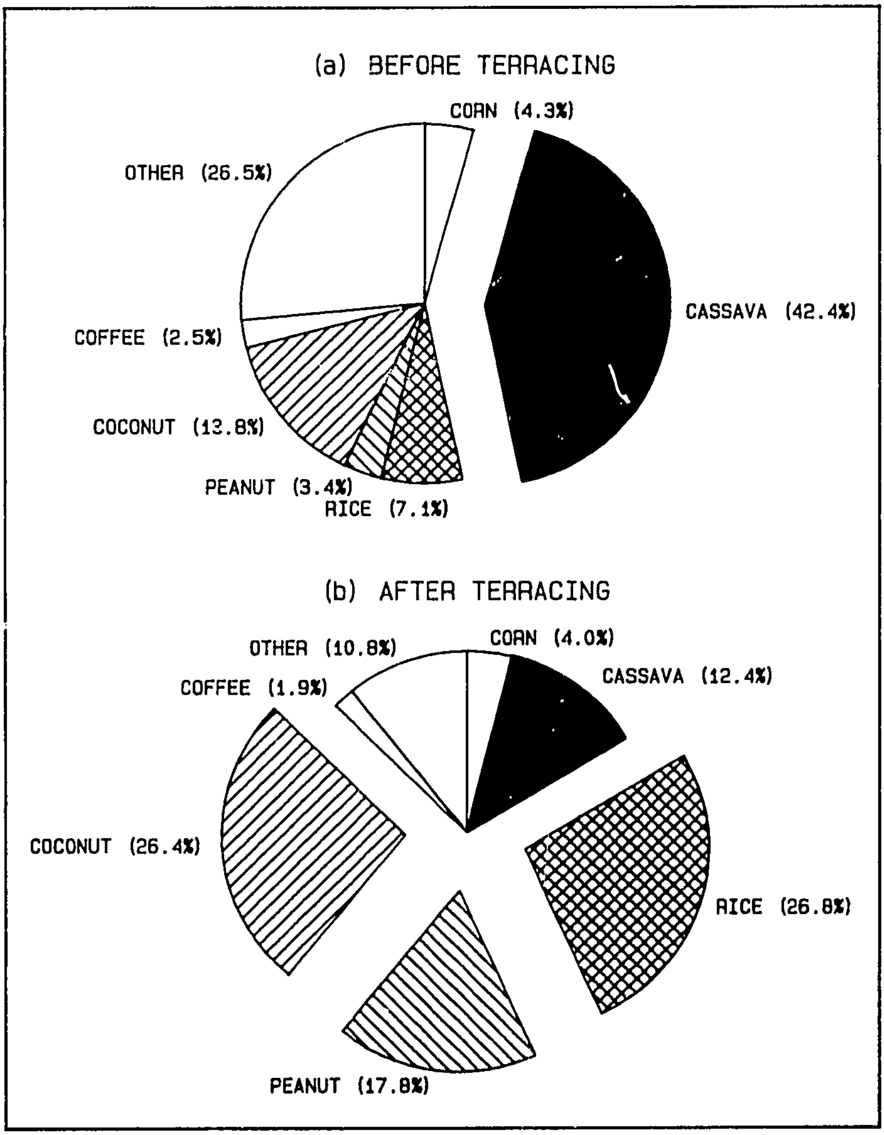

Figure 4. Source of farm income.

defined hypotheses had been posited first and then data collected to test these hypotheses.

► Planning for implementation of the project should include planning for the eventual evaluation of the project. Data collected after implementation of the project measuring farm performance before the project is subject to greater error than data collected prior to implementation. Lack of baseline soil erosion data makes it virtually impossible to assess the soil conservation benefits of the project.

► Deflating pecuniary values using rice equivalents is likely erroneous in a mixed crop economy. Using rice equivalents assumes all prices move in the same direction and at the same rate as rice prices; this is likely not the case. Use of rice equivalents in this study would have implied an inflation rate of 19 percent, when, in fact, that rate appears to have been closer to 11 percent.

12

Institutional constraints to soil conservation on steep lands

Stephen B. Lovejoy and Ted L. Napier

Soil erosion is a problem that exists to some degree in every society in the world (*8, 9, 10*). Some soil erosion should be expected because it is a natural process in the environment. This naturally occurring soil loss is seldom perceived as problematic. However, soil loss generated by the use of inappropriate agricultural practices on erosion-prone land is of considerable concern because the extent of soil loss is often extremely high and unnecessary. Such large soil losses frequently create many problems for land operators as well as for people living in river basin areas downstream.

Soil erosion is generally more severe where farmers are forced by population pressures to farm steep slopes, such as, in the Caribbean (*1, 2*), Europe (*3*), and Indonesia (*19*). Farming on steep slopes often results in loss of agricultural productivity, sedimentation of river basins and delta regions, and degradation of the physical beauty of land and water resources (*1, 4, 6, 14, 16, 17*). In some societies the long-term viability of agricultural production is threatened by soil erosion because irreparable damage to land resources will occur. Reduction of the erosion problem requires action, but the development of relevant conservation programs requires better knowledge of the factors that prevent the use of conservation practices by land operators.

Some social science research has been conducted on the factors affecting the adoption of soil erosion control practices outside of the United States, and several scholars have suggested that sociological variables are important in determining the success and failure of many soil erosion control programs (*1, 2, 5, 9, 18, 19*). Among the issues noted are the following: (1) lack of relevance of the technologically intensive conservation practices being introduced, (2) lack of economic resources by local farmers to adopt technologically intensive soil conservation practices, (3) lack of knowledge relative to how technologically intensive practices are maintained and repaired, (4) inconsistencies in terms of national development goals and continuance of soil conservation efforts, and (5) an inability on the part of conservation agencies to convince farmers there is an erosion problem that should be reduced.

Soil erosion as a social problem

Predicting the adoption of soil erosion control practices is difficult, especially in less developed societies. Clearly, erosion will not be eliminated by technological solutions alone when the cause involves inappropriate production practices employed by land operators. Production techniques have been devised for reducing soil erosion even on steep lands, but many of these techniques are not being used by farmers. Many farmers elect not to adopt erosion control practices because they are unwilling or unable to adopt the necessary techniques. Lack of motivation is one of the most significant barriers to the implementation of soil conservation programs. In other words, part of the world's soil erosion problem is associated with institutional and individual barriers to adoption of soil erosion control practices. Soil erosion is as much a social problem as it is a technological problem (*12*).

Conservation policies and programs are strongly affected by national policies in the agricultural and nonagricultural sectors. Conservation is greatly influenced by the arrangements and relationships among various ministries and agencies that have vested interests in agriculture and conservation. Some of these institutional constraints may block producers from using conservation practices. In fact, national policies to increase food and fiber production can accelerate soil erosion as farmers increase production.

If the conservation goal is to protect soil resources, initiators of conservation programs and policies must learn to operate within structural constraints. It is unlikely that all national goals will be consistent with soil conservation objectives. Emphasis will shift from time to time. Conservation may periodically surface as an important issue. At other times it will be relegated to a lesser role behind issues of full employment, economic development, national security, and international trade.

Conservation policies and programs designed for steep lands must take into account a vast array of institutional and social factors. Future programs that hope to be successful must address the following social and institutional constraints:

Macroeconomic and macrosocial constraints. Conservation policies and programs must be implemented within the context of macroeconomic and macrosocial constraints. Such constraints as high interest rates, low commodity prices, exports, taxes, employment and food policies, trends in crop specialization, technological intensification, peculiarities of agricultural production, and structural characteristics of society often serve to block or hinder producers from using conservation practices. These macroeconomic factors affect overall levels of conservation as well as individual decisions about land use and conservation. Some suggest that these variables are more important than agricultural and conservation policies (*13*). In addition, farm programs, such as commodity supports, subsidized credit, cheap food policies, and export promotion, may be inconsistent with conservation goals.

There is a definite need to strive for consistency among and between conservation, water quality, international trade policies, and other agricultural programs. However, while macroeconomic variables are important in terms of affecting individual decision-makers, they are largely beyond the control of environmental policymakers and certainly beyond the control of individual land operators.

Conservation programs have attempted to negate the influence of structural constraints by trying to ignore them or by direct confrontation. In general, such constraints cannot be ignored, and attempts to bring about confrontation have frequently resulted in a loss for conservation. If the objective is to protect soil resources, then it must be recognized that programs will have to operate within structural constraints and remain flexible as priorities and issues change. What worked well in the past may not be appropriate in the present and in the future (*14*). While macroeconomic and macrostructural factors may constrain the conservation options available for consideration by the individual producer, there are usually conservation alternatives within the constrained set of behaviors remaining.

It should be observed, however, that the dominant thrust of development efforts to promote structural change in the agricultural sector of less developed countries has been in the direction of enterprise and regional specialization, separation of crop and livestock production, and intensification of production. The result has been a long-term trend toward row crop and small grain monocultures, reduced use of crop rotations, specialization of production, and intensification of food and fiber production based on purchased petrochemical inputs. Such a development model may increase soil erosion potentials and will likely enhance the probability that the agricultural sector will treat soil erosion as an externality of production that can be exported with immunity.

Coordination of conservation efforts. Mechanisms must be established to more effectively coordinate the multitude of agricultural programs with conservation efforts. There are a bewildering array of agricultural development and environmental protection ideas and processes that have direct or indirect linkages with soil conservation activities. Among the most noteworthy are aquaculture, agroforestry, fertility maintenance, agricultural modernization, forest products development, and desertification.

Cooperation among these programs must be significantly enhanced. Cooperative efforts can be more effective because limited human and economic resources can be pooled for greater impact. Sociopolitical alliances would also serve to give conservationists greater influence in the determination of macro-level policies and the goals to be emphasized.

Interagency cooperation is difficult to accomplish when multiple groups are involved. Methods must be devised to ensure cooperation and communication among the various agencies. Incentives must be created to ensure that cooperation will be rewarded. Greater cooperation should result in increased efficiency and more effective program implementation for all parties involved.

Information types and dissemination. The types of information provided to client groups and the methods used to disseminate the information must be carefully examined. The important point is that program planners and developers must adopt an approach that concentrates on "selling" soil conservation. It must be recognized that the goal is to alter behavior, not just change perceptions and attitudes.

Farmers must be shown how resolution of soil erosion problems on their land will benefit them directly or indirectly. Farmers are not going to invest limited economic resources on conservation practices to solve erosion problems if the impacts are perceived to be inconsequential in the long run.

Some clients will need precise economic models that specify the profit impacts of alternative production packages. Others will need more general information that they can use in their decision-making process without sophisticated computer modeling. Some will need worksheets to assist them in their decision-making, while others will require more extensive information so they can do the analysis themselves. Some client groups will require personal contact because they will not be able to read printed materials. Such people may require basic awareness information because they may know little about the cause-and-effect relationship between soil loss and reduction in soil fertility.

There are at least three strategies for promoting change in human behavior. These are as follows:

► The empirical or rational strategy, which is based on the assumption that human beings are rational and will alter attitudes and behavior when it is demonstrated that change is in their best interest.

- ► The normative or educational approach, which rests on the assumption that human behavior is supported by a complex system of social and community norms.
- ► The power or coercive approach, which involves the use of force to secure target group compliance with a predetermined behavioral objective.

Evidence to date suggests that the provision of information to farmers, the generation of positive attitudes toward conservation practices, and the development of beliefs that farmers are stewards of the land are necessary but not sufficient conditions to bring about the adoption of soil erosion control practices. Awareness programs, by themselves, will prove ineffective in motivating farmers to adopt erosion control practices (*12, 14, 15*).

Many farmers are forced by economic and market constraints to place high priority on short-run productivity and efficiency criteria when making farm management decisions. Environmental concerns and the desire to protect soil resources are frequently given a lower priority. As many have said, the long run can only be considered if one is around to enjoy it.

Specific objectives in policies and programs. In the course of developing soil conservation policies and programs, consideration must be given to several factors that will determine the objectives of the efforts undertaken. Some of the issues that must be addressed are as follows: Who are the clients? Why is there a need for conservation programs and policies? Who are the conservation efforts designed to protect? Are conservation programs protecting farmers from themselves in terms of long-term productivity losses? Are conservation efforts designed to protect consumers from future food shortages? Are they protecting nonfarm users of water from a degraded resource? Are they protecting other governmental units from sediment damage to reservoirs and roadside ditches?

Answers to these questions will assist conservation professionals in devising programs and will influence the extent to which program implementers can use concepts, such as targeting, microtargeting, purchase of production rights, cross-compliance, mandatory controls, and other mechanisms, to address the problems. These decisions must be made prior to the development of strategies to address identified problems. If the goals of conservation efforts are not specified, the policies and programs produced will probably bear little resemblance to their objectives.

Action option analysis. Institutional and technological options developed using the first four criteria must be carefully analyzed to determine which individuals and groups will benefit, which will lose, and the net social benefit for various groups in the society. The analysis to accomplish this objective should be broad-based, and it must be conducted in the context of numerous types of costs and benefits. In the course of the analysis, some attention should be focused on the issue of altering existing systems of property rights and the implications that flow from modifications of existing rules of ownership. Hopefully, the outcome of this process will be conservation policies and programs that will be more equitable for most client groups affected by the conservation efforts.

Relevance of program to situation of potential adopters. The implementation of conservation policies must be done in the context of relevance to the social, political, and economic situation of client groups. The choice of implementation strategies is important in every society of the world, but it is extremely important in developing countries. The creation of conservation programs that cannot be effectively implemented due to structural barriers is an exercise in futility. For example, conservation programs designed to introduce technology-intensive practices among poor farmers will probably fail in nearly every society of the world. Such practices are certainly doomed in poverty-ravished countries. Poor farmers simply do not have the necessary economic resources to implement and maintain such technological solutions.

A large proportion of farmers in less developed societies are subsistence farmers. They have few economic resources to purchase the basic necessities of life. They cannot afford the luxury of protecting soil resources because their families may die of starvation if the conservation efforts do not produce significant increases in productivity.

Conclusions

Among the important conclusions to be drawn from this discussion are the following:

► Existing social science research is inadequate to develop comprehensive soil erosion control programs in less developed societies of the world. Considerable social science research focused on the adoption of soil erosion control practices is needed before comprehensive conservation policies are created and implemented.

► Institutional barriers to adoption are operative in every society of the world. Policies established without consideration of these barriers are probably doomed to failure.

► The transfer of technical solutions without modification from highly developed societies to less developed societies is questionable. While it is important to exchange information about adoption of soil erosion control practices among societies, strategies for introducing change must be relevant to the client group's situation.

► Soil conservation programs and policies must be reviewed continually and modified to remain relevant to existing situations. What is appropriate now may not be appropriate in the future.

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IV

PRACTICES AND PROJECTS

13

Conservation practices and runoff water disposal on steep lands

N. W. Hudson

Most conventional theory on soil conservation methods started in the United States, under circumstances very different from the rest of the world suffering from soil erosion. So we had, from the beginning, concepts like those expressed by Q. C. Ayres (*2*), "The first step in any rational solution is to restrict open cultivated land to slopes and conditions where erosion can be held within predetermined limits." The assumption that this is possible is continued in the land capability classification, which rules out any land steeper than 12 percent as unsuitable for cultivation.

This assumption is realistic in the United States and wherever flexibility exists in the choice of land; in the humid tropics it is largely an irrelevant ideal. There are many small countries where excluding all land steeper than 12 percent would leave little, apart from valley bottoms. We must accept that in many developing countries there is going to be a lot of farming on steep slopes, and this is often going to result in a lot of soil erosion.

The second mental hurdle to be jumped is that in many cases it is not going to be possible to prevent soil erosion. As a result, we should look for ways to reduce erosion or put it to use, for example, in forming terraces.

I prefer to think of conservation on steep lands as a temporary operation until we can get the strategic land use right. In this book, many people will describe cases where they think they have a permanent solution, and some of the examples certainly are impressive. I will not attempt to describe any techniques in detail, but rather discuss principles. The first of these is that before we start to plan or to design soil conservation works we must be quite sure that we know what we are trying to do.

Defining the problem

The hydraulics. There are no universally applicable conservation treatments, just as there are no universal farming systems. We must be careful not to extrapolate by taking a practice that is successful under one set of conditions and trying to use it in very different circumstances. For example, a system that achieves 100 percent infiltration may prove satisfactory with moderate rainfall and sufficient storage capacity in the profile, but it could be disastrous on shallow soils sitting precariously on bedrock in high rainfall areas. Most of us have seen cases where the whole soil mantle is stripped off by mass movement of saturated soils.

A critical issue is how much runoff is likely to occur. And how often? Surface infiltration is fairly easy to measure and to change, but this is not the case for subsurface percolation and moisture storage in the profile. These are not easy parameters to measure, and they are difficult to change. But they too may affect surface runoff. We also need to know the amount of rainfall and its intensities and frequencies. That information, then, can be combined with soil data to get an indication of what the hydraulic situation will be. We can, of course, get the required information on surface runoff by direct measurement, but this is a slow and expensive process.

It should be possible to predict runoff to the accuracy required for designing soil conservation measures by modelling runoff from farm land. All that is required is some bookkeeping on the inflows and outflows, somewhat like flood routing. The mathematical models I have come across tend to lose themselves in unnecessary complexities, but I once had a student work on a simple physical model that I think is worth pursuing (Figure 1).

Choosing the tactics. Once we know the hydraulic situation, we can begin thinking about what to do about it. Theoretically, sorting out the land use strategy should come first. Moving out of food crops into tree crops or commodities might be the best solution to an erosion problem, but that is not the subject of this paper. We will try to look at that subject in another part of this book, but I must just make the point that using land for what it is suitable for is always better than trying to overcome the problems after using it unsuitably.

Looking at the nuts and bolts of runoff management, let us consider the possible tactics. The first possibility is to minimize runoff, or perhaps prevent it entirely. In many cases, this will be our first choice, and there are several examples of this approach in another part of this book. But minimizing or eliminating runoff is not always possible, for instance, where rainfall exceeds the absorption capacity, nor is it always desirable. Some crops are adversely affected if they do not shed some surface runoff.

The second situation is where we must accept that some runoff is inevitable and aim to control it so that it runs away with minimal damage. This approach did very well in North America and was the mainstay of the work by the U.S. Department of Agriculture's Soil Conservation Service for decades. It is still appropriate in circumstances similar to those in the United States, that is, large-scale, mechanized farming on gentle slopes. Like other useful tools, its success has led to its wide application, including areas where it is not suitable.

The third situation is where surface runoff is desirable because we wish to transfer it either in time or space. There are many methods of harvesting surface runoff. These are receiving particular attention at the moment as

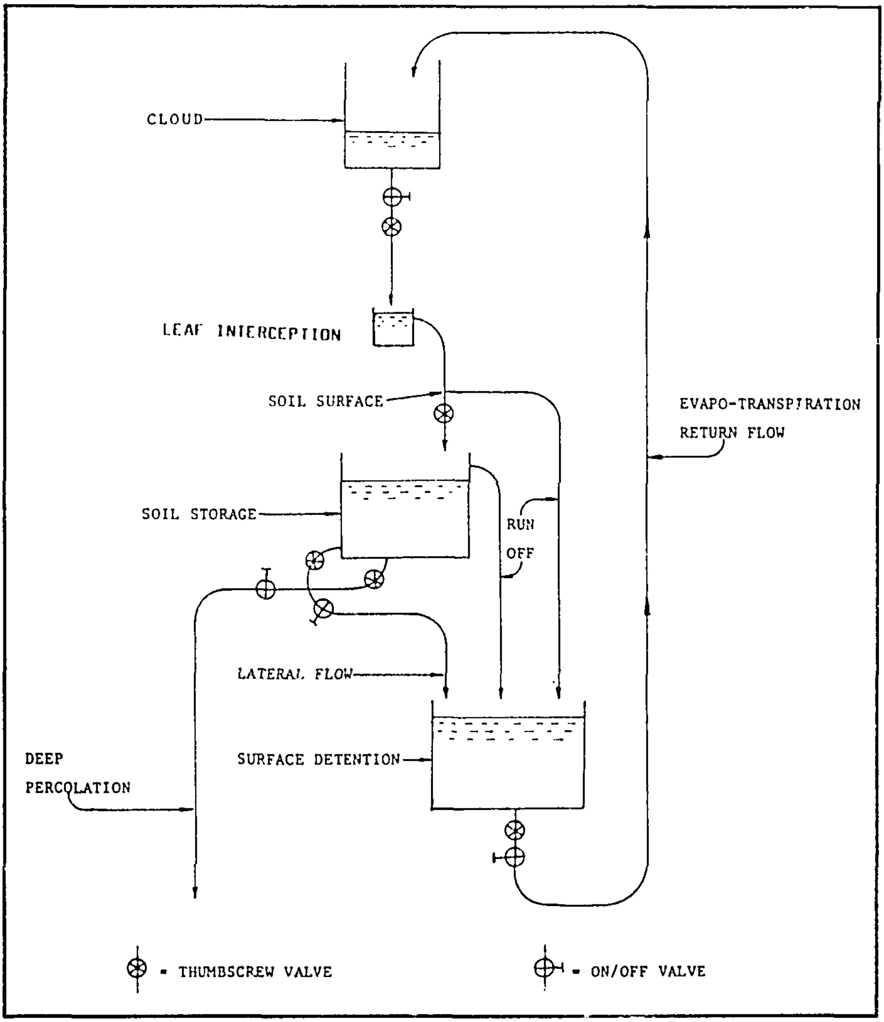


Figure 1. Flow diagram for model of runoff.

the focus on semiarid lands sharpens, for example, the recent Food and Agriculture Organization soils bulletin on "Soil and Water Conservation Methods in Semiarid Areas" (*4*). We should not forget that steep lands are not confined to the humid tropics and that erosion can be severe in semiarid climates.

Some possible techniques

Avoiding or reducing runoff. Some types of terraces. Bench terraces intended to maximize infiltration will probably be level in both directions, or possibly with a slight reverse slope. There may also be ridging or tied-ridging to increase surface storage. Narrow bench terraces, called step terraces, are used for small tree crops, like tea or coffee. The amount of earthmoving is less than for wide terraces, and the depth of soil required is less. In many countries the labor is reduced by partial levelling to give outward-sloping bench terraces. This is common in the Himalayas, such as Nepal, Bhutan, northern India, and northern Pakistan. The effect of reducing slope will have more effect on reducing erosion than runoff.

Intermittent terraces are useful for larger tree crops, such as rubber or fruit trees, and are often called orchard terraces. Platforms are short lengths of orchard terraces for a single tree or bush. The variation called hexagons is described by Sheng (*11*). The term "hillside ditch" is applied to several different types of intermittent terracing, usually involving a small reverse-slope terrace, perhaps with an excavated drain to increase the temporary storage. This may be associated with "lock-and-spill" drains that have pockets excavated in the drain bottom so that some water is held ("locked") in the small basins; in heavy storms the runoff can "spill" along the drain. This practice is widely used in the tea plantations of Sri Lanka.

Absorption terraces are terraces built to impound all or part of the runoff. In Brazil the murrundum is a massive structure with a bank 2 meters or more high, spaced at a vertical interval of about 2 meters. The system has evolved by trial and error and appears to work satisfactorily in spite of occasional, intense thunderstorms. A study of the probable frequency and quantity of runoff might indicate whether the huge amount of earth moving using large crawler tractors could be reduced, perhaps by designing the system to have a capacity corresponding to the 1-year runoff, with an emergency spill for the 10-year runoff. This concept is applied to the similar system used in India and known as the contour bund. These, too, are large structures with a storage volume upstream that is increased by turning both ends of the bank uphill. The emergency spillway is usually reinforced with packed stones. The system has soil limitations. It is suitable for the deep, permeable red clay loams in Brazil and India, but on the black clay soils of India it has proven counterproductive because it floods the crop.

Large trenches to store surface runoff are sometimes used in the early stages of forest establishment as a temporary measure until the vegetative cover takes over. They are usually built without any gradient and with cross-ties every 10 to 15 meters to restrict water movement in the channel.

Terracing in stages. The labor required to construct bench terraces is considerable. It can be reduced in total and spread over a longer period of time by using downhill movement of soil to help level the terraces. This is sometimes described as using downhill erosion to form the terraces, but in most cases the downhill movement of soil resulting from cultivation has more effect.

Maher (*8*) described the use of this system in Puerto Rico in the 1940s, where masonry walls were built up in several stages over a number of years (*12*) (Figure 2a). A more recent application of the same principle occurred in Venezuela (*15*) (Figure 2b). Where stone is not available, the effect can be achieved by earth banks, as in the fanya juu system in Kenya (*13*). The name means to throw uphill because the soil to form the bank is excavated from the downhill side and thrown up to form the bank. Vegetation is planted on the edge of the bank and the downhill face to stabilize the bank and to increase deposition on the uphill side. Periodically, the process of throwing up more soil onto the bank is repeated.

A useful variation that speeds up the process and spreads the labor requirement is to put in fanya juu terraces in two stages (Figure 2c). First, terraces are put in with a vertical interval of 2 meters; then, at a later stage, additional lines are put in-between. In Kenya, use of this method has resulted in nearly level terraces in as little as 7 years.

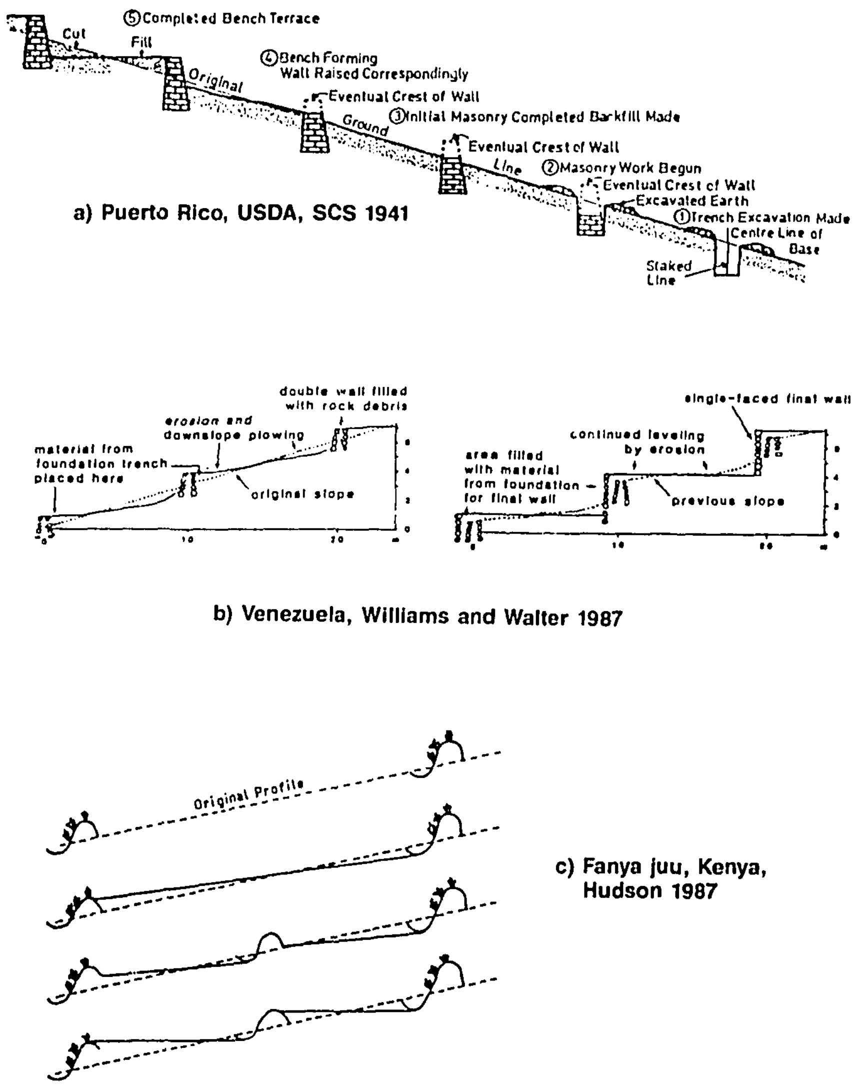
The width and spacing of bench terraces is determined by a few simple factors. The width is usually dictated by the method of cultivation. Oxen and tractors, for example, need a minimum width to turn.

On the other hand, the volume of earth moved increases with the width of the terrace since:

$$C = W \times \frac{Hr}{8} \qquad [1]$$

where C is the cross-sectioned area (m^2), W is the bench width (m), and Hr is the height of the riser (m) and is the vertical interval plus the change in elevation across the terrace if there is a reverse slope (Figure 3).

The possible width of the terrace without excavating into subsoil or rock is a function of both soil depth and land slope (Figure 4). A simple design method suggested by Hurni (*7*) is to use a vertical interval of 1 meter for



1. Terraces built at 2-m vertical interval by throwing excavated soil uphill to form a ridge, which is planted with fodder grasses.
2. Movement downslope by cultivation and erosion starts to build up a lower terrace.
3. Main terrace banks built up higher, and intermediate terrace added. Further levelling occurs.
4. Final profile is nearly level terraces with well-vegetated terrace risers.

Figure 2. Progressive development of bench terraces.

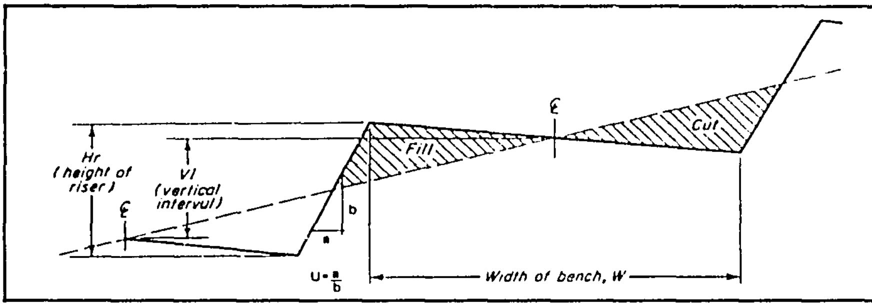


Figure 3. Cross-section of bench terraces.

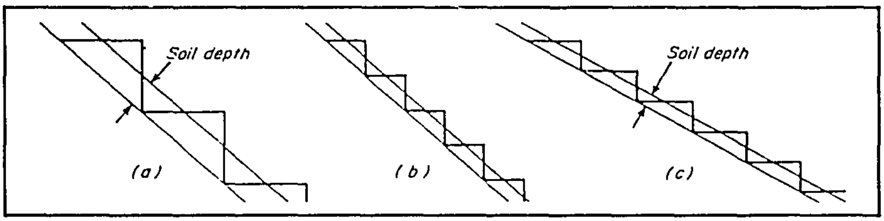


Figure 4. The effect of slope and soil depth on maximum terrace width.

all slopes less than 15 percent; on steeper slopes, the vertical interval is 2.5 x the soil depth.

Grass strips planted on the contour are another way of achieving the terracing effect, and there are many successful examples. In the Philippines, single or double rows are used of Ipil-Ipil (*Leucanea leucocephala*). This can be grown from seed or cuttings; it grows rapidly, fixes nitrogen in the soil, and is a useful source of feed for livestock. A grass used with success in Fiji and India is vetiver (*Vetiveria zizaniodes*) (*1*). This is known as "patchuli" in Puerto Rico; "khus" in India, where it is indigenous; and "usar" in Java. However, it was rejected in Haiti and banned in Java for causing erosion when the roots are dug for oil extraction, which illustrates again the point that there are never universal solutions. Another grass commonly used for contour strips is Elephant grass or Napier fodder (*Pennisetum purpureum*) (*14*).

There are dozens of other possibilities. The critical factor is what the local farmers prefer, and their choice will be influenced by a number of considerations. Is it better to have a palatable fodder that can be grazed or cut and carried? Or is it better to have something unpalatable, like vetiver? Is it better to use a grass that spreads by rhizomes or stolons? Or is this likely to create a problem by spreading into fields? Is it preferable to have a grass that can be propagated from seed? Or cuttings? Or division of root clumps? Is it worth considering grasses that also have an industrial use, such as extraction of oils from lavender, vetiver, or citronella?

Increasing infiltration without terracing. The most simple methods of increasing infiltration are those that can be incorporated into a farming system without any manipulation of the soil surface. These include mulching with crop residues, use of nurse crops, or adoption of one of many conservation tillage variations. Conservation tillage, an umbrella term, encompasses reduced tillage, minimum tillage, no-till, direct drill, mulch tillage, stubble-mulch farming, trash farming, strip tillage, and plow-plant (*9*). Anything that gives increased cover will lead to more infiltration and less runoff.

Mechanical manipulation of the surface can also be used to increase the surface storage and subsequent infiltration. There is a wide range of methods, from simple, small depressions scratched with a hand hoe to basin listing and tied ridging with tractor-drawn machines. Another variation on mechanical works to increase surface storage is the excavation of open drains on a level contour, with the excavated soil spread thinly on the uphill side. If runoff exceeds the storage, the surplus can then spill uniformly over the downhill edge of the drain. This practice in Zambia is called pasture furrows on grazing land or contour seepage furrows on arable land (*5*).

Attempts to improve the absorption of rainfall usually concentrate on improving infiltration at the soil surface because this is most often the constraint. But there can also be situations where the critical restriction is below ground. If the problem is low permeability in a subsoil, the situation cannot easily be changed. But it may be sensible to break up a plow pan or a thin restricting layer, such as that commonly found in oxisols tilled with tractor-drawn equipment.

Controlling runoff. *Variations.* The classic pattern of mechanical works to lead runoff from arable land is well known and well tested. It has three components: a diversion drain or cut-off to protect the arable land from runoff from higher land, graded channel terraces to lead runoff away at a nonerosive velocity, and a channel to take the water down the slope at a nonerosive velocity (Figure 5).

A critical part of the design is to estimate the maximum rate of runoff that the system should accommodate. We have a number of methods for doing this, but all are fairly crude. The rational method requires estimates of the time of concentration for each of the parts of the catchment area and estimates of the probable maximum rainfall intensity for these times. Few countries have sufficient data to construct reliable and accurate tables

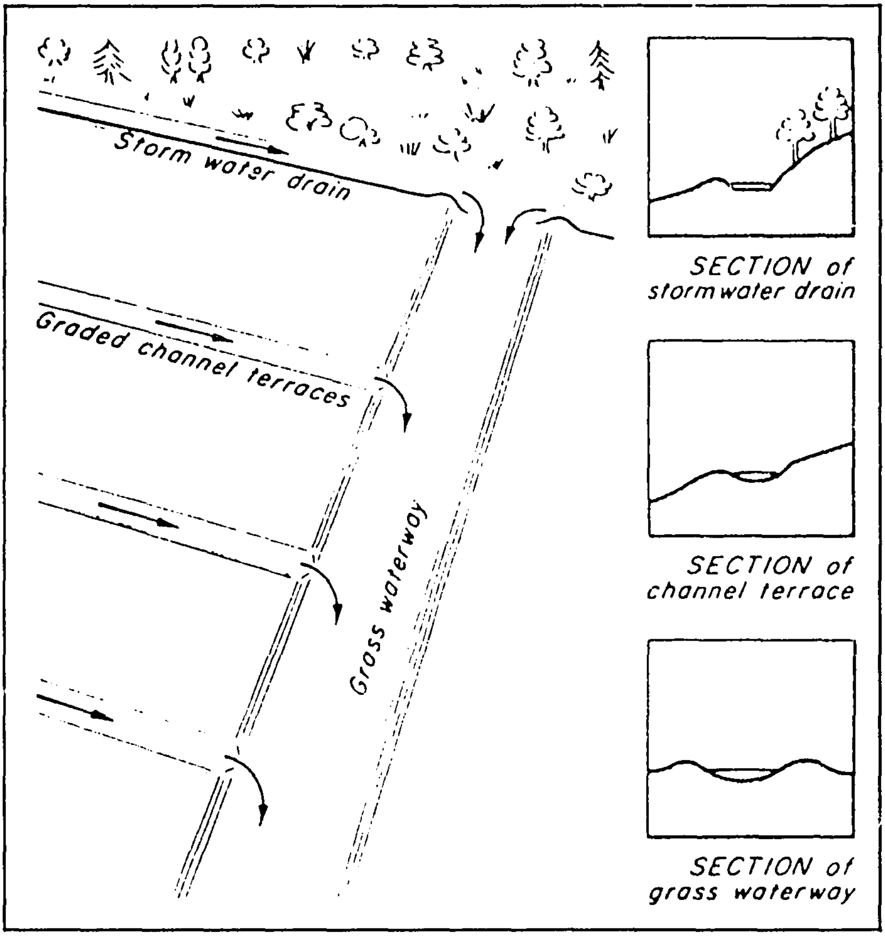


Figure 5. The classic pattern of mechanical protection.

or design charts, however. H. L. Cook's method (*6*), devised in the 1940s, is empirical and depends upon tables built from measurements at instrumented experimental watersheds. Because the United States is the only country that has anything close to sufficient data for this purpose, use of this method in other countries really depends upon guess work as to how the U.S. data should be extrapolated.

The runoff curve method also requires a great deal of accumulated knowledge that is seldom available outside the United States. Moreover, the method was really designed to predict the quantity of runoff. Using it to estimate maximum rates of runoff requires assumptions about the shape of the hydrograph.

Even if these deficiencies in data were overcome, there remains the fact that all of these methods were really designed for small watersheds of mixed use on gentle slopes, and there is a negligible amount of data on catchments of less than 5 hectares of arable land with different types of terracing on 20 to 30 percent slopes.

The second design variation is the return period associated with estimates of maximum rates of intensity and runoff. The normal concept in engineering design is that the safety factor should be related to the damage that would occur in the event of failure. Most design manuals favor a return period of 10 years for soil conservation structures, but I am coming to the view that this leads to over-design. I think if I were a farmer I would use a one or two year return period and accept the slightly higher risk.

The third design question is whether it is practical to establish and maintain grass-lined channels when the rainfall is low or erratic or when long, dry periods are common.

Difficulties. Channels for water disposal are difficult to construct on steep slopes. Grassed waterways are not really practical on slopes steeper than about 10 percent; to keep the flow rate down to a nonscouring velocity requires a low hydraulic radius, that is, a broad, shallow section. Possible ways to overcome this difficulty are to increase the roughness coefficient, for example, by using a tall grass or mixture of grasses, or to increase the permissible velocity by strengthening the channel lining. Use of design velocities up to 5 meters per second was reported in Taiwan, but this must be a special case because few grassed waterways could tolerate such velocities. This might be done by improving the quality of a vegetative lining or by strengthening the lining with brick, stones, concrete, etc., or possibly reducing the slope with the use of drop structures. The difficulty is that all of these options add to a project's cost, complexity, and the need for regular maintenance. A number of alternatives tested in Jamaica are discussed elsewhere (*11*).

The second difficulty is that mechanical works to control surface runoff are not practical on small units of land. For holdings of 1 or 2 hectares, it is not practical to have a separate cutoff or disposal channel for each farm unit. To some extent this can be overcome by designing the system for a group of landowners. One can then have a single cutoff drain protecting a number of holdings. Theoretically, it might be possible also to have graded channel terraces that cross several properties, but it is more difficult to get agreement for this. There also remains the problems of locating the shared waterway and maintaining shared works.

In the Kenyan program assisted by the Swedish International Development Authority, the policy is that the program pays for the construction of shared works, provided there is a written agreement for maintenance. But terracing on a single holding must be built and maintained by the owner. These problems of handling runoff disposal on steep lands and small holdings are a powerful incentive for preferring techniques that either eliminate surface runoff or keep it dispersed.

Schemes that involve concentrated flows of water in designed channels always require regular care and maintenance of the channel's shape and either keeping the channel clean or looking after the grass. The concept of regular maintenance is not usually well developed among small-scale subsistence farmers.

Encouraging and collecting runoff. In low rainfall areas, an alternative to catching and holding the rain where it falls is to collect the runoff from a catchment area and lead it to a run-on area to augment the rainfall. Different ways of achieving this are discussed in the FAO soils bulletin previously mentioned (*4*), so it is sufficient here to mention briefly just a few examples.

A practice used in the drier parts of the southwestern United States is the conservation bench terrace. Level bench terraces large enough for mechanized cereal farming each have a larger catchment area above the terrace. The size of the catchment is adjusted so that runoff from it, together with the rainfall on the terrace, provides sufficient moisture for a crop where the rainfall alone is insufficient.

Another water harvesting method being tested in the semiarid areas of Kenya is the use of collecting drains to pick up runoff from grazing land and lead it to selected areas where it is spread on arable land.

The ancient water harvesting methods used in the Negev Desert in Israel are well documented (*3*). Surface runoff is encouraged by shaping the catchments and by removing the surface stones, then leading the runoff down to farms in the valley bottom. Similar ancient systems exist in North Africa and other semiarid regions.

Sometimes these collecting systems can be made more effective if the runoff is temporarily stored. The water is then used to maximum advantage for supplementary irrigation during drought. An example is the broad bed and furrow system with storage tanks developed by ICRISAT scientists in India (*10*).

The key steps in disposing of runoff

There are many alternative conservation practices for managing runoff on steep lands. It is essential, first, to think out what the objective is. Is it to try to eliminate runoff? To improve infiltration and control the remaining runoff? To encourage surface runoff and make use of it? Or some combination of these?

Then, one must think out which practices are suitable and appropriate for the circumstances of land use, soil, rainfall, availability of labor, and so on. Finally, but most important, it is critical to find out which practices are preferred by the farmers.

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Soil and water conservation lessons from steep-slope farming in French-speaking countries of Africa

Eric Roose

For historical reasons (colonization, large plantation companies, etc.) and recent demographic pressure, deforestation and cropping in some developing countries in Africa have been extended to slopes of 40 to 80 percent. High rates of soil erosion on steep slopes without permanent cover illustrate how serious the degradation of soil fertility and water efficiency is in these countries. Because there is no place for them to move, the native-born people are condemned to subsist on the hills, with a very low standard of living. Under these conditions, a soil and water conservation strategy based on the universal soil loss equation and the restauration des terrains en montagne (RTM = soil restoration in mountainous areas) is no longer applicable because it requires that those steep slopes be kept under perennial vegetative cover (grass or even forest).

"Top-down" engineering approaches, based on mechanical protection (structures) more than on population needs, have led to many failures in soil conservation programs throughout Africa. What can be proposed to improve the situation? One possibility is a rural development approach aimed at increasing production and responding to people's needs. This approach is based on three main points:

► It assesses the needs of farmers and environmental conditions. How do farmers perceive erosion, runoff, and soil fertility problems? This approach involves farmers not only in its execution but also in the program's conception.

► It offers simple, efficient, cheap, and acceptable management methods, some of which farmers will choose. These methods disperse rainfall and runoff energy, and they promote a balanced production of crops, animals, and trees.

► It foresees a general scheme for management of the whole landscape, from individual farmers to the rural community, from individual fields to an entire watershed.

Research on deforested steep slopes in Ivory Coast

Some basic data are available on the erosion risk related to deforestation of steep slopes on plots at Adiopodoume, Ivory Coast. Under rainforest conditions, runoff and erosion remain low even on steep slopes, for example, 1.2 percent runoff and 0.46 ton per hectare per year of soil loss on a 65 percent slope (Table 1). Replacing the forest with cassava or groundnuts resulted in substantial increases in runoff and erosion—to levels nearly as high as bare ground. Average annual runoff was multiplied 50 times, and the maximum percentage of runoff for a storm event increased from 3 to 77. Erosion increased even more dramatically, from 0.05 ton per hectare per year to 750 tons per hectare per year (Table 2).

Experiments on slope and cover show that (a) runoff does not always increase with the slope gradient; it decreases on bare plots and does not significantly change under pineapple cover; (b) runoff is strongly influenced by cover and crop residue management; (c) erosion increases exponentially with the slope on bare plots; (d) under pineapple, erosion increases dramatically on slopes between 7 and 20 percent; (e) under mulched pineapple, runoff and soil loss are negligible on all slopes up to and including 20 percent (Table 3).

Clearing steep slopes obviously induces a high erosion risk. There are two possible ways to reduce this erosion risk under cropping. One is to reduce the slope steepness with bench or progressive terracing. The second is to cover the soil with dense crops (or crop associations) and a surface mulch.

Conservation systems in Burundi and Rwanda

Before the independence of Burundi and Rwanda, Belgian technicians imposed tied ditches on the contour and mulch under coffee plantations, which were reasonable technologies on those permeable soils. Nowadays, the government promotes the system of ditches on the contour. Farmers thought the tied ditches did not improve production. Ditches were not efficient in stopping the soil fertility degradation and losses of topsoil, the farmers contended, and they used up cropping surface and required too much time and labor to dig and maintain. Because they did not like the ditches, farmers did not support their use. Gullies increased and mass movement of soil developed as a result. Farmers today more easily accept pro-

Table 1. Effect of slope gradient on runoff and soil erosion (tons/hectare/year) under a rainforest near Abidjan.

Slope Gradient	*Runoff (% of annual rainfall*)*	*Erosion (t/ha/yr)*
7%	0.2	0.03
12%	0.3	0.04
22%	0.5	0.05
65%	1.2	0.46

*Rainfall = 2,100 millimeters within four seasons (1 year includes two dry seasons and two rainy seasons).

Table 2. Effect of rainforest clearing on runoff and erosion.

	Median 1956-1965	*Cassava on Mounds 1966*	*Peanuts on Flat 1967*	*Bare Cultivated Once/Year 1968*	*1969*	*1970*
Rainfall amount (mm)	2,321	1,496	1,673	2,084	1,951	1,655
Rusa index	1,390	614	990	861	989	1,251
Annual runoff rate (%)	0.5	18.3	25	24.7	26.1	31.2
Maximum runoff rate (%)	3	75	77	65	76	68
Erosion (t/ha/year)	0.05	162	427	622	564	747

Table 3. Effect of cover (pineapple); slope gradient of 4 percent, 7 percent, and 20 percent; crop residue management on runoff and erosion at Adiopodoume on 12 runoff plots under natural rainfall on a sandy clay soil (Ultisol).

Runoff (%) of 3,337 mm rainfall in a 16-month cycle of pineapple

Slope	*Bare Cultivated*	*Pineapple Residues Burned/Plowed*	*Plowed*	*Mulched*	*Average per Slope*
4%	45	7.3	1.7	0.9	13.6%
7%	35	4.4	1	0	10.0%
20%	29	7.5	3.4	0.1	10.3%
Average treatment	36%	6%	2%	0.6%	11.3%

Erosion (tons/hectare/16 months)

Slope	*Bare*	*Pineapple Residues Burned/Plowed*	*Plowed*	*Mulched*	*Average per Slope*
4%	45	1	0.7	0.1	12%
7%	136	4	0.8	0	35%
20%	410	69	33	1	128%
Average treatment	200%	25%	11%	0.4%	58%

gressive terracing with hedges or grass barriers because this practice enables them to produce fruits, forage, mulch, etc., and there is no space lost for production.

Work by Durand in Burundi showed erosion of 440 to 880 tons per hectare per year from bare soil on a 40 percent slope (*1*). Mulch with coffee and cassava and pine forest with no weeding reduced erosion to essentially zero on 50 percent slopes. Two grass strips (*Tripsacum*) with cassava were much less effective—29 to 55 tons of soil loss per hectare per year on 49 percent slopes. Bench terraces with stone walls reduced erosion to 5 to 11 tons per hectare per year on 49 percent slopes, but these required 800 man-days per hectare to build. Traditional cultivation methods for maize and beans allowed 150 tons of soil loss per hectare per year, while traditional methods for cassava on bunds allowed 70 to 90 tons of soil loss per hectare per year on 49 percent slopes.

Working on an agroforestry project in Rwanda, Egli conducted a search for improved conservation farming systems (*2*). To feed a family of four or five people on 1 hectare, production must be diversified and soil fertility improved. Egli suggested an association of tree cultivation (300 trees/hectare), animal breeding in a feedlot (producing manure), and cropping in rotation with forage. He also suggested such conservation practices as cover improvement that would produce a maximum of biomass, manure and compost, and the planting of hedges and grass barriers. Figure 1 shows his proposal for a model agroforestry farming system. Around the house is grouped the feedlot, the compost pit, a banana plantation, and an orchard

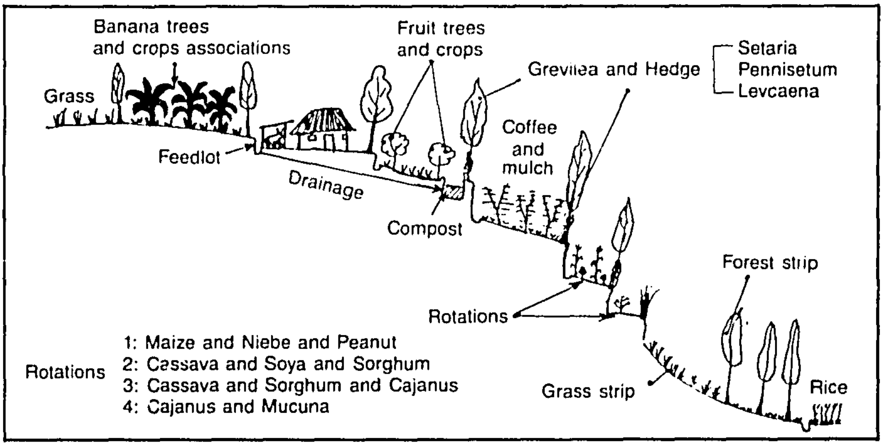

Figure 1. Agroforestry farm on the Central Plateau in Rwanda, Nyabissindou Project (*1*).

with associated crops. Next to this intensively cropped area is 0.2 hectare of coffee plantation with mulch, then a quadriennal rotation of cereals, legumes, and cover crops. Finally, there are some strips of grass and wood, but each strip is bordered by a hedge of legumes and trees (Grevilea) producing fruits, forage, mulch, and wood for fuel.

Soil conservation practices in Cameroon

On Kapsiki volcanic steep slopes, people driven out of the plains by Muslin pressure developed a system that included bench terraces with stone-wall backs, improved surface detention capacity as a result of tied ridging, and improved soil fertility with the use of organic residues.

A very different approach was developed by the Bamileke people on fertile, steep ([illegible] to 30 percent) volcanic soils in a humid, tropical area of southwestern Cameroun with a high population density (150 inhabitants/square kilometer and more) (*18*, *19*). The "broadridge-along-the-slope" system was covered the entire year by a high density of mixed crops: cassava, maize, and sweet potatoes on the ridge and rice, banana trees, and coffee trees with mulch in the furrows. Because rills could develop in the furrows during severe storms just after seeding, some technicians tried to build the ridges on the contour. On the steep slopes, however, ridges on the contour only slightly increase surface water detention; at the same time, they increase the risk of gullying and sliding. The key to this traditional management system is covering the soil completely during the entire year and limiting the catchment area of each furrow. An improvement would be grass barriers that reduce runoff velocity.

Improving soil conservation in the Sudano-Sahelian zone

In the Sudano-Sahelian area of western Africa, people have had a major impact on landscape degradation as a result of overgrazing, bush fires, extensive cultivation, and a high density of human and animal populations. This is in an environment that is fragile because of high-frequency storms, poor vegetative cover, nutrient deficiency, unstable soil structure, and low infiltration of the soil surface when it is overgrazed or cultivated. Field studies have revealed an extension of eroded and desertified spots (*4*, *9*). Measurements conducted in Burkina Faso on runoff plots on ±1 percent slopes have shown high levels of runoff (20 to 40 percent of annual rainfall, 70 percent during heavy storms) and a high risk of selective sheet or even gully erosion (*16*).

In Burkina Faso, the Forest Administration and a soil restoration group, Groupement Europeen de Restauration des Sols, developed a soil conservation program between 1960 and 1965 on more than 200,000 hectares around Ouahigouya. The project included 35,000 kilometers of diversion ditches; low laterite walls on natural waterways; 24 earth dams; and numerous, small crescent-shaped earth dikes in an attempt to retain runoff water for herds near the pasture and to protect the cultivated lowlands. This big project, which received considerable financial and technical assistance, is particularly interesting from a technical point of view, but it failed because the local people were not involved. They were not even equipped with the plows necessary to maintain the ditches (*9*).

Since 1972, many improvements have been made under the Fund for Regional Development, then the Fonds de l'Eau et de l'Equipment Rural, by involving groups of farmers in decision-making, building diverson dikes, and maintaining them (*10*). However, these works are relatively limited (only 18,000 hectares in 7 years) when compared with the problem's magnitude.

Therefore, traditional soil conservation techniques must be applied (*13, 14, 15, 16, 21*). Soil tillage is traditionally very limited on the Mossi Plateau. With the first rainfall, a hoe stroke is made every meter; if available, a handful of manure is deposited in the stroke hole. Five to 10 seeds of millet or sorghum are dribbled into the hole, and the wet soil is compacted with the heel. Subsequently, two weeding operations at 1-month intervals break up the soil-sealing crust. Each operation leads to a temporary increase in infiltration.

Another traditional Mossi practice is "ZAI," which involves small, hand-excavated basins that retain surface water. Infiltration is increased by the activities of termites (trinervitermes) that carry organic matter underground through tunnels in the dry season, leaving holes that increase downward movement of water during rains. Manure and cut leguminous shrubs are placed in the ZAI basins for the dual purpose of improving fertility and encouraging the termites to improve infiltration.

Permeable contour lines of grass or stones are used to accomplish two objectives. In dry areas, these are built across a field to slow down runoff and encourage infiltration and sediment deposition. Similar stone bunds are used to intercept runoff from hillslopes above arable fields. In both cases, there is a self-terracing effect from the trapped sediment.

These permeable micro-dams (Figure 2) have been widely adopted because the farmers are able to manage their own fields (*14, 15, 17, 21*).

In the cotton belt of Southern Mali, rural development is diminished by the problems of soil fertility degradation and runoff (*5, 7*).

Learning from the experience in Burkina Faso, a procedure has been developed for application in southern Mali:

► Discussion with farmers about their own perception of environmental degradation and also their own solutions.

► Selection of simple, efficient, acceptable methods for improving infiltration on their fields and checking the runoff energy with various kinds of micro-dams (hedges, grass barriers, stone lines, etc.).

► Application of a watershed management schedule to balance the

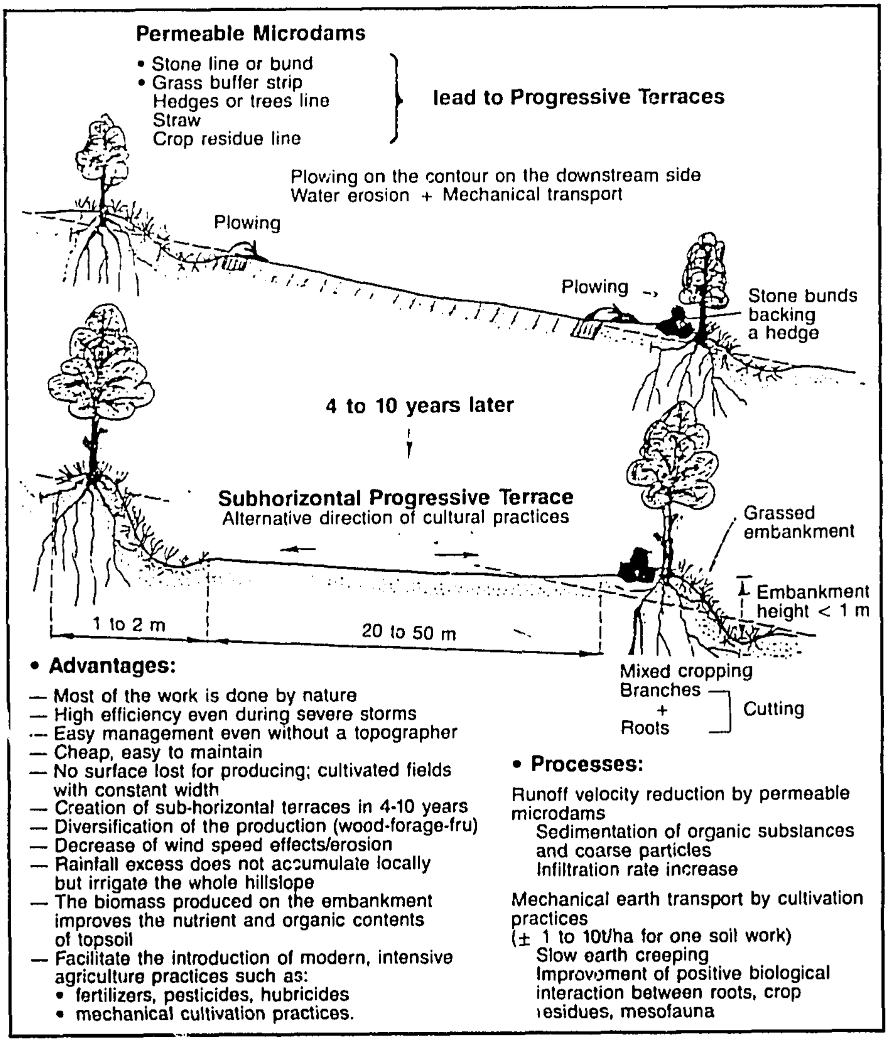

Figure 2. Permeable micro-dam and progressive terracing systems.

development of crops, cattle breeding, and tree production from the individual farm field to the watershed (*15, 20*).

The Mali farmers decided to set as their objectives: (a) protection against water running from the hillslope top (protection bunds and waterways, or permeable stone bunds); (b) protection against cattle (hedges around their fields); (c) improvement of field infiltration capacity (hedges or stone bunds every 25 meters, plowing on the contour, and tied ridging); and (d) management of lower lands for irrigation (little permeable rock dams and gabions). In the Yatenga province, the Mossi farmers prefer beginning with stone bunds around and in their fields, then management of the river environment. These Sudano-Sahelian areas have few steep slopes cropped, but the historical evolution of the procedure could be interesting elsewhere.

The "engineering" approach to soil restoration in Algeria

At the beginning of the century, erosion began to destroy cultivated slopes on some overgrazed mountains and to accelerate sedimentation problems in the reservoirs of Algeria. After Putot's first works (1938) and following Lowdermilk's visits to Algeria (1939-1945), the administration developed an Algerian channel terrace system, based on the Saccardy equation, giving the vertical spacing of terraces in relation to the slope steepness (*3, 11, 12*).

According to Heusch (*6*), this system was suitable for intercepting surface runoff, preventing possible scouring action in the case of loamy soils by short, intense summer thunderstorms. Unfortunately, in the Mediterranean area there are long periods of winter rains, and the clayey soils, widespread in the area, are quickly saturated. The system failed and problems of overland flow, forming of active rills and gullies, and even a starting landslide were observed.

Because of the world economic crisis and a more realistic evaluation of the economic and sociological costs of terraces, the Algerian administration has now practically stopped all terracing works on the hillslopes. Reforestation, along with gully and riverbank stabilization, are being continued to preserve roads, buildings, and reservoirs.

Farmers had not been involved in this action and were afraid of losing their field property if the administration carried out land restoration management. Few managed fields were correctly used and maintained; many were temporarily abandoned; some terraces were even obliterated and the planted trees uprooted (*6*). The problem of soil conservation seemed so crucial to the engineers that they advocated a large-machinery approach. Therefore, few things were done to improve cultivation practices (yield and cover are very low), and the traditional soil conservation systems, such as draining furrows across the plowed fields, stone walls, and cactus or grass barriers at the end of the fields, were not used.

The mechanical logic and the development approach

The "equipment logic." The equipment logic (*8*) holds that:

► There is *one technically good solution* to each erosion problem. That solution is often an hydraulic or a mechanical one.

► It is the engineer in charge of the project conception who defines this solution, and he will use high safety margins that increase the costs.

► In taking into account the general interest of the nation, the engineer will define the structures (roads, bridges, terraces, etc.), and if really necessary, he will try to weaken the resistance of the individual farmers.

► This engineer is "*the* representative of knowledge" for he comes from a high school. The peasants have not been to school and are, therefore, considered not competent.

► Conception, execution, and maintenance are different jobs shared among different people with different qualifications; these people have little dialogue.

► A good project must be carried out in a *short time*; planning engineers rarely meet the people in charge of maintenance. This explains some repeated failures in soil conservation projects.

The "development logic." This new approach must take more account of the socioeconomic constraints and the variability of the physical and biological environment. The agronomist concerned must compromise according to the way the peasants welcome the approach and the efficiency of the methods in the field. He must work for the benefit of the population and needs to go through information processes, training, and practical demonstrations in the field. It takes time to find a solution, then it is more often a biological one than a mechanical one.

This route to rural development looks quite different from the previous one:

► The agronomist concerned must check the farmers' points of view: How do they perceive the problem? Do they prefer certain solutions? There is mutual exchange of information.

► The agronomist must propose cheap, reliable, and efficient methods of dispersing rainfall and runoff energy, improving soil fertility, and promoting balanced production of crops, cattle, and trees.

► The agronomist must also provide a general scheme for management, allowing for reorganization of individual fields, but preparing the progressive improvement of the entire watershed management in the rural community.

General conclusions

Research data have shown that on steep slopes there is little erosion under natural cover, but much more after clearing. There are two ways of reducing erosion under cropping:

► To reduce the slope steepness by different terracing systems.

► To increase the cover with strips of pasture and forest, rotation of suitable associated crops, and mulching. The hedges are useful because they provide both mulch and slope reduction.

Different solutions have been applied by different people under different conditions with different advantages. Clearly, mechanical systems are often expensive and both space- and time-consuming. They require maintenance and do not always improve production (*16*).

Permeable micro-dams (hedges, grass barriers, stone bunds) efficiently reduce erosion on gentle slopes in the Sudano-Sahelian zone (*14, 15*). This concept (hedges and progressive terracing) could also be useful on steep slopes.

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15

Conservation of cropland on steep slopes in eastern Africa

Donald B. Thomas

The concentration of people in hilly or mountainous areas of eastern Africa is mainly a reflection of higher rainfall than on the plains, less risk of crop failure, greater availability of water in the dry season, fertile land of one-time forest origin, and reduced risk of malaria. Security from raiding has been an added reason in the past and remains valid in some areas. The relatively favorable environment, coupled with improved medical facilities, has permitted rapid population growth. Kenya, for example, has a growth rate of about 4 percent per year, and the country's population is expected to grow from 21 million at present to 35 million by the end of the century.

The expansion in population has affected land use in several ways. First, there has been a move to higher elevations that are cooler, wetter, and involve a change in cropping pattern and diet, for example, from maize to potatoes. This upward thrust has led to encroachment on indigenous forest, which has been severely depleted in some countries, notably, Ethiopia. Deforestation is less severe in countries with a colonial history, such as Kenya, where extensive forest areas were demarcated and preserved.

Second, population growth has led to the subdivision of land, reduced holding size, reduction or elimination of fallow, and cultivation of valley bottoms and steep slopes that are less easily managed. The small size of holdings (Table 1) has forced many men to seek employment in urban areas.

Third, there has been outmigration to lower elevations and drier areas where farming is more difficult and where problems of drought and environmental degradation are common.

Statutory control of land use

In Kenya, the Agriculture Act (basic land usage rules) of 1965 states that "any person who cultivates, cuts down or destroys any vegetation, or depastures any livestock on any land of which the slope exceeds 35 percent, shall be guilty of an offense; except that an authorized officer may authorize an owner to cultivate, depasture, cut down or destroy vegetation on the land subject to such conditions as he may decide." An attempt has been made to revise the figure to 55 percent, but land up to 80 percent slope is commonly cultivated without permission. Any attempt to stop cultivation on steep slopes would be difficult to implement and unpopular because of the lack of alternative land. What could and should be done is to use the law to support proper conservation measures. But there is still some uncertainty about the best measures for any given situation, and enforcement of unpopular or unsuitable measures could have negative results.

In Ethiopia, the government or local authorities have decreed that certain hillslopes should be closed because of degradation and either planted to trees or left for bush and grass to regenerate naturally. Once regeneration has taken place, people may be allowed to cut and carry fuelwood and fodder. People who have been moved from hillslopes are forced to find alternative land for cultivation and grazing. Most land is held under the jurisdiction of Peasant Associations, so some readjustments can be made. But in Kenya, where most of the land is under individual ownership and spare land is not available, this kind of land redistribution is no longer possible; closure of hillslopes would be difficult to implement.

Cropping systems on steep lands

Cropping systems can be grouped by those in which perennial crops play a major role and those in which annuals predominate.

Table 1. Percentage distribution of holdings by holding size and province in Kenya (6).

Size	*Province*						
(ha)	*Coast*	*Eastern*	*Central*	*Rift*	*Nyanza*	*Western*	*Total*
0*	29.0	19.7	21.8	36.8	15.8	8.7	21.6
.01-0.4	12.4	18.4	27.6	18.1	34.6	28.0	25.2
0.5-0.9	16.8	22.1	19.8	11.1	23.5	26.3	20.1
1.0-1.9	17.8	21.4	14.5	9.4	14.6	21.8	15.8
2.0-2.9	7.2	8.9	7.6	7.6	5.9	7.3	7.3
3.0-3.9	6.0	3.0	4.8	2.7	2.1	2.7	3.2
4.0-4.9	2.7	1.7	1.3	3.5	0.6	0.9	1.6
5.0-7.9	5.8	1.4	1.6	5.9	1.1	3.3	2.8
8.0+	2.3	3.4	1.0	4.9	1.8	1.0	2.4

*Holdings indicated as having zero hectares include nonagricultural households, households with livestock only, and households that cultivate land on a temporary basis.

Perennial crop systems. Examples of systems based mainly on perennial crops include the following: banana and coffee culture on the slopes of Mt. Meru and Mt. Kilimanjaro in northern Tanzania, ensete culture in Ethiopia, tea culture in Kenya, and coffee culture in Kenya.

Bananas are the staple food crop on the slopes of Mt. Meru and Mt. Kilimanjaro in northern Tanzania and throughout much of Uganda. In Tanzania, they are grown in close association with coffee and various fruit trees, which together provide a good canopy cover and minimal risk of soil erosion. Cattle are kept inside and stall-fed on chopped banana plants and fodder grasses. The return of manure to the land and the traditional use of irrigation lead to a stable, productive farming system that can support a high population.

Ensete (*Ensete edulis*) is grown extensively in southern Ethiopia. It is sometimes referred to as a false banana because its appearance is similar to the banana plant. However, its leaves are more erect, and it is grown for the rhizomes and inner parts of the stem that provide the main food of the Guraghe people. It has been said that ensete can support more people per unit area of land than any other crop, and the system of preserving the mashed up food material in pits, where it ferments, is an insurance against famine.

Tea is grown on an increasing scale in eastern Africa, both on commercial and peasant farms, particularly in central and western Kenya. Once established, tea plants provide an excellent canopy cover, and there is often a mulch of prunings to cover the ground. Kenya has recently embarked on a plan to establish a tea belt around the perimeter of indigenous forests so that encroachment on the latter can be prevented.

Coffee is grown widely in Kenya, Uganda, Tanzania, and Ethiopia. When it was introduced on small farms in Kenya, the colonial authorities insisted on the prior construction of terraces. This is still a common practice. However, some farmers have ignored the need for terraces or have tried to construct them after the coffee has been planted. In these situations erosion is sometimes severe. Where coffee is well managed, there is usually a good canopy cover and the ground is well protected against erosion. Use of mulch is less common than it was due to the lack of suitable material and prior needs of stall-fed livestock for fodder and bedding. However, increased use of herbicides and no-till has improved the mulching effect of weeds.

In all of the above situations, erosion is kept under control so long as there is a good cover, either from the canopy or from surface mulch, or both. The main risk of erosion is during the establishment phase. Othieno (*5*) has shown how this can be controlled in tea by such simple practices, as mulching or interplanting with narrow rows of oats (Table 2). After three years, the canopy cover should be sufficient to protect the soil.

The perennial cropping systems require a humid environment with a long growing season and/or irrigation. They are appropriate for steep slopes, they can minimize erosion, and they can support a high density of population, provided that prices and markets are favorable.

Annual crop systems. Annual crop systems predominate in those areas that are less humid, have a shorter or cooler growing season, or are otherwise unsuited to perennials, for example, because the soils are too shallow or marketing arrangements do not exist. Systems of particular interest include finger millet in Kenya and Uganda; barley, wheat, and teff in Ethiopia; and maize and beans in Kenya and other parts of eastern Africa.

Finger millet (*Eleusine coracana*) is an important, traditional crop grown on steep or very steep land in certain parts of Kenya and Uganda, such as the escarpments of the Rift Valley and adjacent mountain ranges. Most of this land is cultivated by hand or by ox-drawn plow. Seed is broadcast, grows quickly, and provides a thick cover once established, but there is a serious risk of soil erosion during land preparation and establishment. In some places this is countered by means of brushwood barriers pegged to the ground. In other areas, hedges of *Coleus sp.* serve the same function.

The cereal-growing areas of Ethiopia are extensive and include much land that is steep. Elevation ranges from 1,500 meters to 3,700 meters, and climate varies from humid, with a long growing season, to subhumid, with a short growing season. Land is cultivated by means of the ox-drawn "ard," which is capable of working in very stony situations. It breaks the surface but does not invert the soil, like a moldboard plow. The ard is, therefore, capable of leaving a bigger proportion of crop residues on the soil surface. Seedbeds are prepared thoroughly by repeated cultivation to destroy weeds. These cultivations are not always on the contour because of the need to cross plow to control weeds. Contour or graded terraces, which are being promoted, complicate these traditional cultivation practices. The growing

Table 2. Soil loss (t/ha) on a field of young tea after planting (5).

Treatment	*1971-1972*	*1972-1973*	*1973-1974*	*Total*
Manual tillage	161.28	48.28	1.23	210.79
Herbicide (no-till)	168.08	80.71	6.09	254.88
Oat strips between	34.90	4.31	0.42	39.63
Mulch	0.46	0.14	0.08	0.68
LSD (P = 0.05)	17.01	19.66	2.32	14.75
Rainfall (mm)	2,083	2,045	1,985	

of teff (*Eragrostis abyssinica*), which has a very small seed that is broadcast, can increase the risk of erosion because of the need for a very fine seedbed (land may be cultivated up to six times) and the practice of planting some time after the rains have started. Once established, however, teff provides a good cover.

Erosion is a serious problem throughout most of the Ethiopian highlands because of steep slopes and annual cropping. Some control is achieved by crop residues, but these are generally consumed by large numbers of low quality livestock or used for fuel. Even dung is used for fuel if there is nothing else available, though much is being done to establish fuelwood plantations. Control of erosion is assisted by rotation of cereals with leguminous crops, such as horse beans and lentils. Terraces, some of which are ancient and others more recent, are also quite common.

Maize and beans are grown extensively in Kenya and are frequently intercropped. Land is generally prepared by hand or with an ox-drawn moldboard plow. The small size of holdings does not warrant use of tractors. In the more humid areas at higher elevations (above 2,000 meters), with a long growing season, it is not uncommon to find the practice of relay cropping—one crop is being established before the previous one has been removed, and several different crops at various stages of growth are found together. In the lower and drier areas, maize and beans are often combined with such crops as pigeon pea, cowpea, cassava, and pumpkin. Crop residues play some role in conservation, but residues are also being used as fodder and increasingly as fuel (*4*). Residues that are not removed are likely to be eaten by termites. Terracing is common in dry areas.

An agroforestry study by Ngugi and Kabutha (*4*) has shown the great importance of trees in the farming system in central Kenya. Trees are important as a source of cash and for poles, fuelwood, and other uses. In the coffee zone, for example, the researchers found that the area under woody biomass was equal to the area under coffee. Black wattle (*Acacia mearnsii*) is the most common species in the coffee and tea zones and Grevillea (*G. robusta*) and mango in the maize and bean zone. Both trees and woody hedge plants are clearly playing an important role in the farming economy and in controlling soil erosion on steep lands.

Terracing practices

Terracing has been widely used to reduce runoff and soil loss in eastern Africa. The textbook approach, complete with diversion ditches, graded channel terraces, and natural or artificial waterways, is rarely found on small farms, though it has been common and is still found on some large farms. What is more common on small farms is an assorted mix of diversion ditches (cutoffs), various types of terraces, and waterways that are often gullied and rarely designed or constructed to take all of the runoff that comes from farmland, roads, and building areas.

Traditional terrace systems are found in parts of Ethiopia and Tanzania. Two types in Ethiopia exemplify these systems. First, in the low rainfall area of Konso in southwestern Ethiopia, there are stonewalled terraces of ancient origin. Second, in parts of the northern Shoa region and Wollo region there are terraces that may have arisen over centuries from uncultivated strips of land and the combined effects of sediment deposition on the upper side and excavation by plowing on the lower side. Many of these terraces, especially in northern Shoa, are in poor condition. In certain areas, conventional channel terraces have been superimposed in recent years, giving a dissected appearance to the landscape. This situation is further complicated by the traditional practice in some more humid areas of constructing small drainage ditches diagonally down the slope in order to remove excess water during periods of temporary waterlogging. These are, in effect, man-made rills. Because they are many in number and because each carries a small discharge, they are not as damaging as might be supposed. Farmers have sometimes continued with this practice in areas where the government has installed channel terraces (under food-for-work programs). Hurni (*2*) advocates systems of terracing that control erosion but also allow for good drainage when needed.

On less steep land in the Wollo region, there are some large terraces similar in appearance to the steep, grassed-backslope terraces common in western Iowa. To what extent these terraces are the result of deliberate intervention or the consequence of cultivation practices is not clear, but again, more recent terracing, often in the form of stone bunds, has been superimposed on an older system.

Recent terracing practices in Ethiopia include the "fanya juu" system adopted from Kenya, where it has been widely used, especially in areas of marginal rainfall. If properly executed, this system leads to the formation of bench terraces that may be level from front to rear so that rainwater infiltrates more or less uniformly. More commonly, it leads to the formation of outward sloping bench terraces with water infiltration either above the embankment (*8*), in a channel at the foot of the embankment (*9*), or in both places (*2*).

In Tanzania there is a traditional system of terracing that uses what are known as ladder terraces or step terraces (*7*). These terraces are made by laying crop residues and vegetative material in rows on the contour and covering them with soil pulled from the upper side. The high organic matter content, free-draining structure of the soil, and changed profile of the slope are effective in controlling erosion. In the same areas the practice of bench terracing, which was promoted during the Colonial era, was strongly resisted and unsuccessful.

In the coffee growing areas of Kenya, bench terracing has been widely practiced. On steep land the benches are generally made to accommodate a single row of coffee, and banks may be stabilized with a grass, such as *Brachiaria decumbens* or *Panicum trichocladum*, though this is not done as regularly as it should be. Certain grasses, such as Bana grass and Guatamala grass, have proved less satisfactory because of competition with the crop. Terracing of coffee land is less common in Ethiopia, where much of the coffee is grown in association with a forest canopy. However, bench terracing for chat (*Catha edulis*) is common.

Terracing of land for maize and beans in the humid areas of central Kenya has been less popular. One explanation is that the benefits are less conspicuous than in drier areas where water is more often limiting. Another is a negative association with the terracing that was imposed during Colonial rule. A third possible reason for the slow adoption of terracing for annual crops may be the fact that erosion is less conspicuous because rills are removed regularly by cultivation. Erosion in a coffee field exposes roots, and the need for conservation measures is immediately apparent. The soil conservation project, which was started in 1974 with support from the Swedish International Development Authority, initially laid much emphasis on cutoff drains that were dug with paid labor. Terracing by the fanya juu method was also encouraged but not subsidized, apart from some assistance with tools and layout. Although many cutoffs were effective, it is not uncommon to find widely spaced cutoffs on a long slope with few or inadequate terraces between (*3*).

One major problem with graded cutoffs and terraces in the densely populated areas of central Kenya is the difficulty of finding sites to discharge water. Land consolidation led to the demarcation of small holdings that are often long and narrow and aligned with the slope from ridge to valley. Natural waterways are few and far between, and runoff sometimes discharges onto footpaths between holdings, thereby creating gullies (*1*). Procedures for the design and construction of small waterways cum footpaths need investigation. Stone for lining channels or building drop structures can be useful but is not often close at hand. The lock-and-spill system has been used successfully in some areas, but its suitability for different situations needs further study.

Some farmers in central Kenya have found their own solution to the problem of runoff by digging large retention ditches to hold water until it infiltrates. The design requirements for these retention ditches have not yet been specified. They are said to be in common use in Rwanda. On steep slopes with certain soils, such as andosols, the ditches will increase the risk of landslips. In other situations they are appropriate and can be used advantageously.

Another system adopted by farmers is a combination of the fanya juu terrace and a cutoff, which is referred to locally as a fanya juu/chini (*4*). The merits of this system have not been fully evaluated.

The storage of runoff in small tanks and ponds for supplemental irrigation in the dry season has been carried out successfully by some farmers in the Himalayan foothills and might also find application on hillslopes in eastern Africa. A systems approach to the control, utilization, and/or disposal of runoff is needed.

Stabilization of terrace banks is often neglected. Stone is ideal but rarely used either because of the labor required or lack of ready material. Stone could and should be used more widely in areas where it abounds, such as the escarpments of the Rift Valley in Kenya and Ethiopia. Grasses used for stabilization of terrace banks include Napier grass (*Pennisetum purpureum*), Bana grass (*P. purpureum* x *P. americanum*), Nandi Setaria (*Setaria anceps*), Guatamala grass (*Tripsacum laxum*), *Brachiaria decumbens*, and *Panicum trichocladum*. In the drier areas, Makarikari grass (*Panicum coloratum* Var. *makarikariensis*) is still the most popular. The competetive effect of vigorous, productive grasses, such as Napier, Bana, and Guatamala, on the adjacent crop can be severe, especially in seasons of low rainfall. This may not be too significant where terraces are widely spaced. Where land is steep and terraces close, however, the competition must be taken into account.

In areas where there are high-grade, productive dairy cows, the grass produced on terrace banks can be used for feeding, and any competition with the adjacent crop must be weighed against the milk sold or consumed. Fodder grass is becoming a cash crop in some areas, and in certain locations near Nairobi, farmers are even removing wattle trees and replacing them with Napier grass for sale.

Stripcropping and grass strips

The system of stripcropping commonly advocated in the textbooks is rarely found on steep lands in eastern Africa, though there has been an attempt in Rwanda to devise cropping systems with strips of perennials, biennials, and annuals that would maintain productivity and reduce soil erosion (*11*).

Narrow grass strips are quite common in the humid areas of Kenya.

Experimental work indicates that, although they are only a partial solution to the erosion problem, the strips can be very beneficial. The input of labor required for establishment is a fraction of that required for terracing. Moreover, the strips provide fodder that can be used or sold for cash where there are high-grade dairy cattle and a ready market for milk, and they encourage the natural formation of terraces. In an experiment using runoff plots on a 10 percent slope at Kabete in Kenya, narrow strips of grass (0.5-1.5 meters) reduced soil loss by about two-thirds and water loss by about one-half *(10)*. The retarding effect of the grass was found to cause deposition of sediment in a band up to 2 meters wide along the upper edge of the strip. Present observations suggest that several narrow strips spaced relatively close would be much more effective than a few wide ones far apart, assuming the total area under grass were the same in both situations. Grass strips have been widely and successfully used in Swaziland and appear to have a useful role, in conjunction with other methods, in stabilizing steep slopes. There can be problems from rats that hide within the strips and cause damage to the adjacent crops, however.

Conclusions

► Perennial crops can be useful in controlling erosion if they are carefully established and well managed. However, the demand for cereals and pulses for food results in large areas of land under annual crops. Because mulching with crop residues is rarely practiced, land under annual crops has a high risk of soil erosion between planting at the onset of the rains and establishment of crop cover.

► Terracing has an important role to play in controlling soil erosion, but its effectiveness depends a great deal upon the way the terraces are formed and maintained. The benefits are most easily recognized in areas of low rainfall because of water conservation.

► Conservation measures, such as terracing, are given most attention where cash crops, such as coffee or vegetables, are grown.

► The loss of land in terracing can be compensated for if the banks or risers can be used for fodder grass, assuming that there are productive animals that can use the fodder.

► The design and formation of terraces, whether by excavation or by evolution, should be carried out skillfully, and care should be taken to stabilize banks with appropriate plants or stone.

► Narrow grass strips can play a useful role in reducing runoff and soil loss where slopes are not too steep and can lead to the formation of terraces.

► Cutoffs or diversion ditches are useful, provided there are proper disposal areas or waterways to take the runoff.

► Retention-type ditches are being used by farmers on steep lands where there is no place to discharge runoff. The design requirements need to be investigated, as does the possibility of integrating runoff control and water storage for supplemental irrigation.

► Fanya juu terraces, which are similar to steep, grassed-backslope terraces, but smaller and closer, have proved popular in Kenya and are being tried elsewhere. To be successful, however, they need good consolidation and stabilization of the embankment.

► A systems approach to the control, utilization, and/or disposal of runoff is needed.

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A review of watershed development projects in South Korea, Indonesia, Jamaica, and Ethiopia

B. C. John

The causes of soil erosion and the problems it brings are all well known. In an attempt to rectify the problems, there are many soil and water conservation programs at present being implemented throughout the world. Their number has steadily increased since the 1950s. The United Nation's Food and Agriculture Organization alone in 1986 operated 16 conservation projects in 15 different countries. Nevertheless, severe soil erosion continues in many countries. Undoubtedly, conservation programs throughout the world will be intensified to meet this challenge. Before embarking on new programs, however, questions should be asked about how successful those programs already implemented have been and what lessons can be learned from this past experience.

Some conservation programs have been more successful than others. Some may even be termed "disasters." One project in Korea, in the early 1960s, by being poorly designed and constructed actually jeopardized the implementation of new soil conservation measures.

Drawing on the experience gained in the operation of four large-scale, multidisciplinary projects and by reviewing their objectives, inputs, and outputs, it is hoped that some factors might emerge that will assist in formulating and implementing successful soil and water conservation projects in the future.

It is difficult to judge the success of a soil conservation project that has only been operational for a few years. It may have achieved its objectives on paper, but this does not necessarily mean that the benefits of conservation will be sustained over the years.

Multidisciplinary projects may be judged on the success of the components that produce the more rapid benefits, such as irrigation development. On the other hand, soil conservation benefits are not immediately realized in every case and may initially result in crop yield reductions. Providing overall production is increased or at least maintained, however, success in one component should lead to success in others, including the long-term and less obvious benefits of soil conservation.

The four projects reviewed here were all in areas of severe or potentially severe soil erosion. They were widely separated in location; they were in different ethnological regions; and they were in three different climatic zones. This made direct comparison of the projects difficult. Another factor that complicated project comparison was the level of development in the country where each was being implemented.

In chronological order of operation, the four projects were located in South Korea, Indonesia, Jamaica, and Ethiopia. The Korean project was probably the most successful. It was also the largest and featured the most inputs.

All the projects were operated by FAO and funded by the United Nations Development Program. The Jamaican project received additional funds-in-trust from Norway. With the exception of Jamaica, the labor input was funded wholely or in part in the form of "food-for-work" by the World Food Program.

The projects

South Korea: Uplands development and watershed management. This large-scale project, with a final budget of US $5.2 million, became operational in 1967 and ran for five years. The principal objective was to demonstrate the economic feasibility of comprehensive watershed development and management. Emphasis was to be placed on increasing agricultural productivity through improved soil and water management. Mismanagement and neglect in the past had led to serious denudation of steep uplands. Soil erosion was severe, and the siltation of rivers made widespread flooding common.

Initially, the project commenced on a fairly small scale. During the first two years, the international staff consisted of only a project manager and three watershed management advisers. The project manager was located at the project headquarters in Seoul; the advisers were out-posted at three widely separated provincial offices. Within each of the provinces a watershed of approximately 100,000 hectares was selected for development. Each was subsequently divided into subwatersheds of 1,000 to 2,000 hectares. Development activities, on a comprehensive basis, were concentrated in selected subwatersheds.

Comprehensive watershed development involves many interacting components. The full benefit of one particular component may not be realized until another is implemented. For example, bench terracing will increase productivity when followed by the availability of improved seeds and recommendations for optimum fertilizer use and crop rotations. Another example is the construction of a water reticulation system and method of water application after dam construction. It was found in the Korean project that the benefit could be increased as much as 50 percent by reducing channel losses and improving water application to the fields.

Although the international staff covered a range of disciplines, specialists in some areas were missing. In particular, more emphasis was needed on farmer involvement and extension. This led to a request for a major expansion of the project, which was later approved.

Table 1 lists the main components identified as critical to the successful completion of the project. The list is a fairly comprehensive one, but it omits one major component—forestry. This component was not forgotten; because of its importance, a separate project was formed that ran concur-

Table 1. Major components of the Korean project.

i. Preparation of subwatershed development plans
ii. Design and construction of soil conservation measures
- physical
- vegetative

iii. Design and construction of water conservation measures
- dams
- fish ponds
- tubewells (galleries)

iv. Design and construction of flood protection measures
- river training
- hillside levees
- torrent control

v. Wasteland reclamation
vi. Land rearrangement
- consolidation of paddy land
- for irrigation, drainage and access

vii. Irrigation development
- basin
- sprinkler

viii. Improvement of pasture and rangeland
ix. Introduction of improved seeds
x. Introduction of fish culture
xi. Demonstration of heavy equipment and farm machinery use and operation
xii. Socioeconomic improvements
- village and community development
- farm management

xiii. National staff training, including overseas fellowships
xiv. Economic evaluation of the major components implemented by the project.

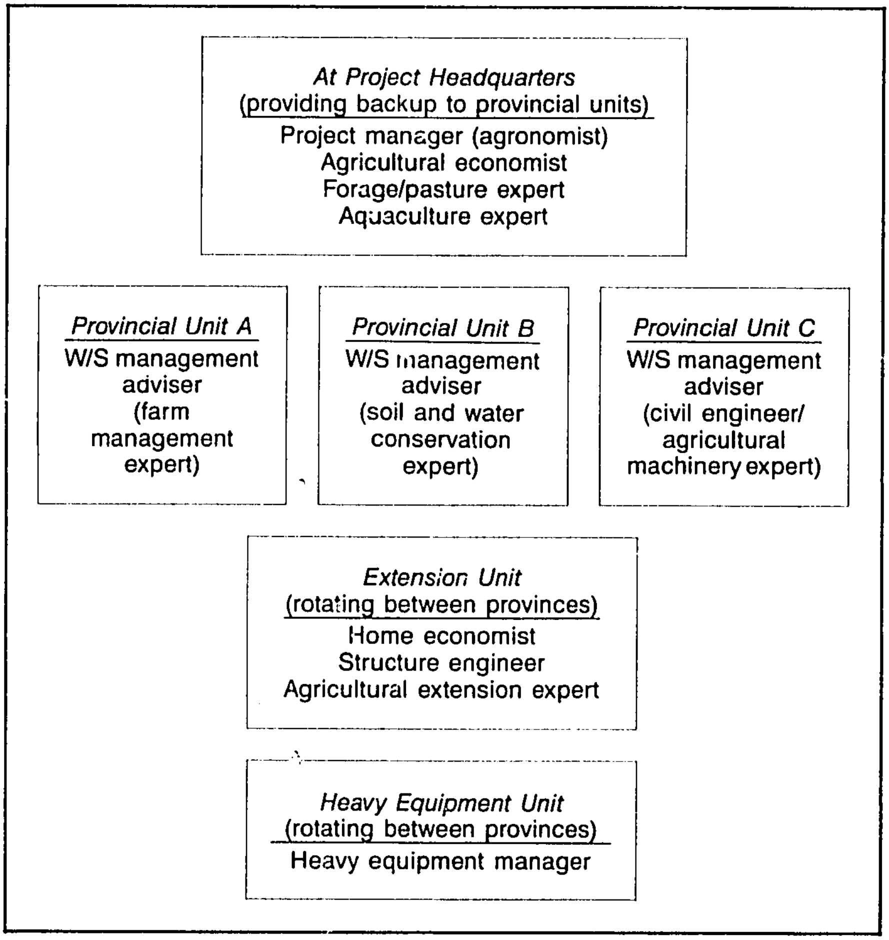

Figure 1. Disciplinary composition of international staff.

rently with the uplands project and in the same watersheds. For the planning of comprehensive subwatershed development, this was not an ideal situation. Fortunately, good cooperation existed between the two projects at the provincial level. Plans were prepared jointly; where necessary, forestry work was scheduled for completion one or two years before the other work. This applied particularly to catchment protection before dam construction.

The composition of the international staff assigned to the project after the expansion is shown in figure 1. Each member had a full-time national counterpart with two or three assistants. In addition, a large number of technicians at the district and lower levels were engaged on the project as required. In Korea, the national counterpart involvement and enthusiasm were excellent, which undoubtedly contributed much to the project's success. This counterpart involvement is essential. Unfortunately, it is not always so apparent in some projects.

Many people would argue that in an agricultural development project it is the farmers who hold the ultimate key to success or failure. This may be so, and communication with the farmers is an extremely important aspect of watershed development. However, experience has shown that *genuine* farmers have always been cooperative, enthusiastic, and ready to exchange ideas, providing there is an open approach based on sound technical information.

The project covered a wide range of activities, as did the disciplines of the staff members. These two factors, together with the positive support of the national staff, contributed most to the success of this project.

Perhaps surprisingly, some of the more profitable improvements introduced by the project did not always prove to be the most acceptable among the small farmers. Grassland development and sprinkler irrigation were two examples. The former was important in the soil conservation program, and the project had expertise in this field. Unfortunately, there was no expertise in animal husbandry. Possibly, grassland development would have been more acceptable had the additional inputs been available to help farmers improve their livestock. Experience proved that in locations with access to good markets the cost of installing sprinkler irrigation equipment could be recovered from the increase in returns in about two years. Yet it proved extremely difficult to organize smallholders into user associations for the disciplined use of the equipment. Possibly, too many individuals were involved. Sometimes there would be as many as 20 farmers using the equipment on a rotational basis.

On the other hand, water storage dams; basin irrigation; flood protection; and, particulary, dual-purpose water storage/fish ponds were readily acceptable. Perhaps the farmers had a greater understanding of these components, although fish ponds were new to most of them.

Bench terracing for sustaining yields, although economically justified for slopes up to about 25 percent, was not readily acceptable. These drylands, usually with poor soil, needed fertilizers and careful management to obtain good returns. Furthermore, two-wheeled power tillers were beginning to be introduced and were difficult to operate on narrow terraces. The construction of orchard terraces, specifically built and spaced apart to suit fruit trees, proved more acceptable.

In a large-scale, multidisciplinary project, structure is important. In Korea there were 11 international staff members, all making field visits and advising

ing on various aspects of the work. These visits were arranged by the provincial adviser, and he was expected to be involved in the work and responsible for any follow-up action.

Although a number of in-service training courses on specialized subjects were held in all three provinces, this activity tended to be limited to on-the-job training, which was a daily occurrence.

This project was judged primarily on what it had achieved in the field by way of demonstration. Based on socioeconomic surveys, demonstrations were concentrated in a number of subwatersheds for visual impact. This may be termed saturation development and included virtually all aspects of economically sound agricultural and community development. Credit unions were built up by the villagers from the increased returns as a result of the development inputs. These funds were used to finance such diverse works as village water supplies and the construction of community centers, bath houses, and drying floors. These activities may be far removed from soil conservation, but by creating stronger community spirit, there is greater will among villagers to face and overcome other problems.

Indonesia: Upper Solo watershed management and upland development. The Upper Solo watershed project, located in Central Java, ran from 1973 to 1976. The total budget of US $2 million for the three years was considerably smaller than that of the Korean project. This reflects the shorter duration and the absence of a heavy equipment unit.

The project was in a densely populated, severely degraded area. Much of the land was in such a critical state, through soil erosion, that it had virtually been abandoned for agriculture.

The government's cooperating agency was the Directorate of Reforestation and Land Rehabilitation. For implementation, however, more use should have been made of the Daerah Aliran Sungai and Instruksi Presiden, both departments within the Ministry of Interior.

The main objective of the project was to strengthen, by demonstration and training, the government's capacity to carry out an expanding program of watershed management and soil conservation. Emphasis was placed on watershed development planning and on-the-job training. Practical demonstrations were implemented in selected subwatersheds, but these were restricted mainly to forestry, agronomy, soil conservation, and improved farm management. Socioeconomic surveys revealed that farmers regarded irrigation facilities as the key to development, and although this activity was included in the watershed development plans, it could not be fully demonstrated because of the lack of funds for materials.

Field work was carried out in four watersheds, with activities concentrated in seven subwatersheds. The watersheds were all in fairly close proximity to one another, which enabled the project to be centrally located. All staff operated from project headquarters. This had both advantages and disadvantages. The main advantage was easier coordination during the planning process. Without anyone having overall responsibility for field activities, however, competition for field technicians and labor did occur at times among disciplines.

The project was successful in proving that agricultural production in the degraded watersheds could be increased and sustained by about 50 percent. Furthermore, the counterparts were trained in the techniques to obtain this increase. Table 2 lists the components covered by the project. They were fewer than in the Korean project. The main difference was the greater emphasis on planning. Composition of the international expert staff was the same in number as in Korea, but the extension unit was reduced to a single extension education specialist, with a forester and hydrologist added to the team.

Three main difficulties were identified by the project. These were not entirely solved and would present problems for any follow-up, whether implemented by government or an international agency. The first was the vertical structure of the government. The Directorate of Reforestation and Land Rehabilitation came under the direction of directorate-general of forestry. As a result, there was a strong emphasis on forestry. Other components tended to be neglected, and it was difficult to coordinate the resources of the Departments of Agriculture, Animal Husbandry, and Irrigation.

The weakness of the Extension Service was another problem. Frequently,

Table 2. Major components of the Indonesian project

i. Preparation of watershed and detailed subwatershed development plans
ii. Design and construction of soil conservation measures
   - physical
   - vegetative
iii. Design and construction of flood protection measures
   - hillside levees/interceptive drains
iv. Forest plantations
v. Farm management
   - introduction of improved seeds varieties, optimum fertilizer use.
vi. Extension education
vii. Hydrology
iix. National staff training
ix. Economic evaluation of components identified in the development plans
x. Farm road improvement

farmers were unaware of the seriousness and the effect of soil erosion. Nor were they aware of the measures that could be taken to reduce or eliminate the problem. In some subwatersheds the project established demonstrations that showed the actual rate of soil loss at times amounting to a depth of as much as 2.5 centimeters per rainy season.

The third problem was the traditional top-down approach. Local people were involved only as workers. This did not instill any sense of identity with the works being done for their benefit. Not surprisingly, subsequent maintenance of the works by farmers posed a problem.

Jamaica: Strengthening the national Soil Conservation Program for integrated watershed development. The Jamaican project, located near Kingston, was operational for two and a half years, from 1980 to 1982. In structure and composition of international staff, it was similar to that in Indonesia, the exception being the addition of a training specialist. The total project budget was US $3.1 million.

At the time, the main objectives of the government's agricultural and rural development policy were to increase agricultural productivity and expand rural employment opportunities as a means of reducing migration to urban centers. To assist in meeting this objective, the project aimed (1) to strengthen the operational capacity of the Soil Conservation Division of the Ministry of Agriculture through staff training, (2) to produce a preliminary appraisal (including economic implications) of integrated watershed development and demonstrate its implementation in selected subwatersheds, and (3) to prepare target development plans for a number of watersheds suitable for possible external financing.

The selected subwatersheds were situated on the southern slopes of the Blue Mountains; the subwatersheds formed an arc immediately to the north of Kingston, where the project headquarters was located. These subwatersheds exhibited many constraints to the development of hillside farming and were recognized as being among the most difficult on the island. In addition to the physical constraints, there was widespread absentee ownership, and many residents showed little interest in farming, even with incentives. Some derived their income from commercial activities, while others were retired farmers. Thirty percent were over 60 years of age, and many were caretaking the land for relatives abroad. Even in the selected subwatersheds it was found that only about 40 percent of the farmers showed any willingness to cooperate with the project, and seldom did they accept all the proposals.

Under such conditions, integrated watershed development could not be effectively demonstrated. The project made the alternative approach of identifying the full-time, interested farmers (about 10 percent) and concentrating its efforts on this group. The aim, of course, was to create a snowball effect. Eventually, about another 30 percent of agricultural households responded, to some extent, to the stimulus of the progressive group. On this basis, the project recommended that the development plans be based on a limited approach.

The development components were similar to those implemented in Indonesia, but with more emphasis on in-service training. Some 16 courses of formal in-service training were conducted. Seven technical training manuals covering the various components of watershed development were prepared, together with lecture notes, and used during the courses. Undoubtedly, the project was successful in meeting its training targets, but it does not necessarily follow that this will lead to a strengthening of the Soil Conservation Division.

Many of the 100 staff members who attended the courses and the 16 who were sent on overseas fellowship training left the agency during the life of the project. Of the 10 professional counterparts who were assigned to the project at its inception, only five remained at its termination. Most of the national staff members were recruited specifically for the project from a university or college and without any guarantee of being retained on its completion.

Ethiopia: Assistance to soil and water conservation program. In terms of international staff, this was the smallest of the four projects. Initially, there were three watershed management advisers outposted to regions. The team leader and a silvipasture adviser at project headquarters in Addis Ababa provided back-up to the regional advisers.

The project was operational from 1982 to 1986 and had a total budget of US $3.5 million. The objectives were similar to those of the other projects, namely, to assist the government in carrying out soil and water conservation campaigns in the mountainous catchments in order to arrest erosion of fertile soil and to minimize the sedimentation of rivers and the effects of floods and drought. Because this objective was to be attained by strengthening the government department responsible for the work, the emphasis was on training department staff members at all levels. In addition, the project was to prepare a methodology for comprehensive watershed development planning and to implement demonstrations according to the plan in selected subwatersheds.

At the field level, the development needs and activities appeared obvious, and it seemed the project could make a significant contribution to the government's objectives. Progress in the regions was reasonably good in spite of numerous petty problems, such as lack of materials and funds for operating vehicles and limited travel allowance for counterpart staff. Nevertheless, by building on some of the good work implemented under the supervision of national staff, small pilot demonstration areas were established with the generous incentives of the World Food Program (food-for-work). The demonstration of comprehensive watershed development could never be fully achieved because the approach was too narrow. Only soil conservation and reforestation components were implemented, and even these were restricted to the inputs of labor alone. There was virtually a complete lack of construction materials and agricultural inputs and nothing to create a spontaneous acceptance by farmers of the development activities. Insecurity of land tenure was an added disincentive for farmers to cooperate in implementing soil conservation programs.

Midway through the project, the Ministry of Agriculture was largely decentralized, and the project's coordinating agency was changed from the Soil and Water Conservation Development Department to the Community Forestry and Soil Conservation Development Department. The decentralization should have benefitted the project's progress, particularly at the regional level. The regions, or zones as they were to be known, were strengthened, given more autonomy, and all agricultural activities came under the direction of the zonal director. Comprehensive watershed development planning and implementation should have become more feasible as a result, but it was at this time that the project's activities were centralized and weakened in the zones.

The decentralization of the ministry coincided with a major revision of the project, and unfortunately, the two events were not coordinated. From the experience gained during the first two years of the project's operation, it was decided by a review mission that there should be more emphasis on training and the project's area of influence expanded. Because no additional funding was available, one of the regional adviser's posts was abolished to finance the extra training, most of which was overseas, and the two remaining watershed management advisers were centralized at project headquarters to cover seven regions. Originally, associate experts were to have been assigned to assist with the field work in the regions. This was possible to the extent that associates were available, but even their supervision was inadequate. The project had insufficient strength to make a significant impact on field activities, as well as the preparation of training manuals and the arrangment of and participation in in-service training courses. Furthermore, many of the more experienced counterpart staff members were on overseas training, which compounded the problem when the project staff made field visits.

Of the four projects, Ethiopia had by far the largest formal training component. Forty counterparts received a total of 390 man-months of overseas training. This included 14 who attended degree courses generally of two years' duration. There were 45 in-service training courses supported by the project. Fourteen technical training manuals were specially prepared, as well as lecture notes for the in-service courses. A large quantity of audio-visual training materials was also provided through the project.

Some results and conclusions

With different degrees of emphasis, there were three main objectives in all four projects. First, there was the training of national staff—overseas fellowships, formal in-service courses, and on-the-job training. Second, there was the preparation of plans for comprehensive watershed development. Third, there was the practical demonstration of watershed development by implementation.

Korea. In Korea, the emphasis was on practical, on-the-job training in all aspects of comprehensive watershed development. The socioeconomic considerations were given particular attention during the preparation of the development package. The project was able to demonstrate a wide range of development activities. With the exception of sprinkler irrigation, it was found from the socioeconomic surveys that the development of traditional irrigation facilities (dams, channels, paddy land) was high on the list of farmers' priorities. Special attention was paid to this activity, which undoubtedly led to greater farmer cooperation in the implementation of some of the less attractive components, such as bench terracing or closure of hillsides, required for long-term watershed protection.

On completion of the five-year project, there was a nucleus of well-trained national staff, with some practical experience, at project headquarters and in each of the three provinces. In addition, a number of subwatersheds had been treated carefully to serve as lasting demonstrations of comprehensive watershed development. With the departure of international staff, watershed development was continued by national staff along the lines established by the project.

Indonesia. In Indonesia, project efforts were more evenly divided between the preparation of watershed development plans and their implementation. There was little formal in-service training and no overseas fellowships. On-the-job training figured largely in the normal daily functions of the project.

The addition of an hydrologist to the project's international staff should have permitted a more sophisticated approach to water-related matters in the planning process. But possibly an irrigation engineer or an hydraulic engineer would have been more suited in view of the construction work involved. In any case, it was not possible to demonstrate any improved irrigation facilities due to lack of funds, and this stemmed from the vertical structure of the government's coordinating agency.

The presence of a forester facilitated the comprehensive planning process, but at the implementation stage, competition for labor between forestry and soil conservation tended to cause problems. Differentials in labor rates were another source of trouble. These problems tended to occur at the field level and, while not insurmountable, did draw attention for the need to plan labor inputs at uniform rates. Labor availability and seasonal farm requirements should also be taken into account.

The comprehensive watershed development plans took into account the villagers' needs that were identified in the socioeconomic surveys. It is important that components in development plans focus on the villagers' most urgent needs.

Preparation of development plans was assisted by the presence of up-to-date, large-scale orthophoto mosaics and aerial photographs. However, some of the first plans prepared relied on field surveys because mosaics were not available. The big difference between the two methods was the time factor. Within the life of the project, it would not have been possible to prepare such detailed plans for whole watersheds without the use of up-to-date, large-scale aerial photographs.

Jamaica. The project in Jamaica was similar to that in Indonesia; in fact, four of the eight international staff members served on the Indonesian project. The main difference was the stronger training component. A training specialist was included in the team, and formal in-service courses and preparation of technical training manuals formed a significant part of the project's activities.

As in Indonesia, aerial photographs and mosaics were specially prepared for the project, and comprehensive watershed development planning proceeded on similar lines. In Jamaica, the development proposals were, to some extent, limited by the extreme steepness of the terrain.

The project encountered difficulties in establishing demonstration watersheds because some farmers were reluctant to cooperate. There was also a lack of community spirit. Waterways, for example, could not be run from one farm to another. Another problem was the high turnover of national staff due to their insecurity of position. This certainly would have a detrimental effect on any continuation of the project's activities by government after its termination. Even the national project director left the project during its life.

At the time of the project's inception, there appeared to be a strong justification for its presence and location. It was only after the results of the socioeconomic surveys became known and the attitude of the inhabitants realized that doubts began to emerge as to what success the project would have in establishing field demonstration areas. Also, it was not known at the beginning that the project was to operate during a time of political change. It may be for this reason that project counterparts faced insecurity in their positions.

Ethiopia. Although the original objectives of the Ethiopian project were similar to those of the other projects, fundamental differences in project composition, organization, and government direction had a marked impact on results. Staff training, both overseas and in-service, and preparation of training materials dominated project activities. Preparation of comprehensive development plans and the establishment of demonstration subwatersheds should also have formed an important part of the project's activities. However, because of the lack of support both from within the project—due to insufficient staff and resources—and from the government, little was achieved.

This does not infer that there was little soil conservation work carried out. Indeed, vast areas were treated under the World Food Program food-for-work campaign, but not as part of an integrated watershed development package. Except for the benefit from greater water retention, it will be some years before crop yield increases are realized. This will not lead to a spontaneous acceptance of soil conservation measures, and it is questionable as to what extent the work will be maintained. Instances have occurred where new soil bunds have been built between old. This may not be the norm, but it suggests that the work is being implemented as a task in return for food rather than a desire to conserve soil. In areas where there are shortages of food, inefficiency in a food-for-work campaign may be acceptable, but at no time should it have a negative effect on soil conservation or afforestation. Obviously, there is a lack of understanding by some farmers, and this clearly indicates the need for a stronger, more energetic extension service, with possibly a better message. Wherever there is a food-for-work campaign, whether by World Food Program or another agency, a prerequisite should be the availability of competent field supervision. This should not be confused with emergency food aid in areas of famine, which is another matter.

Table 3. Details of overseas training.

Country	Project	Overseas Fellowship Training Candidates	Overseas Fellowship Training Number of Man-months
Korea	KQR/67/522	27	65
Indonesia	IND/72/006	-	-
Jamaica	JAM/78/006	16	90
Ethiopia	ETH/81/003	40*	390

*Including 14 candidates who attended degree courses of one to three years duration.

Training. Formal training, whether in-service or overseas, was justified in all projects, but it should have been oriented to meet the needs of the country. Details of the overseas training provided by the four projects are shown in table 3.

It is important that training be balanced between the immediate and long-term requirements. Possibly the immediate requirements, usually at the lower level, can best be met by in-service training. In a country, such as Ethiopia, where the level of development is in the early stages, it is questionable whether the emphasis on overseas training was justified. In any case, overseas training should be restricted to neighboring countries that have similar conditions and the facilities to train.

Greater importance should be placed on improving facilities and tailoring the training to meet the resources available in the home country. Many months may be authorized for overseas training, but all too often in-service courses are restricted to a week or so. To have real impact, these courses must be carefully graded, with a progressive sequence, and the participants chosen using some criteria for qualification.

It would seem elementary to have a logical in-service training program that could easily be coordinated by a counterpart. But it needs continuity, and counterparts in this seemingly nonessential task often are reassigned at a moment's notice. If a project is to contain a large in-service training program, it is imperative that there be a full-time training officer.

Of the four projects, Jamaica was the only one that contained such an officer, and only in this project was a regular in-service training program established. Even if many of the participants subsequently departed from the project, their training may still be put to some use. This cannot reflect adversely on the project.

Maps for watershed development planning. For watershed development planning, it is essential that the basic materials, maps, and aerial photographs are available or can readily be obtained. After the socioeconomic survey of the area, and this includes contact and exchange of ideas with farmers, some form of base map is required on which is recorded the physical and present conditions of the watershed. So that sufficient detail can be shown, maps or aerial photographs to a minimum scale of about 1:15,000 are required. These are seldom available, however, and it becomes the task of the planner to prepare them, using the best information available, supplemented with field observations.

Preparation of the base map in Korea relied largely on field observations, but this task was greatly assisted by use of large-scale cadastral plans as planemetric control. In addition, there were topographical maps and aerial photographs, both at 1:50,000 scale. In both Indonesia and Jamaica, controlled orthophoto mosaics at a scale of about 1:15,000 were specially made for the project.

Preparation of base maps in Ethiopia was more difficult. In most areas the largest scale maps were only 1:250,000, and the aerial photographs, at 1:50,000 scale, were more than 20 years old. Therefore, a considerable amount of field work was involved.

In all four projects, watershed development planning was possible. In some, however, basic maps and aerial photographs were lacking. Where this occurred, additional field work was required.

Demonstration areas. Only in Korea was the establishment of comprehensive watershed development demonstration areas fully realized. Indonesia lacked inputs in water development. In Jamaica, farmers showed little interest, while in Ethiopia, the inputs were mainly limited to manual activities.

Composition of staff. The composition of the international staff and that of the national counterparts should be closely related to the objectives of a project. If the objective is comprehensive watershed development, then it is inevitable that a broad range of disciplines should be covered. Unfortunately, possibly because of budgetary constraints, there were frequent gaps in expertise. In such cases, it is important that the project have the mechanism to enlist expertise from other projects or departments. Training is a component often omitted on the assumption that the various specialists are capable of imparting their skills. However, training is a specialized subject as much as other disciplines, and it requires experience in presentation and coordination of programs.

Farmer training. Farmers' training, it may be argued, must be an activity of national counterparts because of the difficulties with language. This is true, but it was evident in all projects that some impetus is required. All too often the necessary training aids are not available unless they are a project input. It was significant that in Ethiopia, where farmers and many junior technicians had little or no knowledge of English, not one of the project's technical training manuals was translated into Amharic. These included some that were specifically prepared for junior technicians and leading farmers using simple terms and diagrams.

Resident adviser. For watershed development and training, the ideal composition and structure of a project is to have a resident adviser as close to the site of work as possible, with access to backup expertise as necessary. The resident should have a broad knowledge of watershed development activities. Possibly someone with a background in farm management would be most suited. More important, he or she should be able to identify areas where development opportunities exist and not be shy in seeking additional advice when necessary.

Government structure. The vertical structure of government departments that is found in many countries can be a serious obstacle to comprehensive watershed development. Yet it is the comprehensive approach that greatly assists the successful implementation of a soil and water conservation program.

The department responsible for soil and water conservation must cover or have access to a broad range of disciplines. Perhaps a title such as "Land Rehabilitation" or simply "Watershed Development" might infer a more general approach and move the policymaker away from the idea of rigid, monodisciplined departments with little coordination.

17

Demonstration and extension of soil and water conservation principles in Latin America

Jerome E. Arledge

Most countries have used soil conservation practices for many years, some for centuries. Why, then, have not more hectares of adequate conservation measures been installed where they are so badly needed? Why have not masses of people learned from others who have applied conservation work?

Perhaps part of the answer is the extreme poverty among farmers in developing nations. The immediate need of the people may outweigh the concern for resource conservation. It is then unrealistic in such circumstances to expect soil and water conservation to be given a high priority.

The primary intent here is to offer some conservation ideas, philosophy, principles, and guidelines for individuals and groups working in developing countries. In addition, successful experiences are reported that help answer the following questions. How does one approach and deal with people? How does one develop a sales pitch or demonstration? What factors must one keep in mind during the approach and the follow-up stages to assure the program objective of increasing agricultural production by uniformly trapping and infiltrating, as much as possible, the available moisture?

The soil and water conservation system described herein has been applied in many areas in Central and South America and in the Caribbean. The system of demonstration and extension has even broader application for other countries. Keep in mind that there is never only one *right* way to reach an objective. There are many alternatives, and one or more of these may fit any specific condition encountered in the field.

Principles of soil and water conservation consist of increasing infiltration to furnish water for plant use instead of contributing to runoff. This can be done by covering the soil with living or dead vegetation to slow runoff or stop runoff with terraces or contoured ridges and storing that runoff until it infiltrates. All farmers, technicians, bankers, lawyers, doc-

Table 1. Watershed management practices.

	Land Uses Where Practices Apply		
Conservation Practices	*Cropland*	*Grassland*	*Forestland*
Level bench terraces	X		X
Contour farming (level ridging)	X		
Natural seeding		X	X
Short-duration grazing		X	
Small infiltration ditches (1 ft. x 1 ft. x ?ft. long)		X	X
Watering holes (uniformly distributes grazing)		X	
Mulching (residue management)	X		X
Gully plugs (dams less than 1 m high)	X	X	X

tors, nurses, housewives, or anyone else who controls land should be able to understand and apply these simple principles.

Changing land use

Conservation leaders have the responsibility to show a community how to use conservation practices to manage their steep lands, whether in crops, grass, or trees, for minimum loss of water and soil. Those farmers who are accustomed to farming steep cropland need to be shown how to increase production while at the same time conserving water and soil. However, the community already has established a way of life with priorities well entrenched. Every community has its own means of making a living. The objective is to work as much as possible within the constraints of this established land use, or, alternatively, if necessary, to try to convince operators that land use must be changed.

Comparative field trials

Conservation of soil and water usually is not accepted unless it increases returns to farmers. Five thousand small, comparative conservation plots in Peru demonstrated 13 to 1,019 percent increases in production of 42 different crops. The usual 50 worldwide conservation practices were reduced to eight. These eliminated runoff and increased production of crops, grasses, and trees. The eight practices that proved effective are shown in table 1.

Comparative field trials established by the land users on their own land have been very effective (*1, 2, 3*). Other land users naturally compare their neighbor's new system with their traditional method of operation. Farmers are always interested in how time and expense can be reduced while simultaneously increasing yields.

The comparative field trial method of testing and demonstration brings conservation directly to the land users with little cash outlay. It takes advantage of opportunities for improvement, and in existing systems the results have been very successful. The comparative method has four important advantages to farmers. He or she gains awareness that there are other ways to improve productivity with conservation of water and soil; gains practical experience by doing the job himself; gains expertise by repeating the operation many times; and gains confidence to teach his neighbors, which spreads the successful improvements very rapidly by word of mouth.

The comparative test plot system is designed with the flexibility to make improvements in a practice at any time. For example, a young Guatemalan farmer devised a method to save the topsoil during the construction of bench terraces and leave the valuable topsoil on the surface of the bench without moving the topsoil twice. Two Guatemalan technicians designed a method to save 50 percent of the labor required during the construction of wide bench terraces.

On cropland, level bench terraces, level ridging of contour rows, mulching (residue management), and gully plugs were tested and demonstrated. No matter what crop the farmer grows, at least two essential practices, level bench terraces and level contour rows, should be compared with the traditional method of land preparation. On grassland, practices that proved effective were natural seeding, short-duration grazing, small infiltration ditches, watering holes, and gully plugs. For existing trees and for establishing any type of new tree crops, terraces, natural seeding, level absorption ditches, residue management, and gully plugs proved adequate. The minimum size of comparison plots were 3 meters long and 5, 7, and 30 meters wide for cropland, tree land, and grassland, respectively. Plots were laid out on the contour, with a 30 x 30 centimeter level protection ditch along the upper end.

Only differences between the conservation practices (land preparation) should be compared the first year. After 100 percent of the moisture has been uniformly absorbed, the agronomic practices can be compared (usually the second year).

Contour planting

Every 10 meters, a farmer marks a contoured, baseline row across the field using the "A" frame or equivalently simple level (*1, 2*). Parallel to this level base line, he or she then plants five parallel rows uphill and downhill. The short rows are releveled and fit into the remaining spaces. The farmer's planting, cultivating, and hilling-up (sometimes 30 centimeters high) of each row forms many absorption ditches on the contour. Each row is expected to store the rain that falls between each row. The contour planting and hilling-up practices will eliminate 80 to 90 percent of the erosion occurring even on steep mountain soils (*1*). The effectiveness of the method will depend upon the soil's infiltration rate, intensity and duration of rainfall, steepness and length of slope, and the human factor (accuracy of layout and uniformity of height of the ridges).

Level bench terraces

Farmers realize they must construct terraces above contour rows broken during heavy rains. This approach provides flexibility and allows a farmer to plan bench terraces only where they are needed (*2*). An adequate terrace is exactly level along the front edge and the base of the slope. The cultivated bench must be inclined into the mountain (15 percent or more) enough to store all of the rain that falls on each terrace. The counter slope of the flatter area depends upon the soil type and the amount and intensity of rainfall.

The entire backslope must be protected by a rock wall or by planting perennials. Many grasses and other perennial plants can provide slope protection.

Before terracing, farmers would not sacrifice any of their land to plant grass for cattle feed. Now, as a result of terracing, crop yields are greater, less fertilizer and seed are used, less land is cultivated, and cattle feed or other economical crops, such as cut flowers, herbs, and spices, are produced on the terrace backslopes.

Farmers have increased the land area in crops by means of terracing. On slopes of 30 percent, bench terracing increases the productive land surface by 25 percent. In other words, for every 4 hectares of bench terraces, a farmer gains a fifth hectare. Flatter slopes produce less than a 25 percent increase; terracing on steeper lands produces more than a 25 percent increase. Bench terraces require considerable labor, but once constructed, maintenance is minimal (*2*).

Gully control

Gullies may occur in any land use system and may need treatment. After all the cropland, grassland, and land in tree crops have been prepared for the uniform infiltration of rainfall, then only a minimal amount of rain will concentrate and run off through the gully. The gully may heal itself and not need the additional work of constructing gully plugs, especially if livestock is excluded from the gullied area so natural vegetation is able to provide protective cover. However, it may be necessary to establish vegetation in addition to excluding grazing.

Sometimes after conservation measures have been established above the gully, check dams may still be required. Check dams no more than 1 meter high are recommended. Dams placed in a stairstep fashion shorten length of slope, reduce runoff velocity, and form terraces when sedimentation occurs. The elevation of the base of each dam should equal the top of the dam immediately below (Figure 1). Check dams may be made of rocks, stakes, living plants, sod, or sacks of various materials. The top of the dam should be concave in shape to provide maximum capacity for the rising water of heavy rains. Once check dams are constructed, the walls of the gully can be shaped to the angle of repose and vegetated.

Success of principles

The soil and water conservation principles described here have been successful over 14 years in nine Latin American and Caribbean countries,

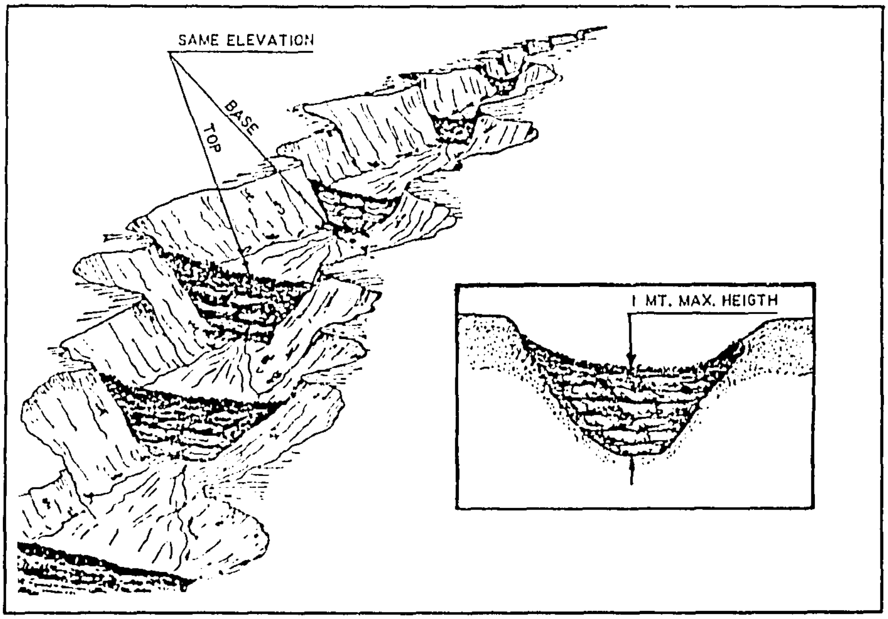

Figure 1. Gully plugs constructed with sacks, sods, sticks, rocks, living plants, etc.

especially Guatemala, Peru, Saint Vincent, Barbados, and for the past two years in Puerto Rico and the Virgin Island. They have produced substantial increases in yields of 42 crops that were compared. Farmers are working hard to conserve their fields. Appropriate conservation practices that increase production and use less fertilizer, labor, and seeds are acceptable and attractive to farmers.

For the past nine years, Guatemalans have been in a position to retire 45 to 59 percent of their most highly erodible cropland acres because of the 81 to 141 percent average increase in production over traditional farming methods on their remaining acres (*1, 2*). Where cropland was not retired, farmers opted to diversify their crops instead of overproducing the demand and flooding the markets. Overall production was achieved by uniformly infiltrating the available rainfall by installing conservation practices, which immediately increased their standard of living. Guatemala's version of a low cost (only technical assistance) Conservation Reserve Program (U.S. system of retiring erodible land) is well underway.

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18

Soil taxonomy and steep lands

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Soil classification is a means of ordering our knowledge of soils. For example, one classification scheme may catalogue soil properties that relate to the characteristics and conditions of soils as they occur in natural landscapes. Another scheme may group soils by perceived processes of soil formation. Soil classification can help to communicate knowledge from one place to another. There is a need to predict what may happen as steep lands are used. Soil classification systems can serve that need.

Researchers are currently looking for ways to compress the knowledge from centuries of trial and error in agriculture on steep lands into an accelerated, one-generation program for today's developing world. How can it be done? We contend it can be accomplished through agrotechnology transfer.

Planning agricultural land use

In the process of developing agricultural systems, the major difficulty is not in developing alternatives but in predicting the outcome associated with alternative actions. The whole system needs to be understood in order to evaluate changes in any single component of the system. Such an approach brings together existing knowledge of the production system, identifies the major components and processes and their interactions, and seeks to identify the bottlenecks to improved performance (*1*).

Historically, the inability to establish satisfactory farming systems on some land has been due, in part, to the domination of the people in one area by those elsewhere; on other land it has been due to people attempting to force a pattern of use on new land that is not suited to them (*4*).

In deciding the patterns of use on new land, system simulation is an effective process. A useful concept is that farms should not be established on land so poor that, in the experience of the farmers of the region, the income cannot be made to provide a level of living consistent with the standards of the region and at the same time maintain the farm capital required for continued farming (3). These kinds of decisions must be based on factual data that provide reliable estimates of the chances for success.

In most instances these decisions need to be made by government planners, as farmers are the least able to afford a failure. Some soils are especially suited to certain plants, but other plants may not be able to grow in them at all and require an entirely different combination of characteristics. People have discovered these things by trial and error. By the time they learn, however, many may have lost everything—wealth, labor, spirit. If such bad relationships between soils and man's use of the soils are to be avoided, these things must be known in advance and account taken of them (*4*).

As Caguan (2) points out, small, individual operators make up the bulk of farmers throughout the developing world, and the aggregate total of their farms holds the greatest potential for increased production through proper application of agrotechnology. He says that for this reason all government programs are targeted toward individual farmers. Society wants the small farmer to absorb and use more sophisticated technology to produce enough food for its nonfarming citizens. This paradox exists, he suggests, because society itself has not invested in the development of the small farmers so that they are able to absorb and use the technology that increased production requires.

Now, what about situations where land has slopes greater than 75 percent? This land is considered by most to be marginal for farming, but the social and economic pressures are strong enough in some areas to bring this land into production. In these situations there is a need to know the prior responses of such soils to management in areas that have similar kinds of soils and climate.

Soil scientists have learned how to combine the experiences of farmers with the technology of soil science to predict the probability of successful agricultural development. Soil scientists have learned some things of importance to those who would manipulate steep lands.

Different soils result from interactions of parent material, climate, time, position on the landscape, and biology. Soil scientists have learned to read the effects and relate them to the way the soil will respond to management. They have also learned to show the location and the extent of soils and to group soils that are alike in morphological properties and in response to different management. Through this process of soil survey and soil classification, soil scientists can take what is learned about a particular kind of soil in one part of the world and apply that knowledge to other areas where similar soils occur. In other words, they contribute to effective agrotechnology transfer.

Managing soils on steep slopes normally means dealing with rates of runoff, rates of infiltration, rates of water percolation, shallow soils overlying rock or paralithic materials, and high risk of mass movement when soils are saturated.

Hundreds of years of experience have shown us that steep lands can be cropped where these problems can be dealt with successfully through proper management. The primary management practice used is terracing. Terraces serve to control erosion, to provide a stable bedding area for crops, to provide a secure footing for hand labor or for animal-drawn or mechanical tillage implements, and to aid in making effective use of water. Terracing is a satisfactory practice where soil materials are permeable, where there is a sufficient rooting depth for the crop to be grown, and where surface water can be controlled. The soil materials should be mechanically stable or a source of stone or rock available to build retaining structures. Terraces are most successful in semiarid climates or in climates with a distinct dry season.

Using soils information in technology transfer

Soil Taxonomy, the system of soil classification developed and used in the United States, is a system based on grouping soil properties that are thought to have developed in a similar manner (*6*). It has been clearly demonstrated that soils having similar properties (a group) will respond similarly to management practices. Classes in *Soil Taxonomy* are mutually exclusive; they are defined by a set of properties that are operationally defined (specified set of procedures). Hence, *Soil Taxonomy* is particularly useful for technology transfer. It is now an approved system for grouping soil information in more than 40 countries throughout the world.

Although *Soil Taxonomy* does not deal specifically with slope gradient except in cases of very wet soils—level or sloping—it does, generally, provide information on soil depth, soil moisture, soil temperature, lithic and paralithic contacts, particle size, calcareous and reaction classes, coarse fragment content, and soil mineralogy.

Using this type of information, predictions can be made about the infiltration and percolation of water in soils. For example, soils with coarse particle size classes, no strongly contrasting particle sizes within the soil, high amounts of coarse fragments, and volcanic parent materials (ashy, cindery, pumice, etc.) tend to be permeable, have rapid infiltration rates, and are relatively stable with a high water content. This information on steep soils aids in the transfer of technology to other areas.

The temperature and moisture regimes used in *Soil Taxonomy* indicate the amount of water that might occur in the soil and the general climate of the area. The lithic subgroups and shallow families indicate the volume of soil available for moisture storage and effective rooting depth. Mineralogy often provides insight into the stability and fertility of the soil. Soils with kaolinitic or micaceous mineralogy on steep slopes tend to be susceptible to mass movement under conditions of high moisture. For example, Vandalia and Upshur soils in the Appalachian Mountains of the eastern United States are known to be unstable soils, very susceptible to slumping. Both of these soils are classified as fine, mixed, mesic Typic Hapludalfs. That is, they have a fine particle size class of mixed clay mineralogy in an argillic subsoil horizon, have a mesic temperature (mean annual soil temperature at 20 cm between 8° and 15° C), and are moist much of the time (udic moisture regime). Laboratory data show the mineralogy to be high in montmorillonite clay, but not high enough to class as montomorillonitic. Interpreting this information indicates that these soils are in an area with high precipitation; they are also high in 2:1 interlattice clay content. This combination allows the soils to absorb large amounts of moisture that, in turn, greatly increases the total mass. The 2:1 clays expand upon wetting and, with the increased mass, the materials on steep slopes begin to creep downslope. Continuing precipitation can, by lubricating the structural faces, cause these materials to slip downslope. Similar soils on steep slopes elsewhere can be expected to behave similarly. This is information transfer, an important part of agrotechnology transfer.

These features deal primarily with the mechanics of keeping the soil in place, maintaining water in and on the soil, and providing a stable area for cropping. Where the soil resources are so limited that cropping is extended to steep lands, these features are paramount.

Where conditions are conducive to terracing, such land is often developed for cropping. The physical characteristics of a site may be the major limitation to use, whereas, the chemical characteristics influencing productivity can usually be manipulated. Thus, the husbandry of the soil, that is, the care needed to produce the crop, is commonly of secondary importance. Soils on steep lands can be managed so long as the sites are found to support agriculture.

Preventing land degradation

The transfer of agrotechnology through the use of *Soil Taxonomy* and soil survey technology can help in the identification and selection of steep lands most physically suitable for agriculture. Using this information can lead to more successful farming. It can also help to prevent the damage that results from farming that fails: erosion, loss of productive and frequently shallow topsoil, and off-site sediment damages.

Usually, soil is abandoned in a poorer state than its natural condition. In many places soil erosion is a result, a symptom rather than a cause of declining fertility and rural distress. The decline in productivity happens partly because of the inability of the people to establish conservation farming systems. This commonly is due to the selection of soils not suited to the use. Many areas on steep lands were previously forested and would have better been left as forest land. By choosing suitable sites and appropriate technology with the use and application of *Soil Taxonomy* and soil survey techniques, it may be possible to prevent the degradation sequence of cutting the trees on these areas, converting the land to cropland, abandoning the fields, increased erosion, loss of fertility, and the inability of vegetation to recover.

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Controlled-erosion terraces in Venezuela

Lynden S. Williams and Bob J. Walter

In 1961 the Ministry of Agriculture in Venezuela initiated a major soil conservation program in several states in the central and western Andes. One of the projects focused on the construction of agricultural terraces in small highland valleys. Terracing was accomplished by building strong rock walls along the contours of the slopes and allowing the normal actions of erosion and cultivation to level the surface.

This "controlled-erosion" construction method resulted in terraces large and stable enough to use animals or machines for cultivation. Terraces of similiar dimensions built by physically leveling the land would require far more labor, perhaps prohibitive amounts. Controlled-erosion terraces are durable, and they may be suitable where long-term soil conservation is a prime objective. However, the benefits of higher yields through increased water absorption are postponed or reduced when this method is used.

The Venezuelan case study illustrates a successful terracing project that may have application in other tropical highland regions. Of specific concern are method of terrace construction, advantages and disadvantages of the controlled-erosion method, and the social and economic impacts of this form of soil conservation.

Field investigation was conducted in August and September of 1985 under sponsorship of the U.S. Agency for International Development. This work included a comparison of the controlled-erosion system used in Venezuela with the methods of terrace construction being used in Peru and Guatemala in two USAID-sponsored projects (*12*).

The geographic setting

The terracing project focused on small valleys at elevations ranging from 1,600 to 2,500 meters. As in most tropical highland regions, environmental conditions vary widely. Precipitation ranges from 600 to 1,200 millimeters, and mean annual temperatures range from about 12 to 20 degrees centigrade. There is a pronounced dry season during the low sun period from three months in the wetter areas to six or seven months in the drier areas. Killing frosts are rare at these elevations; consequently, with irrigation, multicropping is possible. The small valleys usually have slopes ranging from 10 to 40 percent in the direction of primary drainage and are enclosed by ridges with steeper slopes.

Before 1960, the more level areas were used for pasture, and most of the population practiced shifting cultivation on steep slopes. Although relatively close to major urban centers, the region was isolated by poor highways and the absence of feeder roads to local farm communities. There was little opportunity for off-farm employment, and living standards were among the lowest in Venezuela.

Beginning about 1950, population growth in the region and the increased demand for marketable production in regional cities led to a rapid increase in the intensity of land use. The fallow period was reduced or eliminated, and larger fields on steep slopes were cleared of natural vegetation. Deforestation was common, and soil erosion increased. Because fertilizer and organic matter were generally lacking, soil fertility tended to decline rapidly under continuous cultivation. For many farmers, the problem of obtaining subsistence and a meager income from marketable surplus production became increasingly difficult because of resource scarcity and environmental deterioration.

Purpose of the terracing project

The *Subsidio Conservaionista* (conservation subsidy), as the Ministry of Agriculture program was called, aimed primarily at achieving long-term conservation objectives. It began in 1961 when a large amount of capital was available and the government was searching for labor-intensive investment schemes that would reduce rural unemployment. In the case of terrace construction, a cash subsidy was paid to rural workers according to the amount of rock retaining wall built. The payment, set initially at five bolivars (about US $1.25 at that time) per cubic meter of wall, along with the economic benefits of terracing, was sufficient to motivate participation by many landowners and other rural workers during the program's early stages.

Justification for the soil conservation program was not tied directly to the achievement of short-term economic benefits for participants. Payment of the subsidy was made partly to reduce unemployment in the region, and it may have been assumed that short-term economic benefits would be forthcoming from successful conservation. Nevertheless, the cost accounting used did not require the justification of specific expenditures on the basis of increased yields or profits from the land affected.

The package included a number of features that resulted in important short-term economic benefits. Penetration roads, constructed in part to allow vehicles and heavy machinery to be brought in for the construction project, improved accessibility to markets. The removal of rock from the fields for wall construction improved and increased the cultivated surface. Agronomists who directed the programs frequently encouraged farmers to use their subsidy payments to pay for improved farming infrastructure, notably, the installation of sprinkler irrigation systems, and probably sparked many innovations in land use practices.

Over the past quarter century, other changes only indirectly related to the conservation program have profoundly altered the economy and society in the region. The most important was the rapid growth in demand for vegetables in regional cities; the high valleys possess the climatic, social, and locational characteristics needed to serve those markets. The valleys are cool enough to allow for the production of high quality vegetables, but they can still be cultivated throughout the year. The high man-resource ratio, where farmers generally work from 0.25 to 1 hectare of land, made intensive cultivation desirable. These conditions, along with the direct and indirect effects of the soil conservation program, led to an almost total transformation of the region, from one of the poorest in Venezuela to a highly productive, intensive farming area with a much improved standard of living.

Ironically, the economic improvements in the region made it increasingly difficult to maintain the project's original conservation focus. Poverty and unemployment in the region had made the modest subsidy payment for conservation sufficient for farmer participation. New employment opportunities in horticulture, along with rapid out-migration to urban areas, greatly reduced unemployment and increased the rural wage. Although the subsidy was raised periodically, eventually reaching a level more than triple the original payment, farmers became ever more reluctant to build terraces. By the late 1960s and early 1970s, the inclusion of other infrastructure projects, especially the building or upgrading of irrigation systems, had generally become an essential part of the incentive package for farmer participation.

During the middle and late 1970s, when public funds became more scarce, terracing and other soil conservation aspects of the program were phased down, and attention was directed more narrowly to the achievement of short-term economic goals. The Ministry of Agriculture program was shifted out of the conservation office to another agency (*Corporacion de los Andes*), with a mandate to improve social and economic conditions in the region and only an incidental commitment to soil conservation. Given the enormous economic impact of irrigation systems and penetration roads, it was perhaps inevitable that the focus of attention would shift away from long-term conservation objectives.

Terrace construction methods

Terrace construction was accomplished by controlling the natural process of erosion. Substantial rock retaining walls were constructed along the contours of a slope at intervals of 10 to 40 meters. Thereafter, erosion and downslope plowing provided the fill behind the retaining walls.

Selection of the controlled-erosion method appears to have resulted from the diffusion of ideas from the U.S. Department of Agriculture's Soil Conservation Service and from Inca terraces or other native techniques of rock wall construction. A translated version of an SCS manual apparently was used as a model for the construction of rock barriers along the contours of the hillsides (*9*). From the manual, it appears that the rock barriers were originally envisioned as little more than stacks of rock that would break the downslope flow of water. However, when combined with expert rockwall building techniques, these barriers became strong walls with a firm foundation in the subsoil that could retain soil that eroded or was deliberately plowed downslope. The result was the evolution of terraces over a period of a decade or two. It seems probable that many of the ancient Inca terraces were constructed with the controlled-erosion method (*13*).

Advantages of the controlled-erosion method

The obvious advantage of this form of terrace construction compared with conventional bench terracing is the reduction in the work requirement for moving soil and subsoil. Also, it tends to produce cultivation surfaces that are relatively large and stable. In fact, for functional utility and stability, controlled-erosion terraces are likely to be superior to those constructed by alternative methods. Disadvantages include the work and skill required for wall construction and the postponement of benefits that may result from surface leveling.

The retaining wall need not be designed to allow for complete leveling of the cultivation surface. Potential benefits of achieving a level surface are postponed for a decade or more. Thus, the initial builders may have little incentive to expend effort to this end, and they may be only vaguely aware that leveling will take place. In Venezuela, the wall height required for complete leveling was given little attention; rather, wall height was dependent mostly upon the amount of rock on the surface, the degree to which removing the rock was desirable to enlarge or improve the cultivation surface, and the willingness of the farmer to expend additional labor. Wall height does correlate to some degree with slope. On gentle slopes, walls are usually no more than 1 to 1.5 meters high; on steep slopes, higher walls were sometimes constructed.

The amount of work required per unit of land terraced is mainly a function of the distance between the walls, that is, the work is inversely proportional to terrace width. There is a strong incentive, therefore, to save labor by spacing the walls at wider intervals. The result is a wider cultivation surface, but one that will probably retain considerable slope after the leveling process by controlled erosion has been completed. In Venezuela, wide terraces were essential because the land is worked with oxen. However, even if the land were to be worked by hand, there would be a strong incentive to space the retaining walls at wide intervals simply as a means of reducing the labor requirement.

When the land is worked by animal or machine, a wide cultivation surface is desirable, if not essential. Even when hand labor is used now, a cultivation surface suitable for animal or machine traction may prove useful in the future. In Japan, many tiny terraces have now been abandoned because they are unsuitable for the small farm machines used today.

Soil erosion on steep slopes is a function of rainfall intensity, the amount and velocity of runoff, and sometimes as a landslide or soil slip in response to extreme weather or seismic events. Building retaining walls along the contours of slopes and leveling the surface behind the walls can reduce the velocity of runoff by reducing the length and degree of the slope. A more level surface will also promote increased water infiltration and thus reduce runoff. Terraces built with the controlled-erosion method will probably tend to rank high as erosion control systems.

Limitations of the controlled-erosion method

The most obvious limitation of the controlled-erosion method of terrace construction is that achieving level terraces is postponed indefinitely and will probably remain incomplete unless an additional construction effort is undertaken later. The time required for leveling (to the top of the wall) depends upon local conditions and farmer treatment, such as downslope plowing. In Venezuela, soil fill-in by the processes of soil erosion and cultivation was generally sufficient to reach the top of the retaining wall in about

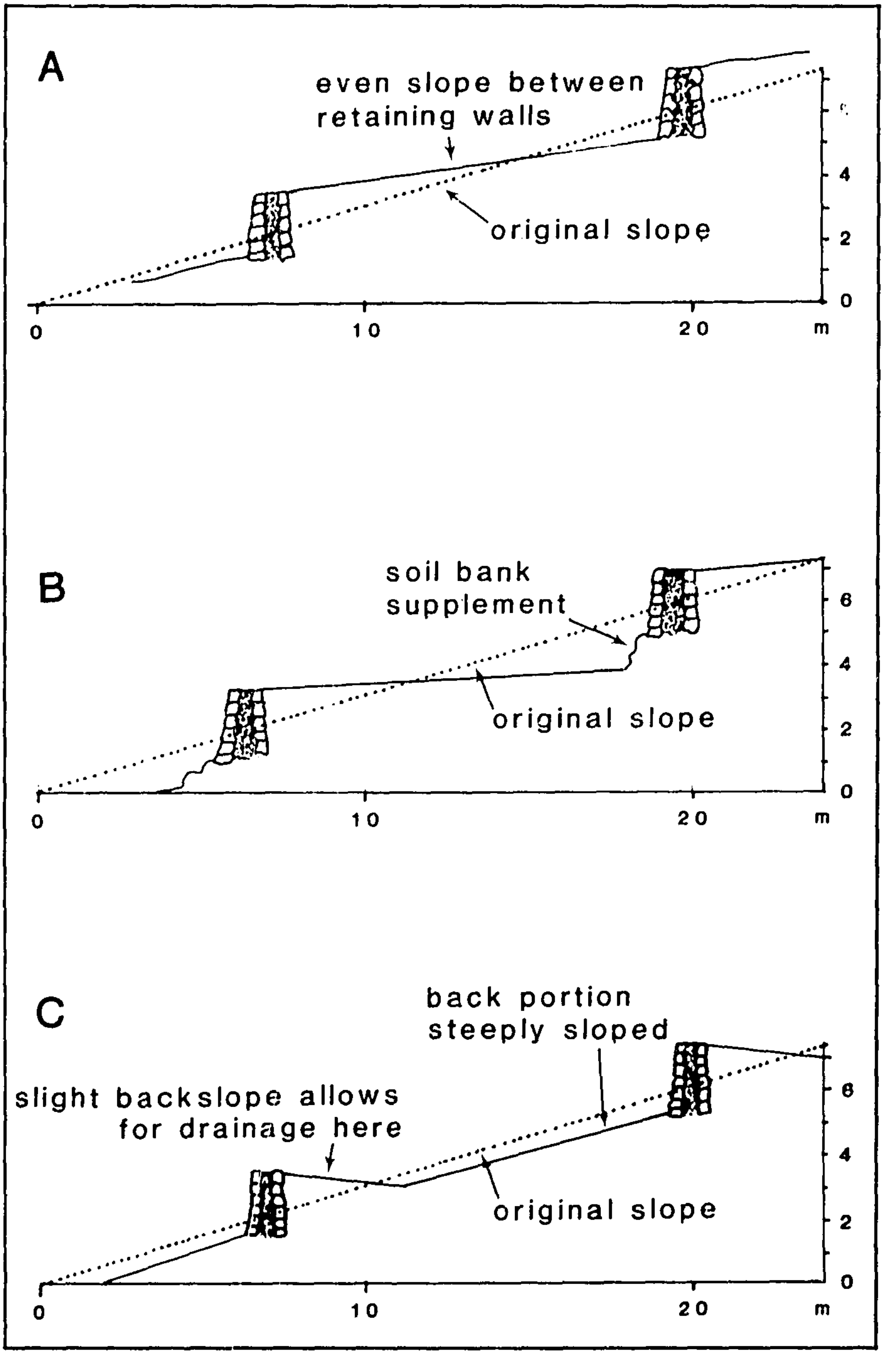

Figure 1. Alternative slope patterns on controlled-erosion terraces in Venezuela.

10 years. In cases where the land had been in pasture much or all of the time, the process was much slower (about 20 to 40 centimeters of soil accumulation behind the wall per decade in the small number of cases examined). Even after the soil reaches the top of the retaining wall, the cultivation surface will usually have a substantial degree of slope. In effect, the controlled-erosion method reduced slopes from 20 percent to 10 percent and from 45 percent to 25 percent. Some of the slope patterns that can develop are shown in figure 1.

The benefits of increased water retention and reduced loss of nutrients will gradually increase as the terraces form. This can be a disadvantage where short-term benefits are needed as an incentive for the farmers or as a justification for public expenditure.

The controlled-erosion method of terrace construction will tend to be cost-effective only in those cases where relatively wide terraces are possible. It has been estimated that the terrace must be at least 8 meters wide on steep slopes or 15 meters wide on gentle slopes to achieve a reduction in labor requirement over alternative methods (*12*). It follows that on a slope of more than about 40 percent the farmer must choose between an extremely high retaining wall, a very steep final cultivation surface, or a more narrow terrace. If he chooses the latter, he may find that physically leveling the surface and building a single-faced wall will be more cost-effective and provide the added benefit of immediate leveling.

In Venezuela, the terraces were built with rock retaining walls because the rock was available nearby, usually from the field. Indeed, the removal of rock from the cultivation surface was one motivation for building the retaining walls. If rock were not available in the field, the labor cost for transporting materials to the construction site from a remote location would be great.

The controlled-erosion method can be used in conjunction with a vegetative rather than rock barrier. Terraces of this type are reported in Peru, Honduras, and Africa (*4, 7, 11*); they have the advantage that the work requirement is minimal compared with building stone walls.

If the walls are built as shown in figure 1, they will not be big enough to support level terraces. In this case it may be appropriate to build a new wall, as in figure 2. Whether the farmers (or their children) will be willing to make this effort remains to be seen.

Social and economic impacts

The immediate and short-term economic benefits of terracing appear to have been minimal in the Venezuelan highlands. Some studies argue that terracing resulted in higher yields and reduced costs, but the work failed to allow for the transition to intensive horticulture (*1, 2, 10*). Unquestionably, agricultural output and land values increased substantially during the period of terrace construction, and most farmers achieved major gains in living standards. However, there is no way of separating the impact of soil conservation from that of irrigation and other changes in technology, nor from access to markets.

The conservation program did have some direct impact on production and the transformation to intensive horticulture. Terrace construction improved the cultivation surface by removing rock and in some cases filling in poorly drained areas. Surface leveling is not essential for intensive horticulture, but it does make plowing and many other operations easier.

The indirect impact of the conservation program was enormous. Agronomists who directed the projects suggested and encouraged many innovations, and subsidy payments for wall construction were frequently used to pay for improved farming infrastructure. In some cases, the conservation project came as a package that included irrigation and other essential infrastructure. Nevertheless, terracing per se was probably not the critical factor, and intensive horticulture on steep slopes is by no means confined to terraced land.

Most farmers reported that reducing the rate of erosion and leveling the land resulted in little or no increase in yield or reduction in costs. This view was expressed both by those farmers who had terraces and those who worked steep slopes. We were surprised by this view, but there are several possible explanations. First, the effect of increased water absorption is diminished by the fact that leveling takes place over a long period of time. It is possible that yields do increase with surface leveling, but that farmers

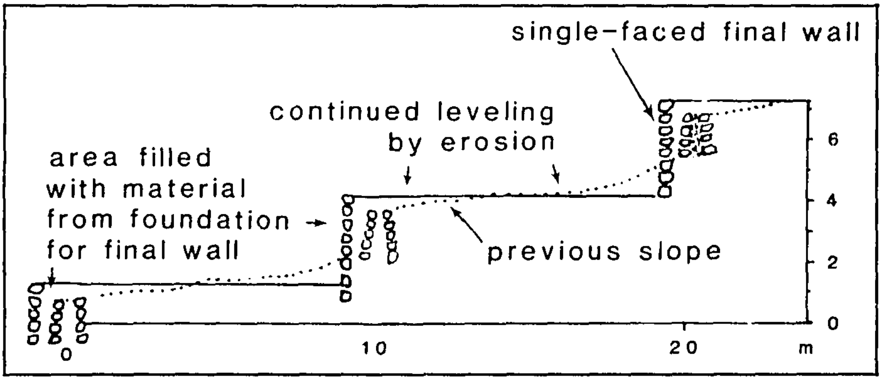

Figure 2. Second-stage controlled erosion: hypothetical.

do not notice because of the slow pace of change. Also, almost all terraced land is irrigated.

Second, Venezuelan farmers use other conservation measures to reduce erosion under normal weather conditions. These include contour plowing, digging drainage canals around the tops of fields to carry off excess water during heavy rain, heavy application of organic matter, and frequent tillage, which increases the absorptive capacity of the soil and reduces runoff. Farmers sometimes prefer steep slopes because they permit a more upright position for hand cultivation, planting, and harvesting.

It appears that the most damaging aspect of erosion on steep slopes is the major slope failure during extreme weather events that occur at intervals of 10 to 50 years. Incremental erosion does not seem to affect yields sufficiently to attract the farmer's attention. Although Venezuelan farmers are aware of the danger of mass movement during extreme weather events, they may not realize that the current system, in which large areas are permanently stripped of perennial vegetation, represents a greater threat than the previous system of shifting cultivation. Those farmers interviewed appeared to be unaware of (or unwilling to acknowledge) the connection between their use of the land and major erosion disasters. The Venezuelan Ministry of Agriculture had hoped to "eliminate the attitude on the part of the farmer that he is simply a spectator of the forces of erosion that drain away his future income" (*3*). Clearly, this goal has not yet been achieved.

Lessons learned

The terracing project in the Venezuelan highlands provides a number of lessons. First, the project demonstrates that terraces can be constructed without physically leveling the land. The method makes use of the natural forces of erosion to the advantage of the farmer. Rock on the surface becomes a resource rather than an impediment to cultivation. Second, the method requires little knowledge of terrace engineering, though the final result may have a form and functional utility that suggests such technical knowledge and skill. Third, the advantages result from the natural tendency of the builder to reduce his work effort and use convenient, simple methods.

However, the achievement of long-term conservation objectives was largely incidental; it was a result of the method of construction used rather than purposeful actions on the part of the builders. Indeed, Venezuelan farmers seem to have relatively little awareness of, or concern for, the conservation objectives achieved by terrace construction. The possibility that farmers elsewhere in the tropical highland may share that lack of concern is disturbing; it suggests that voluntary and purposeful efforts at soil conservation may be limited to those cases where conservation is coupled with short-term economic gains and/or public subsidies.

Significantly, most terracing in Venezuela was completed just before major gains in living standards through intensive horticulture. We are sometimes tempted to assume that environmental concerns must be given a lower prority than economic issues on grounds that people will be better able to deal with conservation after they have achieved significant gains in income. The experience of Venezuela suggests otherwise. When incomes were low and underemployment common, relatively modest subsidies were sufficient to motivate farmer participation in the terracing project. As living standards and employment opportunities improved, it became increasingly difficult to motivate farmers to pursue conservation objectives. There may be a "window of opportunity" for soil conservation in many poverty-stricken highland areas that will tend to close with success in economic development schemes. That possibility suggests the need to move with haste in the area of soil conservation.

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20

Elephant grass for soil erosion control and livestock feed

Grant W. Thomas

Use of elephant grass (*Pennesetum purpureum*) for soil erosion control apparently has been rather limited. Sachdeve and associates (*5*) used elephant grass and a related species to control erosion in waterways in Nepal with considerable success. Baker (*2*) used elephant grass in strips as a windbreak in fields of tomatoes and reported good results. He warned of the necessity to control its growth to avoid reducing yields of adjacent crops. Bhutia (*3*) reported using elephant grass in crop systems in India similar to those reported herein. In addition to these reports, elephant grass has been tried in various countries for erosion control without reports having been published or published in English (*1, 4, 6, 7*). The work reported herein describes the use of elephant grass as live barriers and grass strips for erosion control and livestock feed in the Dominican Republic.

The conservation work reported herein was done under the Natural Resources Management Project by the government of the Dominican Republic and the U..S. Agency for International Development. This work was set up on both a national and a local pilot scale.

The pilot project was in the Ocoa River Valley watershed, located about 60 miles west of Santo Domingo. The valley rises from sea level to an altitude of 2,000 meters. Most of the project work was done at altitudes of 400 meters or more, where many farms are on steeply sloping land. Erosion is a serious problem because of the lack of soil cover and high rainfall intensities, coupled with a distinct wet-dry seasonal pattern.

Average rainfall and calculated evapotranspiration potential are shown in figure 1 for San Jose de Ocoa. Notice the extremely dry period in the winter and early spring and the exceptionally wet month of May. Notice also the fact that there is insufficient water in most months of the year. In practical terms, this means that the chances of crop failure are always fairly great.

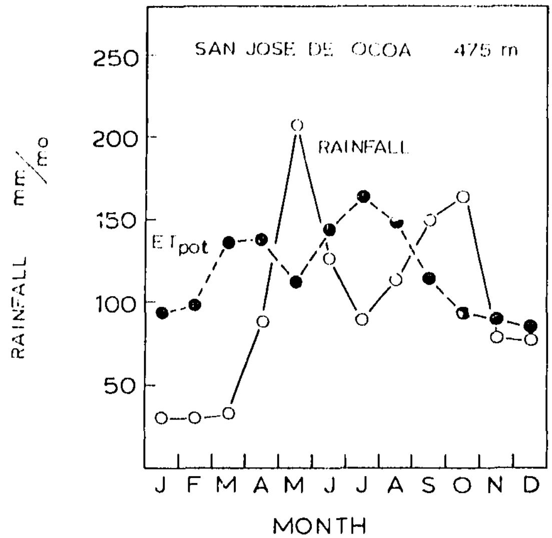

Figure 1. Monthly rainfall and potential evapotranspiration for San Jose de Ocoa, Dominican Republic.

Soils in the zone are either very young or relatively young and, except for levels of phosphorus, are relatively fertile. Only on the mountain ridgetops are the soils very acidic. On the slopes below the ridgetops, soils are slightly acid to neutral, and their basic cation and potassium statuses are adequate. Soils high in phosphorus are a result of past fertilization, usually of potatoes or vegetables.

Conservation practices

Farmers in the Ocoa Valley have used contour planting for many years, so the first conservation treatments used on the steep fields were hillside ditches protected by live barriers of citronella (*Cymbopogon nadus*). The citronella was used because animals would not eat it, giving it a good chance to survive. The ditches were designed to catch runoff water and transport it to a drain. In addition, the hope was that additional water would soak into the land from the ditch.

In general, the ditches were placed farther apart than the slope would warrant. The result was that in a truly heavy rain they failed, causing more damage than if there were no ditch. Moreover, the ditches were relatively expensive. Nevertheless, the combination of ditches and live barriers gave visibility to conservation work in the watershed. A practice that is cheaper and probably more effective is the erection of rock barriers on the contour.

In early work we tried no-tillage and minimum tillage as conservation practices. They were very successful in reducing erosion, moderately successful in producing crops, and not very successful in adoption. A major problem was the need for herbicides, which cost money. An even greater problem was that the falling value of the peso tripled the price of these herbicides in a few months, killing most interest in the practice.

The sondeo

In the spring of 1984, personnel at the project in Ocoa, under the guidance of Federico Poey, Billie de Walt, and Romeo Solano, conducted an informal survey ("sondeo") in three parts of the watershed roughly representing three cropping systems. One of the most interesting findings of the sondeo was this: While everyone either had or wanted livestock, none had sufficient feed for them. The types of livestock most common in the watershed are work stock (horses, mules, and oxen), cattle, and swine.

As a result of the sondeo, research was begun on the production of feed for these livestock, keeping in mind soil conservation at the same time. One of these lines of research was the use of elephant grass (*Pennisetum purpureum*) as a live barrier with the hillside ditch or as a wider grass strip without the ditch. The idea was to use the soil trapping qualities of elephant grass, along with its forage capabilities, as a dual-purpose plant on farms in the Ocoa Valley.

Establishing the elephant grass

There was little elephant grass in the Ocoa Valley in the spring of 1984. That which did exist was in clumps near houses. None was planted as contour strips. To get material for the first plantings project, personnel begged and occasionally stole cuttings from the existing clumps. Availability of cuttings turned out to be such a problem that a small nursery field was eventually established in Sabana Larga, near Ocoa, to ensure planting material for the future. This has been used over and over again since early 1985.

Between spring and late summer of 1984 enough cuttings were obtained to establish live barriers along ditches and/or grass strips without ditches on several different farms. The first objective of these plantings was determining survival and growth; the second objective was measuring yield. As soon as these plantings were established, the amount of elephant grass planted as live barriers and grass strips by farmers increased noticeably.

Table 1. Yields of elephant grass, with and without fertilizer, at two sites.

			Yield at 45 Days (kg/ha)	
Community	*Type of Planting*	*Cutting*	*– Fertilizer*	*+ Fertilizer*
El Rifle	Live barrier	1st	18,500	31,219
		2nd	3,574	6,254
Los Almendros	Grass strip	1st	6,006	12,012
		2nd	2,252	2,583
Mean			7,583	13,017

Many farmers who were not project cooperators planted strips, more or less on the contour.

Although farmers liked citronella as a live barrier, they strongly disliked the idea of using their scarce land for a plant having no economic use. It is highly probable that the good reception given to elephant grass was due to its potential as livestock feed. From observation it was and is widely used. It should be noted also that even though elephant grass is not very high quality forage it is at least as high in quality as other grasses available in the zone. According to Puerto Rican experience (*8*), elephant grass is about 55 percent digestible when cut or grazed between 45 and 60 days of growth.

Experiments on yields

Yield experiments have been carried out on elephant grass plots at two locations and only for a short time. One of the locations is near El Rifle, at an elevation of about 1,300 meters; the other is near Los Almendros, at an elevation of about 1,000 meters. Yields measured thus far at El Rifle were taken from a live barrier of a single row, those at Los Almendros from a grass strip of three rows.

Table 1 shows the yields at the two locations. First cuttings at both locations yielded much higher than second cuttings. This was due to an extremely dry period in late summer, which gives an idea of yields under stress conditions. In addition, it should be mentioned that yields taken under these conditions in strip plantings are likely to be unusually high because there is a strong border effect on practically all the samples harvested. Even so, the yields represent those of elephant grass planted in this manner where nearly all of the plants get extra sunlight, water, and plant nutrients.

Unfortunately, there are no yields available as yet for an entire year. It could be expected that seven to eight cuttings per year could be made. Of these, two or three should give a relatively high yield and the rest a considerably lower one. It also is probable that without fertilizer the yields will decline unless the adjacent crop is heavily fertilized. Rough calculations on fertilized elephant grass indicate that the equivalent of between 0.1 and 0.15 hectare of grass planted in strips would maintain a dual-purpose cow on a mountain farm, although protein would be marginal.

Erosion control

In terms of erosion control, no real measurements were made, but from observations, grass strips of two to four rows are more effective than the single-row plantings. One three-row strip established in August 1984 had built up a terrace about 30 centimeters in height by February 1986. One comparative measurement that is needed is the loss of soil on an unprotected slope and on a protected slope with various numbers of rows of elephant grass.

Elephant grass also quickly and effectively stabilizes gullies. In fact, it is the only available grass that has the potential for gully control in relatively short time (a few months).

Although the crown of elephant grass spreads gradually so that it covers more and more of the soil surface, it can be controlled manually and does not establish stems at a distance. The biggest effect on adjacent crops is shade. This can be controlled to a degree by frequent cutting (about 45 days), a schedule that tends to optimize yield and quality of elephant grass.

Farmer acceptance

Farmer acceptance of elephant grass as a conservation measure and as a forage has been rapid. Not only was elephant grass accepted by the great majority of farmers to whom plant material was offered, it was also planted by farmers who were not even cooperating with the project. In La Nuez, in the upper part of the watershed, there was no elephant grass at all in 1983-1984. In February 1986, there were elephant grass strips established on a majority of the fields. It seems to have been a case of working with some farmers, then having the rest of them copy their neighbors—in a very short time.

Summary

Use of elephant grass as live barriers and grass strips was first attempted in the Ocoa River Valley in late spring 1984. It was planted as a response to the twin problem of soil erosion and a lack of animal feed. Observations indicate that it is effective in reducing soil erosion, especially when planted in two or more rows. When cut at 45-day intervals and fertilized, it has great potential for augmenting animal feed on a small farm. Acceptance of elephant grass for the dual purposes of erosion control and animal forage has been rapid and not limited to project cooperators.

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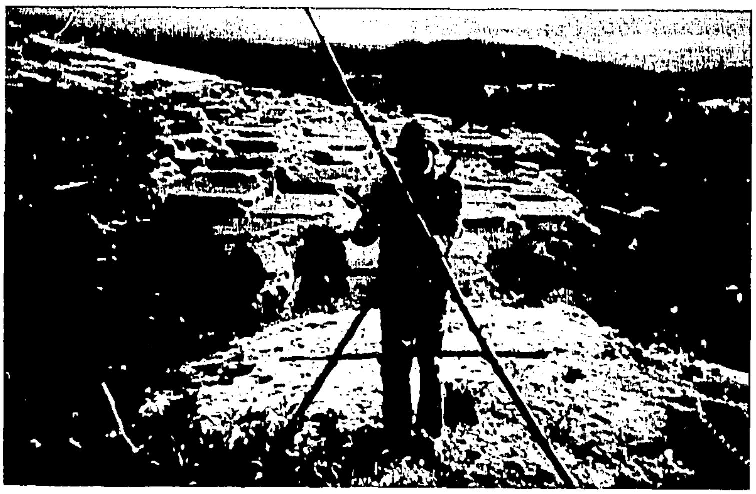
V

CASE STUDIES AND COUNTRY REPORTS



21

The Kenyan model of soil conservation

Carl G. Wenner

A soil conservation service was established in Kenya as early as 1937. Under British colonial rule, graded channel terraces were constructed on most large farms in the "White Highlands." On native farmland the policy of instructing, sometimes forcing, the peasants to carry out conservation works generated much resentment and was not always successful (*4*).

After independence in 1963, there was initially a move against soil conservation: soil conservation stations with tractor service, establishment of laws for soil conservation, and appointment of staff to check the obedience of laws. However, during the decade after independance, more terraces on small-scale farms disappeared than were constructed, and the government sought to reestablish a soil conservation program. At the 1972 Stockholm Conference on the Environment, the government of Kenya defined soil degradation as a major national problem and requested assistance from the government of Sweden. This eventually led to the Swedish International Development Authority program, which I planned and initiated and was involved with full time from 1974 to 1981 and part time since (*5, 6*).

Conservation objectives

The objectives defined by the government of Kenya were that the soil conservation program should (1) be limited to high and medium rainfall areas; (2) concentrate on densely populated, small-holder areas; and (3) be labor-intensive with low costs.

The technical director of the Ministry of Agriculture formulated the strategy for the program to include (1) strengthening the soil conservation input in the general extension package, (2) close supervision of the extension staff in its promotion of soil conservation, (3) individual approach by the extension staff to the farmers in the dry season when there is time for soil conservation activities, (4) better transportation for the extension staff, and (5) acceptance of public responsibilities for structures extending beyond individual landowner's responsibility.

Application technique

Possible use of tractors or earth-moving machinery was ruled out at the start, mainly because they are not suitable on small plots and steep slopes, but also because the record of government-operated tractor service in Africa is extremely poor. Nor was it logical to introduce machinery in a country with troublesome unemployment. On the other hand, the traditional methods of building terraces by hand were seen as acceptable to farmers and effective. One of them is the "fanya juu." It consists of digging a drain across the slope and throwing the excavated soil uphill to form a ridge above the ditch (Figure 1). Soil is moved downhill by erosion and during cultivation

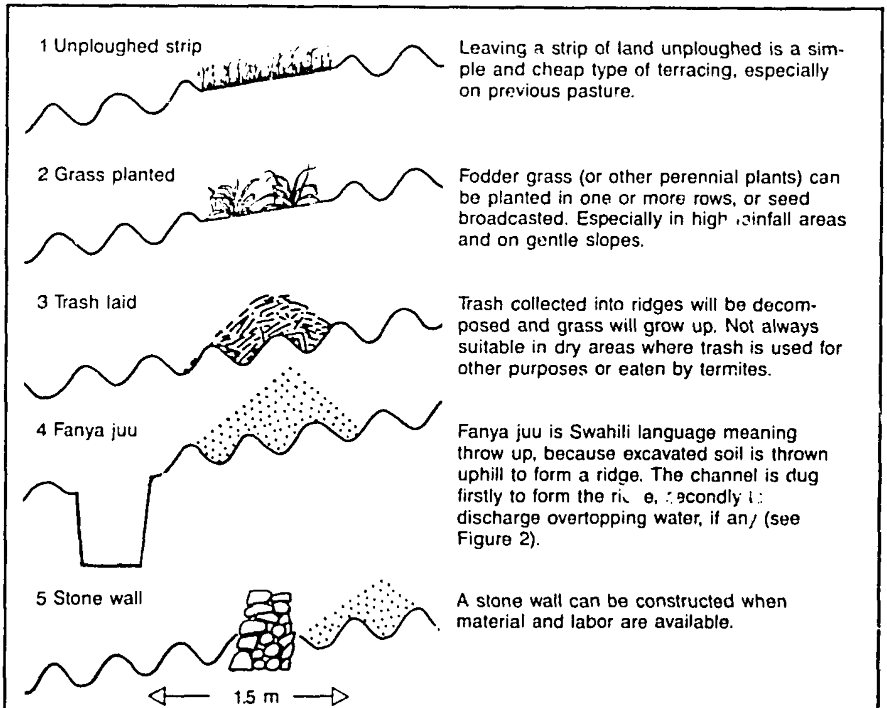


Figure 1. Different ways of developing bench terraces in erodible soils. In high rainfall areas conservationists have sometimes been too eager to introduce the fanya juu method instead of leaving the choice of terrace construction method to farmers as recommended.

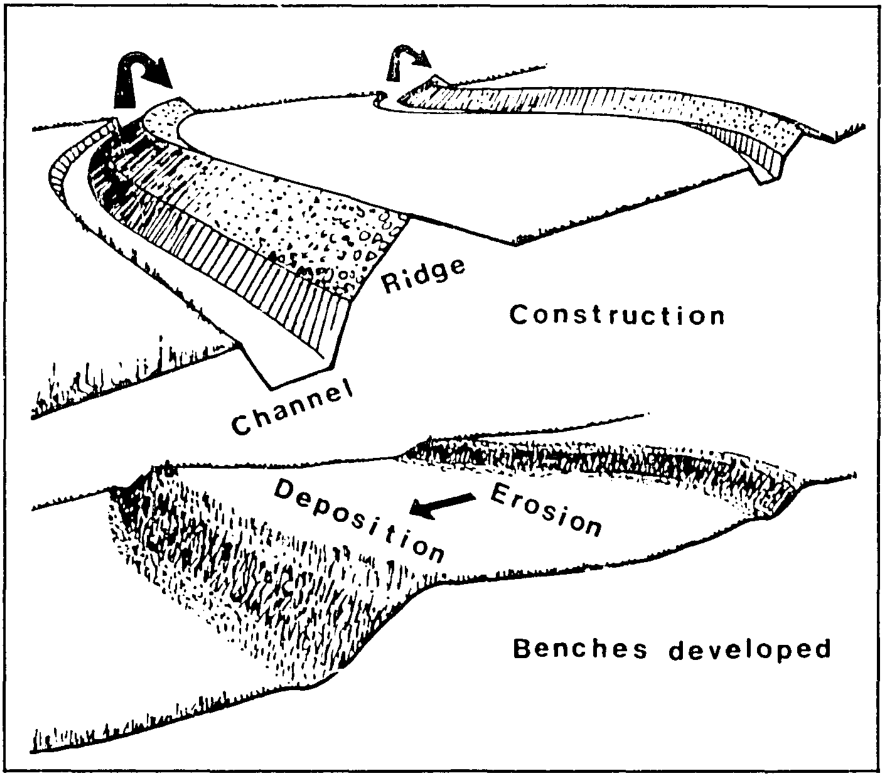


Figure 2. The bench terrace permits collection of dispersed soil particles, plant residues, water, and nutrients, which increases crop yields. Perennial grass on the edge of the terraces (or a cover of stones) will protect them, and the undisturbed riser will infiltrate water. This ingenious type of terracing fits slopes with erodible soils, especially in climates with unreliable or marginal rainfall.

and builds up behind the ridge, leading to a progressive development of nearly flat terraces (Figure 2). When the land behind the ridge has filled level with the ridge, the process is repeated by more excavation from the channel at the foot of the ridge, again using the soil to build the ridge higher.

The bank riser is planted to perennial crops, usually grass for cut-and-carry feeding to animals and sometimes fruit trees. Being able to use all the land constructively overcomes one of the main objections to terracing—that of losing some land for production.

Even in areas with better than average rainfall, the distribution is uneven and erratic, with drought periods. Terracing by the fanya juu method leads to better infiltration and moisture storage, and significant increases in crop yields are frequently observed immediately after terracing. The farmers quickly adopt a practice that offers an immediate advantage (*1, 2*).

Approach to farmers

Poor small-holders cannot be expected to begin terracing to save the future national food base, or even to save soil for their grandchildren. Better reasons for terracing are needed, especially when the results of severe erosion are not obvious. Tangible, short-term benefits to the farmers are the most persuasive reasons for them to accept terracing. Some of these are (1) that terraces maintain or increase crop yields (Figure 3); (2) that edges of terraces can be used for highly productive fodder grass, providing for more or better cattle and producing manure to increase crop yields (Figure 4); (3) that terrace edges can also be used for planting bananas or trees (Figures 5 and 6); and (4) that, consequently, terracing does not mean any loss of land (the yield of grass or trees is more valuable than the yield of a corresponding strip with grain) (Figure 7).

The farms on which conservation was to be applied had to be visited

Figure 3. Developed bench terraces generally mean static or increased crop yields. Fanya juu terraces can bring about benching within a year. The farmer in this case said his maize yield increased (Southeastern Zone in Ethiopia, October 23, 1986).

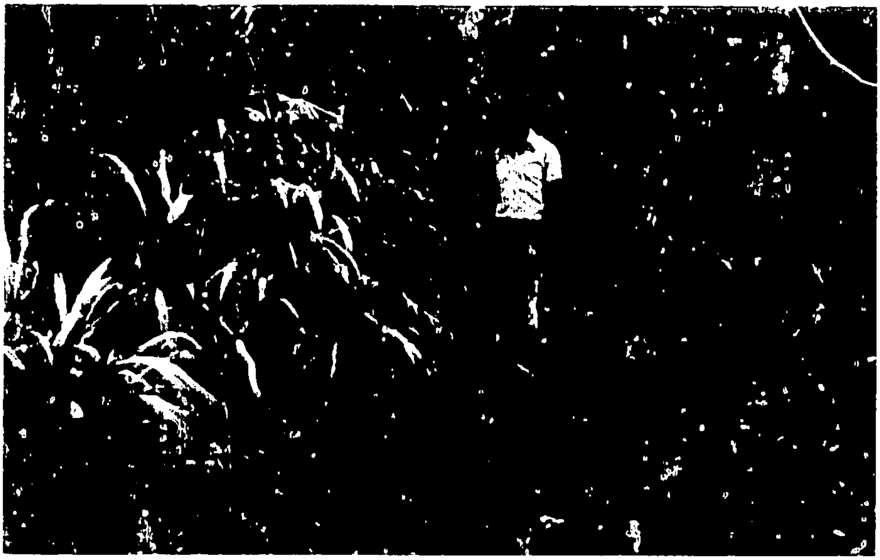


Figure 4. Terraces do not result in loss of land because their edges can be used for a perennial crop, in this case elephant grass. There is no monoculture. On the field above the riser, traditional cultivation occurs, with a mixture of various crops; below the riser, maize and beans are intercropped. This is a rather wet farming area (Nyeri District in Kenya, November 21, 1984).

Figure 5. Edges of terraces can be planted to bananas, which have a small root system. In wet areas bananas are planted above the riser; in dry areas, as here, below the riser (Machakos District in Kenya, March 6, 1980).

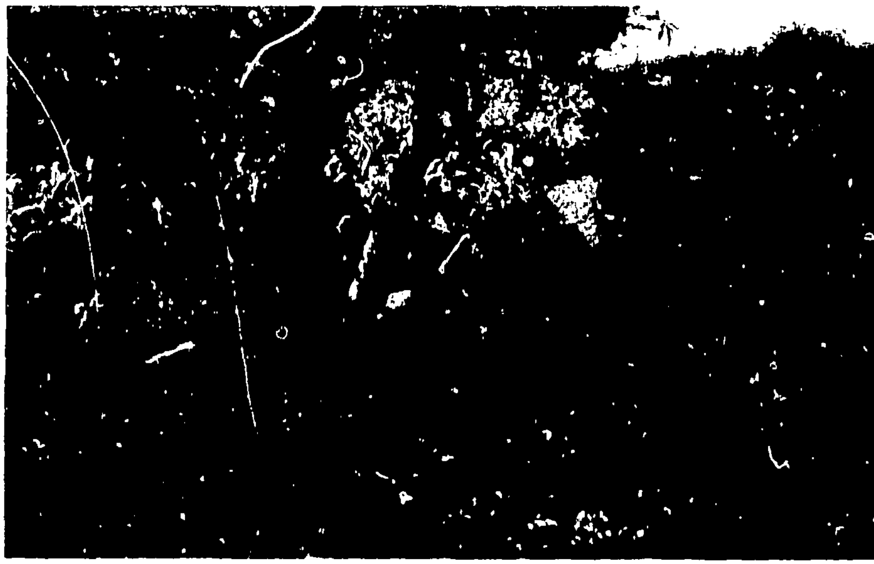


Figure 6. Terrace edges can also be used for trees. Farmers accept only small and useful tree species, preferably with a tap root and with a thinly wooded canopy. These peach trees produce fruit at a higher value than the maize on the terraces (Machakos District in Kenya, December 13, 1984).

Figure 7. In dry areas of Kenya, fanya juu terracing is a prerequisite for cropping, especially during drought. Above the riser with fodder grass, there is a row of small trees (*Bixa orellana*); below the riser, ridging with pineapple (Kwale District in Kenya, March 28, 1980).

Table 1. A summary of the Kenyan conservation training program.

Budget Year	Agricultural Staff			Administrative Staff		Other Categories	
	District Officers (1 Week)	Extension Agents (2 Weeks)	Agents Retraining (1 Week)	District Officers (3 Days)	Chiefs and Sub-chiefs (3 Days)	Teachers (1 Day)	Farmers (1 Day)
1974-1975		16					
1975-1976	27	92					
1976-1977	77	224					
1977-1978	96	319					
1978-1979	131	628					
1979-1980	269	895					
1980-1981	147	650		150	670		4,900
1981-1982	120	530	240	40	240	60	7,150
1982-1983	130	450	350	140	560	720	8,500
1983-1984	196	636	575	70	528	881	15,736
1984-1985	171	541	1,331		845	1,971	44,651
Total	1,364	4,981	2,496	400	2,843	3,632	80,937

by extension agents because farmers cannot lay out terraces properly without some experience. Farmers also needed advice on how to integrate soil conservation into farm planning and cultivation patterns. Farmers should do the terracing work themselves using the measures they prefer. As a principle, farmers should receive assistance with things they cannot do themselves, such as (1) design and construction of cutoff drains (diverting water flows coming from areas outside the farm), (2) lay out of terraces or infiltration zones, (3) acquisition of cuttings or root splits of a good fodder grass, and (4) acquisition of seed or seedlings of useful trees (trees are not so much for erosion control, but to prevent removal of terraces and, above all, as an incentive for terracing).

Approach to extension agents

The program recognized that the main contact with the farmers had to be through the existing network of extension agents. A strong training program for the extension service was, therefore, devised (Table 1). This included training courses of varying lengths for officers at all levels. Retraining of agents consisted of visits to treated areas for discussions. There has also been a major effort of arranging visits to good sites for groups of farmers.

Development from trial areas

The program began tentatively with one area in each of four districts. These were selected in different tribal areas with different styles of farming traditions. There were about 160 small-scale farmers in each trial area.

Fanya juu terraces were introduced and compared with other methods, such as open drains, trash lines, and grass strips. The local extension officers closely monitored the trials, and this experience was used to plan a national program that expanded. Beginning in 1974 with trial areas in the four districts, the program expanded rapidly to 22 districts after two years and to 30 districts after three years. The government of Kenya paid all of the program costs except for one expert. Further, expansion to a national program embracing 40 districts was safeguarded by funds from SIDA.

Other components

It was recognized that the national program should use every opportunity to reach the greatest number of people. Farmer Training Centers and District Development Centers operated through the Department of Agriculture were strengthened by the provision of equipment and material so that all their training courses could include soil conservation. A small program of demonstration farms was tried for a year or two, but this was soon abandoned because of nepotism and favoritism in the selection of farms.

Another component with rather disappointing results was the school's program. One of the ideas was that home economics officers should start soil conservation and tree planting on school campgrounds or adjacent slopes. A later attempt was to support and encourage selected teachers to generate an interest in soil and water conservation through school vegetable plots or tree planting. This program has now been replaced by the idea of introducing conservation thinking into the curriculum at all teacher training colleges to achieve a more widely based national impact.

Tree nurseries

The main purpose of establishing tree nurseries was to ensure the availability of supplies to small-scale farmers actively carrying out soil conservation. Another goal—supplying farmers with tree seed or seedlings to be planted anywhere on their farms—was thought to be a cheap, efficient way to increase the country's wood resource. The tree nursery program has had a mixed record of achievement. There are now also other tree nursery programs in the country run by other agencies.

Hand tools

The basic hand tool in peasant agriculture in Africa is the hand hoe. The hoe is useful for cultivating soil, but inefficient for moving soil. Providing other hand tools, particularly shovels, has been an important part of the program. These may be loaned to casual laborers or farmer groups, or as payment for work on cut-off drains or other group work, such as gully control.

Gully control and rehabilitation

Gully erosion is common in overgrazed and semiarid areas with erodible soils. These areas were not included in the soil conservation program. However, there was pressure to control gullies on farmland. Gully studies of design and cost using check dams and other meaures were not continued or followed up, but outlines for gully control were written later (*7*). The policy of the Ministry of Agriculture must be to concentrate on control in the early stages of formation while control is still reasonably inexpensive. With large gullies, estimates must be made about possible future growth and loss of land and a decision made whether or not to control based on these considerations.

Funds were supplied to districts for development of methods to rehabilitate degraded and unused land near land being cultivated. Some of these trials were interesting. Again, however, there was no follow-up, and there is still no program for rehabilitation.

Important features of the Kenyan program

Hudson (*3*) reported that this program "has undoubtedly been very successful. There have been relative strengths and weaknesses among the activities; there have been changes, mostly minor; there have been disappointments, fortunately few; but on the whole, this program has gone from strength to strength and, in many respects, provided a model from which other programs can learn."

Aspects of the program leading to its success, according to Hudson, are as follows:

► It is a long-term program, not a fixed-period project. It has already run successfully for 13 years (1974-1987) and will hopefully continue as long as the assistance is welcomed by the Kenyan government.

► The policy is to work entirely through the existing government structure and within existing government policies. The program may seek to give a lead where it feels that changes would be beneficial, but always working with the government, never opposing it.

► The main components are institution-building and institution-strengthening through a staff training program. There is also an operational program of field soil conservation, working through the existing departmental structure, with a major component of approach to farmers.

The assistance is all grant, not loan. The budget is not large (currently about US $2.75 million per year). The limitation is not how much money is available but how much can be usefully absorbed by the program.

Concerning personal leadership, any reasonably sound project can be made successful by good leadership, or spoiled by poor leadership. This program was a one-man show in the early stages, but it had time to develop its own strength so that when the original leader left it could continue.

Application of the program outside Kenya

The basic ideas of the Kenyan soil conservation program have made it successful for many years, at least in parts of Kenya. The concept of the Kenyan model of soil conservation is being studied in detail in neighboring countries—Zambia, Tanzania, and Ethiopia—and there is a strong exchange of ideas among these four countries through visits and training programs. The model is also becoming known over a wider area in Africa, particularly in the neighboring countries of South Africa.

When considering the possibility of applying the Kenyan model in other countries, one should bear in mind that each country, and even different parts of the same country, need a separate approach carefully built up and tested in small areas before starting regional or national programs.

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Demonstrating conservation practices on steep lands in Jamaica

Ted C. Sheng

Demonstrations are often needed for soil conservation projects in new areas. At the initial stage of the first United Nations Food and Agriculture Organization forestry and watershed management project in Jamaica in 1968, the government required the project to select and establish proper demonstrations in a watershed in the northwest part of the island. After a survey, two demonstrations were selected for subsequent treatment, one on public land and the other on private land. This paper discusses the experience of setting up the demonstration on public land, called the Smithfield Demonstration Center, and explains its results and impacts.

Seventy-five percent of Jamaica is hilly land that is used to produce domestic food and some export crops. Soil erosion has long been recognized as a serious problem. The need for soil conservation was pointed out in the 1930s. A lack of proper institutions, trained personnel, and effective conservation practices has greatly hampered progress in conservation. The objectives of the demonstration were (1) to demonstrate soil conservation practices together with proper land use and cropping; (2) to collect and analyze data on costs, returns, and soil erosion for future planning; and (3) to serve as a national training center in watershed conservation.

The average annual rainfall at the site is 3,300 millimeters, with intensities of 75 to 80 millimeters per hour common. Slopes range from 10 to 35 degrees (18 to 70 percent). The site had been used for many decades for cultivating yams. Erosion was severe. In many areas, topsoils were eroded away, and gullies were as deep as 2 meters.

A new "treatment-oriented" land capability classification

The land capability classification, based on the U.S. Department of Agriculture system used in Puerto Rico and introduced in Jamaica in 1953 (*10*), caused a dilemma for farmers and the government. More than half of the land in Jamaica exceeds a slope of 20 degrees (36 percent), and many small farmers were making a living on such slopes, which were excluded from cultivation by the classification system.

A new, practical "treatment-oriented" land capability classification based on experience in Taiwan was introduced. The central idea of the system is this: If land can be treated and protected from soil erosion, it should be approved for intensive cultivation. Figure 1 portrays the scheme of the system. Implementation details are given elsewhere (*4, 7*).

This system permits cultivation of land with deep soils on slopes up to 25 degrees (46 percent). Fruit trees, tree crops, or agroforestry are allowed on slopes up to 30 degrees (58 percent) if conservation practices are applied. This new treatment-oriented classification was tested in the demonstration area, together with proper land use, and has since been used in Jamaica El Salvador, Honduras, Thailand, and other countires.

Conservation treatments for steep lands

Grass barriers, contour furrows, and stripcropping, the major conservation practices used in Jamaica, are mainly suited for gentle slopes and areas of lower rainfall. These practices had failed to control erosion (*1, 2*). Contour furrows were expensive to build and broke easily if they were not precisely on the contour. Outward-sloped bench terraces also failed.

Eight structural practices and seven waterway types were introduced to this area of steep slopes and frequent, intense rainfall with inevitable runoff. The eight structural practices were bench terraces, hillside ditches, individual basins, orchard terraces, intermittent terraces, convertible terraces, natural terraces, and hexagons (Table 1, Figure 2); their details are described elsewhere (*6, 8*). Diagrams of the waterways and their use are shown in table 2, figure 3. Other work included gully control, slope stabilization, road drainage improvement and protection, and revegetation.

Soil loss data

For demonstrating erosion control effect, two sets of soil loss and runoff plots were established. A check plot in yams lost 133 tons per hectare per year of soil over a four-year period compared to 17 tons per hectare per year from bench terraces with continuous mounds and 32 tons per hectare per year from hillside-ditch plots (*9*). A subsequent five-year study using bananas instead of yams showed similar soil losses from the check and bench-terraced plots. Plots treated with hillside ditches, individual

Soil Depth \ Slope	Gently sloping <7°	Moderately sloping 7°-15°	Strongly sloping 15°-20°	Very strongly sloping 20°-25°	Steep 25°-30°	Very Steep >30°
Deep (D) >36 in. (90 cm)	C_1	C_2	C_3	C_4	FT	F
Moderately Deep (MD) 20-36 in. (50-90 cm)	C_1	C_2	C_3	C_4 / P	FT / F	F
Shallow (S) 8-20 in. (20-50 cm)	C_1	C_2 / P	C_3 / P	P	F	F
Very Shallow(VS) <8 in. (20 cm)	C_1 / P	P	P	P	F	F

1. Symbols for most intensive tillage or uses:
   - C_1: Cultivable land 1, up to 7° (12%) slope, requiring no, or few, intensive conservation measures, e.g., contour cultivation, stripcropping, vegetative barrier, rock barrier, natural terraces, and in larger farms, broadbase terraces.
   - C_2: Cultivable land 2, on slopes between 7° and 15° (27%), with moderately deep soils needing more intensive conservation e.g., bench terracing, hexagon, mini-convertible terracing for the convenience of four-wheel tractor farming. The conservation treatments can be done by medium-size machines, such as bulldozer D5 or D6.
   - C_3: Cultivable land 3, 15° to 20° (36%), needing bench terracing, hexagons and mini-convertible terracing on deep soil and hillside ditching, individual basin on less deep soil. Mechanization is limited to small tractor or walking tractor because of the steepness of the slope. Terracing can be done by a smaller tractor with 8-foot-wide blade.
   - C_4: Cultivable land 4, 20°-25° (46%), all the necessary treatments are likely to be done by manual labor. Cultivation is to be practiced by walking tractor and hand labor.
   - P: Pasture, improved and managed. Where the slope is approaching 25°, and when the land is too wet, zero grazing should be practiced. Rotational grazing is recommended for all kinds of slopes.
   - FT: Food trees or fruit trees. On slopes of 25° to 30° (58%), orchard terracing is the main treatment supplemented with contour planting, diversion ditching and mulching. Because of steepness of the slopes, interspace should be kept in permanent grass cover.
   - F: Forest land, slopes over 30°, or over 25° where the soil is too shallow for any of the above soil conservation treatments.
2. Any land which is too wet, occasionally flooded or too stony which prevents tillage and treatment should be classified as: (a) below 25°: pasture; (b) above 25°: forest.
3. Gully dissected lands which provent normal tillage activities: forest/pasture.
4. Mapping symbols: It could be labelled as follows:

$$\frac{\text{Most intensive use}}{\text{soil - slope - depth}}$$

$$\text{example: } \frac{C_2}{32 - 2 - D}$$

$$\text{means: } \frac{\text{Cultivable Land 2}}{\text{Wirefence Clay Loam - } 7^\circ \text{ to } 15^\circ \text{ - 36 in.}}$$

Or, it could be simply labelled as C_2.

Figure 1. A treatment-oriented land capability classification scheme for Jamaica.

Table 1. Specifications and applications of eight types of land treatment structures.

	Specifications					*Applications*		
Structure Type	*Width of Flat Bench*	*Length*	*Horizontal Grade*	*Reverse Grade*	*Riser Slope*	*Land Slope*	*VI* or Spacing*	*Auxiliary Treatments*
1. Bench terraces								
(a) Hand made	2.5-5.0 m	< 100 m	up to 1%	5%	0.75:1	7°-25°	$\frac{S \times W_b †}{100 - S \times 0.75}$	–
(b) Machine built	3.5-8.0 m	< 100 m	1%	5%	1:1	7°-20°	$\frac{S \times W_b}{100 - S \times 1}$	
2. Hillside ditches	1.8-2.0 m	< 100 m	1%	10%	0.75:1	< 25°	$\frac{S+4}{10}$ or $\frac{S+6}{10}$	Agronomic conservation measures‡
3. Individual basins	1.5 m (Round)	–	–	10%	0.75:1	< 30°	Distance of crop	Hillside ditches, orchard terraces, and agronomic conservation measures
4. Orchard terraces	1.75 m	< 100 m	1%	10%	0.75:1	25°-30°	11-13 m along slope	Agronomic measures, individual basins
5. Intermittent terraces	2.5-5.0 m	< 100 m	1%	5%	0.75:1	7°-25°	3 times bench terrace	Agronomic measures, individual basins
6. Convertible terraces	3.5m	< 100 m	1%	5%	0.75:1	7°-20°	as hillside ditch	Agronomic measures, individual basins
7. Natural terraces	8-20 m	–	–	–	0.75:1	< 7°	1 m VI	Agronomic measures
8. Hexagons								
(a) Terraces and operation routes	3.5 m	< 100 m	1%	5%	1:1	7°-20°	8-13 m along slope	Individual basins, agronomic measures, grass or marling
(b) Peripheral road	3.5 m		< 12%	5%	1:1	7°-20°	–	Cross drains

*VI is vertical interval between two succeeding terraces, which determines spacing.
†S is slope as percentage, W_b is width of bench.
‡To be applied mostly between the ditches (or on the individual basins) such as contour planting, close planting, cover cropping, mulching, etc.

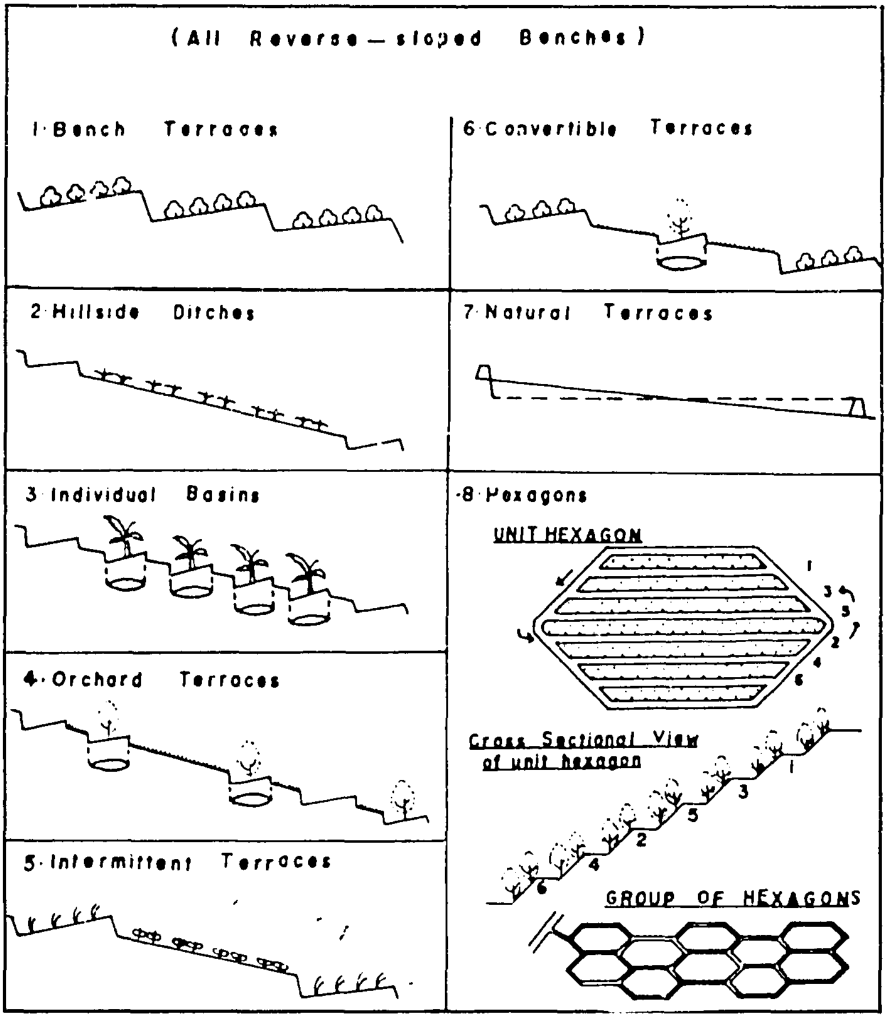

Figure 2. Cross-sectional view of eight types of land treatment structures.

basins, and cover crops lost 7 tons of soil per hectare per year, while plots with cover crops alone lost 22 tons of soil per hectare per year.

Cost-benefit analysis

In cost analysis it was found that one man-day was able to cut and fill 3 to 4 cubic meters of soil material. A D-6 bulldozer could move 40 cubic meters in an hour. One hectare of hillside ditches on a 20-degree (36-percent)

Table 2. Major types of protected waterways, their uses and limits.*

Type	*Shape*	*Channel Protection*	*Velocity Limit*	*Slope Limit*	*Uses*
1. Grassed waterway	Parabolic	By grass	1.8 m sec^{-1}	<11° (19%)	For new waterway or depression
2. Grassed waterway with drops	Parabolic	By grass and concrete or masonry	1.8 m sec^{-1}	Between two structures: 3%, overall slope <11° (20%)	For discontinuous type of channel
3. Ballasted waterway	Parabolic	By stones or stones in wire mesh	3 m sec^{-1}	<15° (27%)	Where stones are available
4. Prefabricated (a) Parabolic waterway	Parabolic	By concrete structures and grass	–	<20° (36%)	A stilling basin is usually needed and where rainfalls are frequent and flows are constant
(b) V-notch chute	90° V-notch	By concrete structures and grass	–	>20° (36%)	Same as above and on very steep slopes
5. Stepped waterway	Parabolic and rectangular	By grass and concrete or masonry drops	On grass part: 1.8 m sec^{-1}	Overall slope <20° (36%)	For 4-wheel tractors and in the middle of bench terraces
6. Waterway and road ditch	Parabolic	By grass and stone ballasting	3 m sec^{-1}	<8° (14%)	For 4-wheel tractor mechanization
7. Foot-path and chute complex	Trapezoid or rectangular	By concrete or masonry structure	–	>20° (36%)	For paths on small farms and on very steep slopes

*These limites are approximations for general reference. In practice, the volume and velocity of runoff and site conditions should all be taken into consideration.

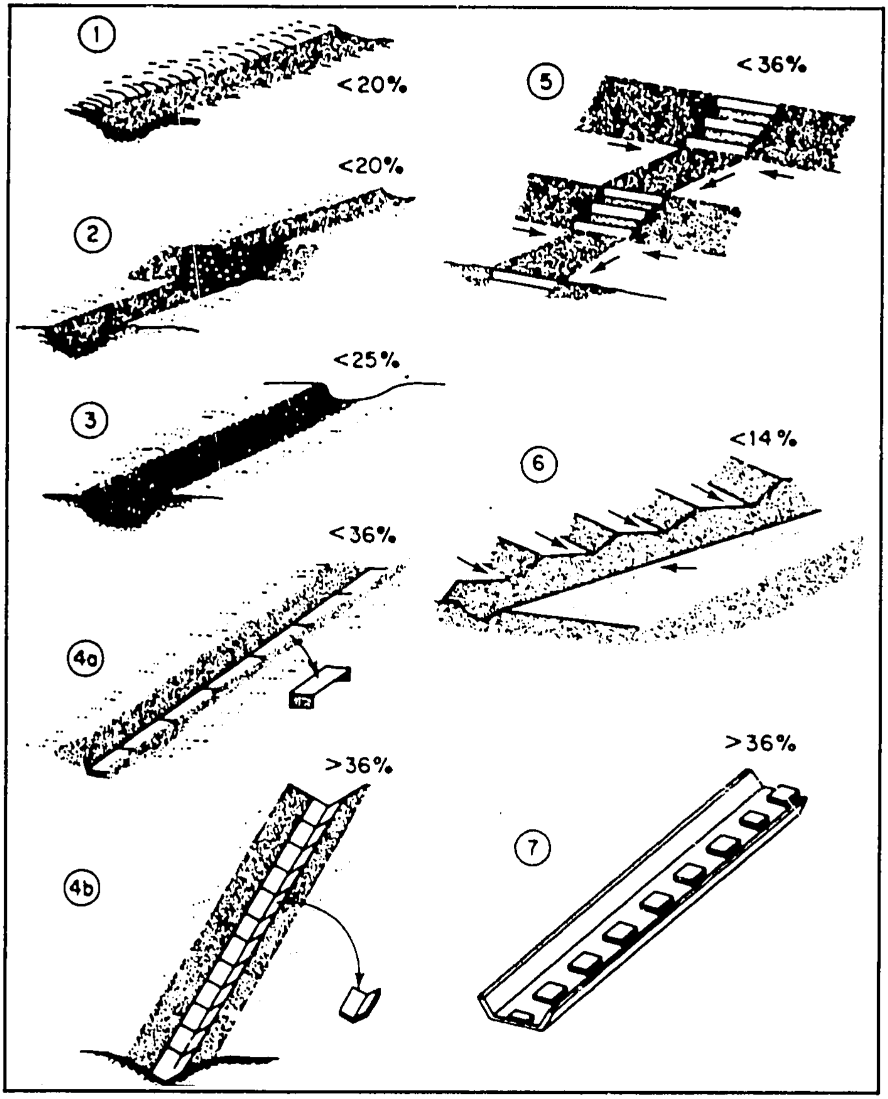

Figure 3. Major types of waterways, as described in table 2.

slope required about 80 man-days, whereas a hectare of 3-meter-wide bench terraces on a 24-degree (45-percent) slope required 470 man-days to complete.

Detailed cost and returns for cropping were published (*3*) and the annual cost of terracing was examined (*5*). The annual cost of bench terracing per hectare (including waterway) on moderate slopes was about US $175, while the net returns of yams per hectare was about US $1,850. The yam crop produced on the project was always 100 percent higher per hectare than local yields.

Hillside ditches plus agronomic conservation measures reduced soil erosion 80 percent or more, yet the cost per unit area was only one-third to one-fifth of the cost of bench terracing.

Labor was generally reduced because tractors could be used. Steep land could be kept under permanent cultivation without reversion to fallow as before, thus greatly increasing production. Estimates showed sediment delivery could be reduced by 20 tons or more per hectare.

Results and Impacts

The project has served as a practical and educational model for proper use and conservation of steep slopes in the Caribbean and Central America. The project has provided basic data for watershed and conservation project planning. Moreover, about 400 technicians were trained at the site, and experience from the demonstration was used in developing conservation policy and in formulating a nationwide soil conservation program for Jamaica.

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Integrating conservation into farming systems: The Malawi experience

M. G. Douglas

Agricultural research workers in eastern, central, and southern Africa have recently begun to address the problems of smallholder farmers within a farming systems perspective. This is in recognition of the fact that many recommendations on improved agricultural practices are not adopted because they are inconsistent with the circumstances in which farmers operate. There is an urgent need for soil conservation and land use specialists to adopt the same approach. It is increasingly clear that many conservation programs fail because little consideration is given in their design to the economic, social, and political environment in which farmers actually make decisions about land use and farm management practices (*10*).

To be successful, conservation must be viewed as an integral part of a productive farming system rather than a separate land management practice. So far, farming systems work in Africa has tended to concentrate on agronomic aspects of crop production. Conservation concerns, such as soil erosion control and fertility maintenance and regeneration are only likely to be considered when conservation specialists become integral members of interdisciplinary farming systems teams.

The conventional soil conservation approach

The Land Husbandry Branch of the Ministry of Agriculture in Malawi until recently followed the conventional "top-down" approach to soil conservation typical in much of Africa. Conservation "experts" would go out, identify the problem in the field, arrive at a solution according to predetermined guidelines in their technical manual, and only involve the farmers through an extension package at the implementation stage.

Such an approach has been found to work reasonably well with commercial farmers, notably tobacco estates, where there are few constraints (such as land, labor, and finance) to implementing a conservation farm plan. Attempts have been made to follow this approach in tackling the problems of soil erosion at the smallholder level, but with little success. Experience leads inevitably to the conclusion that for small, resource-poor farmers whose primary goal is to satisfy their families food needs, the socioeconomic circumstances are more important considerations in designing an effective conservation package than the constraints imposed by the physical environment. Such farmers are rarely able or willing to adopt improved conservation and land use practices solely for the sake of conserving the soil, particularly because many of the standard recommendations require the farmer to forego short-term benefits for the sake of long-term sustainability. For instance, farmers with only 1 or 2 hectares of land, struggling to produce sufficient food for the family, cannot afford to take land out of food crop production to put it under physical conservation structures, nor can they be expected to adopt a crop rotation that may require (in the case of land classed as C Arable (equivalent to Land Capability Class III) 40 percent of the land to be under perennial crops at any one time (*19*).

The Lilongwe Land Development Program

Conventional conservation thinking regards the catchment as the appropriate framework for planning purposes. This is the basis for the approach to conservation in the Lilongwe Land Development Program, an agricultural integrated rural development project covering some 280,000 hectares and 100,000 farm families in the central region of Malawi. Between 1968 and 1977, an integral network of 357 kilometers of crest roads, 7,325 kilometers of diversion ditches (bunds), and 933 kilometers of artificial waterways were constructed using heavy earthmoving machines. The total cost was K 5.5 million (approximately US $5.0 million).

As an attempt to stop soil erosion in one of the most productive parts of Malawi, it was an expensive failure. The program sought to prevent erosion by intercepting and controlling runoff from farmers' fields, but failed to tackle the primary cause of erosion in Malawi, namely raindrop splash caused by rainfall and poor ground cover. The conservation program was designed and implemented by outside experts without directly involving the farmers on whose land the structures were constructed. These farmers were unimpressed by the alleged long-term benefits and were not prepared to commit scarce labor to maintain something they did not construct or ask for. Lack of maintenance has led to the structures silting up and overtopping, the net result being an aggravation of previous erosion problems (*14*).

Integrating conservation, extension, and research services

The Ministry of Agriculture in Malawi undertook a major review of its activities in the 1970s. This review culminated in 1978 with the introduction of the National Rural Development Program focusing the bulk of its resources on the smallholder farming sector. Under the program, the various extension technical services were amalgamated with the conservation service (Land Husbandry Branch) to form one Department of Agriculture. The Land Husbandry Branch changed from being a separate technical division dealing mostly with the commercial sector to one in direct contact with smallholder farmers. With subject matter specialists working at all levels of the extension service, the branch is able to integrate conservation into the agricultural extension messages going out to farmers.

The Department of Research underwent a similar reorganization in the early 1980s, and the introduction of "on-farm research with a farming systems perspective" has provided a means of bringing research, extension, and the farmer closer together. Some land husbandry officers have been involved with this work, and their experience has led to serious questioning within the branch about the applicability of the existing conservation recommendations to the smallholder situation. Out of this has come the realization that good land husbandry can only be promoted within the context of area-specific farming systems.

Integrated land use

A new approach to conservation and land use planning is emerging in Malawi known as "integrated land use." This approach seeks to integrate fully within a farmer's individual holding the production of annual crops, pastures, livestock, and trees with the aid of a contour layout. Its basic aims are to:

► Increase the total productivity of the land per unit area on a long-term, sustainable basis.

► Enable farmers to make the most efficient use of available resources (i.e., soils, climate, water, crop residues, cash or credit, and labor).

► Meet as many of the farmers' basic needs as possible from their own land (i.e., food, firewood, building materials, and cash).

► Cut input costs while maintaining and increasing yield levels through better use of organic materials, such as compost, animal manures, mulches, green manures, and crop residues.

Farmers in Malawi already practice a form of integrated land use, even if at a somewhat low and inefficient level. Trees are a part of the farming scene. Mango trees occur in most farm fields, and many indigenous species were left when the original woodland was cleared for cultivation because farmers value the products they yield. A rapid survey in 1981 showed that most of the indigenous species growing in the fields were leguminous and potentially compatible with crop production (*15*). Farmers are aware of tree and crop interactions and will cut back the side branches when the trees compete excessively for light and nutrients with adjacent crops.

Livestock are an important feature of many smallholder farming systems, and manure is frequently used for crop production. The successful smallholder dairy program in Malawi is based on planted Rhodes grass pasture. Much of the country's beef production comes from steers fattened in stalls on crop residues during the dry season.

From the technical point of view, the catchment should be the framework for conservation planning. But this is a less natural unit of perception and action for the farmer than his or her own holding, where the boundaries are determined more by social and administrative needs, rather than conforming to the natural features of a watershed (*10, 18*). Individual catchments are likely to contain many farmers with separate holdings and marked differences in farming skills, education, interests, and needs; this makes working together for the conservation of resources not solely their individual responsibility difficult. The priority with integrated land use is to motivate individual farmers to adopt good land use and conservation practices within the boundaries of their own plots.

Components of integrated land use

Integrated land use consists of the following components (*4*) (Figure 1):

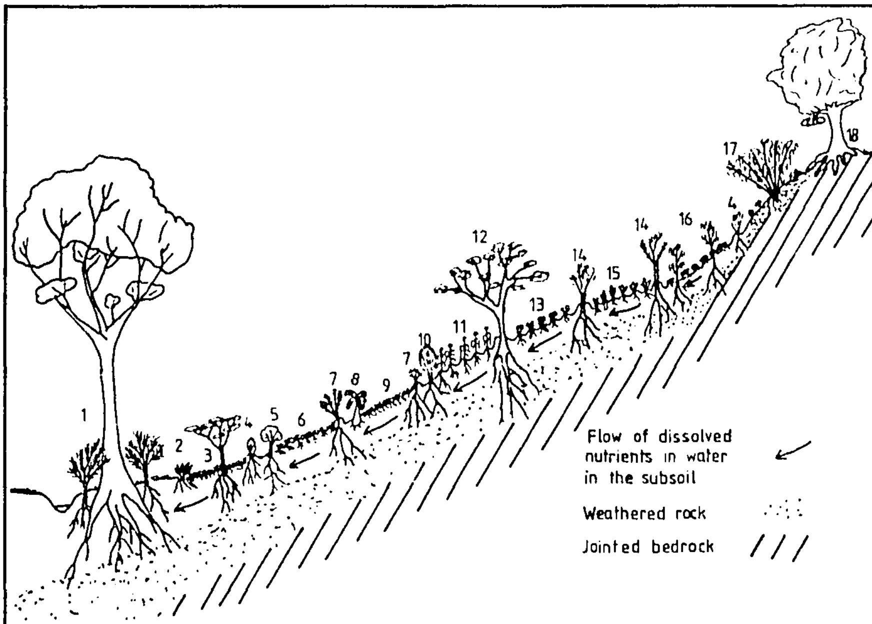
► All annual crops to be grown on boxed contour ridges, aligned parallel to the contour with the aid of permanent, raised contour marker ridges.

► Good crop husbandry practices to be adopted (i.e., early planting, optimum plant spacing, complementary intercropping, and use of fertilizer and organic manures).

► Incorporating into the field layout permanent contour buffer strips planted to productive perennial crops.

► Integration of livestock into the farming system through the planting of pastures, growing fodder crops, feeding crop residues, and using the manure for crops.

► Integration of trees into the farming system by planting them on the



Key

1. Khaya nyasica (Mbawa) planted to protect the streambank with an initial shade/nurse crop of Sesbania sesban. Mbawa to be used eventually for timber.
2. Sisal hedge to control livestock. Old leaves to be cut and the fibers extracted and used for string and making sisal cement roofing, sheets for the house.
3. Improved permanent pasture for grazing, some natural trees like Mtet (*Acacia* species) left for shade and to provide thorny branches for temporary fences.
4. Planted goat proof hedge, e.g., *Caesalpina decapetala*.
5. Buffer strip on the contour of Guavas underplanted with a legume ground cover, which is cut and carried to feed livestock fattened in a stall.
6. Field of groundnuts on boxed contour ridges.
7. Raised contour marker ridge planted to leucaena (*Cunningham cultivar*) used for fodder, fertilizer, thin poles, and firewood.
8. Bananas planted on the contour and heavily mulched.
9. Planted pasture of Rhodes grass/legume mixture grazed by livestock.
10. Buffer strip on the contour of citrus and mango fruit trees underplanted with a legume ground cover, which is cut and carried to stall fed livestock.
11. Field of maize interplanted with beans on boxed contour ridges.
12. Raised contour marker ridge planted with *Acacia albida* (Nsangu), which enriches the soil by dropping its leaves at the start of the rains. Inbetween the Nsangu trees leucaena is planted on the contour ridge.
13. Field of soya beans planted on boxed contour ridges.
14. Raised contour marker ridge planted to leucaena (Hawaian Giant cultivar) used for fodder, fertilizer, building poles, timber and firewood.
15. Field of fire cured tobacco planted on boxed contour ridges.
16. Woodlot underplanted in first few years of rotation with sweet potatoes and cow peas.
17. Bamboos planted in pockets of deeper soil on a rocky hillside.
18. Natural trees left on rocky hills to reduce surface runoff. Can be carefully cropped for firewood, poles, string, local medicines, etc. A useful place to put a bee hive. Bees will help pollinate many of the crops grown on the farm, both annuals and perennials.

Note: Strips numbered 6, 8, 9, 11, 13, and 15 form the land used in the arable rotation. In practice, maize will occupy a larger percentage of the annual cropland than is shown in the diagram.

Figure 1. Schematic representation of an integrated land use layout for the Nathenje Area, Lilongwe Northeast Rural Development Project, Malawi.

marker ridges, in the buffer strips, as hedges and in woodlots, and using them to provide fuel, fruit, fodder, fertilizer, etc.

Contour crop ridging

Growing crops on ridges is a practice common throughout most of Malawi. Therefore, much of the land husbandry extension effort is put into assisting farmers to align their ridges with the aid of pegged contour marker ridges. Farmers are encouraged to plant raised marker ridges to a perennial crop, such as leucaena, Napier grass, or bananas, thus ensuring that the part of the field under the structure contributes directly to total farm production. Boxing the crop ridges (ties every 2 to 3 meters in the furrow) requires extra labor for field preparation, and those farmers who feel the practice is worthwhile have adopted the recommendation to conserve water because of the benefits to crop growth rather than to conserve soil.

Good crop husbandry

The crop husbandry practices required for good soil conservation coincide to a great extent with those required for increased crop yields (*7*). Practices, such as early planting, correct spacing, use of fertilizer, and use of improved seed, produce vigorous crops that provide increased groundcover, thereby diminishing the amount of bare ground exposed to rainfall impact (*4, 18*). Recommended good crop husbandry practices may be difficult to follow for a variety of reasons, and from a conservation point of view, it will be more productive to identify these and overcome the constraints to adoption within the farming system than to spend time designing earthworks.

Many traditional cropping practices have a sound ecological basis (*16*) as well as a productive rationale. Of particular interest is mixed cropping—growing two or more crops together—which has many advantages to the subsistence farmer. It maximizes the chance of obtaining a food supply by spreading risks; it provides increased variety in the diet; and it requires less labor than would be needed to grow the crops separately (*20*). It also has major conservation benefits because most traditional intercrop mixtures will provide at least 40 percent mean ground cover, regarded as the critical figure for reducing soil loss (*5*), whereas many poor, unfertilized monocrops do not (*20*). Adaptive research trials in Malawi have shown that maize/bean and maize/pigeon pea mixtures are more productive per unit area than pure stands of maize. Such intercropping is currently recommended as a way of increasing crop production, soil nitrogen levels, and ground cover.

Contour buffer strips

Contour buffer strips on the uphill side of the marker ridge are recommended to serve as infiltration zones and sediment traps when the boxed contour ridges are unable to cope with the rainfall received during a severe storm event. Farmers are advised to use the strips to grow perennial crops that are both productive and provide good ground cover, for example, fruit trees undersown with a grass/legume mixture, strips of livestock fodder for feeding on a cut-and-carry basis, or firewood. The important thing is that the perennial crops should be productive and used to meet some of what households see as their needs.

Integration of livestock

Integration of livestock into the farming system by planting pasture as part of a crop rotation, by using crop residues as feed and livestock bedding, and by applying manure to the land is a realistic and profitable way for farmers to improve the surface condition of their soil and maintain organic matter levels. Pastures can be used for dairy and beef production, farm enterprises that can produce higher returns than the equivalent land area under annual crops (*3*). Farmers are being advised that pastures, such as a Rhodes grass/silverleaf mixture and Napier grass, can be successfully established under a maize crop without significantly reducing the maize yield (*17*). Farmers are also being encouraged to fatten steers on crop residues in a stall during the dry season, thereby converting an otherwise low-value farm resource (crop residues) into high-value beef and organic fertilizer.

Trees in an integrated land use layout

A variety of a farm family's basic needs—fuel and shelter—can be met with trees. In an integrated land use system, trees can also be used to enhance land productivity and sustainability (*12*), which are important for small farmers with limited access to purchased farm inputs. It is recommended that suitable trees be planted on the contour marker ridges, in the buffer strips, or along field boundaries. In an integrated layout the need is for species that offer several benefits to the farmer with a minimum of adverse side effects on crops. Leguminous species are ideal, especially if they grow rapidly, produce protein rich leaves or pods, can be used as green manure, and supply good quality firewood and poles. *leucaena leucocephala* is one such species that farmers are being encouraged to plant where soil and climatic conditions permit. A specific recommendation is that it should be planted in association with *Acacia albida* along the contour marker ridges. Acacia seedlings should be planted at 10- to 15-meter intervals, with leucaena direct-seeded between (*2, 3*).

Acacia albida is a moderately fast-growing, indigenous species valued by farmers and retained for its agricultural benefits. Its fine leaves are shed at the onset of the rains and rapidly decompose, releasing valuable nutrients. Soil analysis has shown that the organic matter content and nitrogen levels are consistently greater beneath the trees than away from them. Samples from under one tree near Salima in central Malawi produced increases of 113 percent for organic matter and 125 percent for nitrogen, respectively (*13*). Where sufficient mature trees occur in farmers' fields, as in parts of the Rumphi District in northern Malawi, reasonable maize yields can be obtained without using purchased inputs (personal observation).

Woodlots

Where farmers are interested in trees as a cash crop for fuelwood and poles and have enough land, they are advised to have a woodlot. This should be contour-ridged, with the tree seedlings planted in the furrows and a shallow rooting crop, such as sweet potatoes, on the ridges. The contour ridging and cover provided by the food crop reduce the erosion hazard associated with the practice of clean weeding, which is necessary for eucalyptus establishment. Once a closed canopy is obtained, the woodlot can be undersown with a pasture legume and grazed by livestock.

Live fencing

Successful planting of perennial crops in many parts of Malawi requires a goat-proof field boundary. Barbed wire, while a simple form of fencing, is too expensive for most smallholder farmers. The alternative is to plant a live fence. A number of plant species already are in use by farmers. These include sisal, *Caesalpinia decapetala*, *Commiphora africana*, and *Euphorbia tirucalli*. Additional multipurpose species must be sought.

Organic manures

The rapid increase in fertilizer prices in the early 1980s has led to revived interest in the use of organic manures. Farmers are being encouraged to make compost, to collect and use animal manure, and to bury surplus crop residues as a means of fertility maintenance and regeneration.

Adaptive research trials have shown that fertilizer costs can be reduced for maize production by using manure as a basal dressing and only applying the chemical fertilizer as a top dressing. Similarily, the use of fresh leucaena prunings (2-4 percent nitrogen) as a green manure has met with favorable results in terms of grain yields when compared with the recommended chemical fertilizer rates, i.e., in 1983-1984, 4,259 kilograms/hectare and 4,320 kilograms/hectare for 18.5 tons/hectare prunings and 92 kilograms/hectare nitrogen, respectively (*11*).

Alley cropping

Investigations are underway on the potential for alley cropping with leucaena as a low-cost nitrogen input farming system and as a way of permitting sustainable cultivation of annual crops on steep slopes. The locally devised system is to plant single rows of leucaena by direct seeding between every row or every two rows of maize, the maize being grown on contour crop ridges at the standard recommended spacing of 90 centimeters.

Each year, leucaena hedgerows are pruned to a height of 30 to 40 centimeters some two to three weeks before the first rains are expected and the prunings laid on the intervening crop ridges. When the first rains occur, the woody stems are removed and used as firewood, leaving a mulch of leaves and fine stems through which the maize is planted. During the cropping season, the hedgerows are periodically pruned to prevent them from shading the maize, and the prunings are left on the crop ridge as a mulch. Near the end of the season, the hedgerows are left to grow unchecked to give maximum regrowth and leaf production before the next season.

The trials were conducted on 7 percent and 40 percent slopes on the grounds of a farmer training center, where they have provoked much farmer interest. The results are encouraging. Reasonable maize grain yields have been obtained without chemical fertilizers (4,600 kilograms/hectare in the 1983-1984 season, 4,130 kilograms/hectare in 1984-1985). On the 40 percent slope, much soil has been lost from the pure-stand maize control plot. In the leucaena plots, meanwhile, terracettes have formed with leucaena stems as the risers (personal observation).

A synthesis

Within an integrated farming system, individual farm enterprises can interact beneficially with others to enhance the total system. For example, fruit trees planted on buffer strips not only produce fruit but act as windbreaks and check erosion. When livestock is grazed on communal hillsides, much of their dung and urine is lost. By stall feeding animals or grazing them on planted pasture, their manure is retained within the farm. Groundnut haulms have a high protein content, making them a valuable livestock feed, which increases the financial value of the crop above the cash value of the shelled nuts alone. Leguminous trees grown for fuelwood or fodder can also raise soil nitrogen levels for the benefit of nitrogen-demanding crops, like maize.

To the farmer, integrated land use offers a means of increasing productivity and satisfying a variety of needs within the resources of the farming system. The long-term sustainability of the system comes about by enhancing soil fertility (manures, pasture, etc.), protecting the soil surface by increasing the ground cover (good crop husbandry and perennial crops, including trees), and controlling runoff with boxed contour ridges, buffer strips, and raised marker ridges. In other words, conservation is integrated into farm practices that make productive sense to the farmer.

As yet, there is probably no farmer in Malawi who is implementing the fully integrated land use package, but many farmers have begun to incorporate one or more components into their systems. The approach is deliberately flexible and aims at a "bottom-up" adoption and dissemination, with farmers investigating for themselves which of a range of demonstrated land use and farm management options are actually economically, ecologically, and socially appropriate to their particular circumstances.

Reports from Lilongwe Agricultural Development Division, the most advanced region in terms of adopting this approach, indicate an increasing demand from farmers for assistance in realigning crop ridges through the pegging of marker ridges. Several farmers have put in contour buffer strips (Rhodes grass for feeding to livestock being the most popular use of these so far), and many farmers have begun using compost heaps (Table 1).

Table 1. Land husbandry activities, Lilongwe Agricultural Development Division, Malawi, 1984-1985 and 1985-1986.

Rural Development Project	*Number of Compost Heaps*		*Number of Farms Planned with Buffer Strips*		*Area Pegged with Marker Ridges*	
	1984-1985	*1985-1986*	*1984-1985*	*1985-1986*	*1984-1985*	*1985-1986*
Ntcheu	600	1,385	4	8	N/A	750 ha
Dedza	2,280	6,849	8	6	N/A	459 ha
Thiwi/Lifidzi	400	723	2	-	N/A	332 ha
Lilongwe NE	-	407	1	4	N/A	80 ha
Lilongwe	1,540	2,510	3	2	N/A	-

Although alley cropping is still under investigation by Land Husbandry Branch staff, farmers are keen to try it for themselves. In the 1985-1986 cropping season, some 61 farmers in Ntcheu, Dedza, and Lilongwe established small plots of leucaena for use in the 1986-1987 cropping season.

The next few years will be critical in determining whether the concept and practice of integrated land use will take root in Malawi and be incorporated into the farming systems of smallholder farmers. By starting at the level of the individual farmer and working within the existing extension system, the ideas can spread without the need for a massive injection of donor funds. The initial farmer interest gives one hope that the ideas are acceptable and will be adopted.

Staff training

To be certain that what is recommended and demonstrated to farmers as part of an integrated land use approach is appropriate, it is necessary to develop among trained soil conservation and land use officers an awareness of the economic, social, and political environments in which a farmer makes decisions about land use and farm management. The Commonwealth Secretariat, in conjunction with the Malawi government, has developed a four-week in-service course to meet this need.

This course draws upon principles outlined in the Food and Agriculture Organization's "framework for land evaluation" (*6*), the International Council for Research in Agroforestry "diagnosis and design" methodology (*8, 9*), and the International Maize and Wheat Improvement Center "farming systems" approach (*1*). It aims to introduce participants to the critical issue of how to balance ecological and socioeconomic considerations in designing conservation projects targeted to the smallholder farmer. Recommendations then are not only technically correct but appropriate and acceptable to the situation in which they are expected to be implemented.

Integrating conservation into the farming system involves taking a problem-oriented or diagnostic approach to land use planning. The training course, therefore, has as its primary activity a practical exercise whereby the participants must diagnose the land use problems and farmer circumstances within a nearby study area and then make appropriate recommendations for improved, area-specific land use practices (*4*).

Some final points

When seeking to integrate conservation into smallholder farming systems, the following points need to be borne in mind:

► The social, political, and economic circumstances of the farmer need to be considered, along with the environmental conditions.

► A bottom-up approach aimed at motivating individual farmers to conserve their own holdings, while slow to start with, is likely to be more successful than the top-down approach in the long run.

► Conservation must be an integral part of the farming system, rather than a separate exercise, so that crop husbandry, animal husbandry, and land husbandry become one and the same.

► Agronomic conservation practices, including good crop management, must precede, not follow, physical conservation measures.

► Traditional practices offer a good starting point for the development of improved, area-specific practices because they have evolved from the needs of the farmer and generally have a sound ecological basis.

► Techniques recommended to farmers ideally should be (1) simple, so they can be readily demonstrated and understood by farmers; (2) low cost, within the financial reach of farmers; (3) productive, leading to substantially increased benefits (i.e., higher crop yields, increased fuel wood, guaranteed fodder supplies), preferably in the first year of operation; (4) sustainable, requiring limited effort or purchased inputs to maintain them; and (5) acceptable, practices farmers are willing to implement themselves.

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The Eppalock catchment project: A soil conservation success story

D. W. Sanders

In 1960 the Government of Victoria, Australia, started construction of the Eppalock Dam. The 2,000-square-kilometer catchment was seriously eroded, and sedimentation threatened to reduce the effective life of the dam if left untreated. The government agreed to make available US $110,000 annually for 10 years to do the necessary conservation work.

Erosion in the catchment

The catchment originally had been a dense eucalyptus forest. In 1960 it consisted largely of poor, eroded grazing land. This resulted from clearing of the land for firewood and timber during the gold mining period, over-cultivation of land not suited to cultivation, followed by over-grazing by sheep and rabbits.

In the drier northern area, where annual rainfall is less than 650 millimeters, the shallow soils were extremely erodible. Extensive tunnelling and gullying was present. Sheet erosion produced stony surfaces on steep slopes, which, in turn, produced high runoff and more gullies. In some places the altered hydrologic system resulted in greater seepage and dryland salting. This was an example of land degradation rarely paralleled in other parts of Australia.

The central area, with poor granitic soils, was also badly eroded. However, most of the steeper southern part of the catchment, in a higher rainfall area, was not badly affected by soil erosion.

Apart from some state-owned forests, most of the land was held by private farmers. Holdings varied in size from about 4,000 hectares to plots of less than 10 hectares. Many small landholders were part-time farmers who also owned small businesses or worked part-time at woodcutting, shearing, or casual labor.

Approach to the problem

It was not considered fair to expect the landowners to bear the cost of repairing the erosion damage. Conservation work, it was said, would protect the dam, and the community as a whole would benefit. Therefore, a policy was developed under which the cost of conservation measures would be shared by landholders and the government.

The conservation measures were divided into two categories: "nonproductive" and "productive" works. Nonproductive works included such things as construction of gully head structures, fencing out and retirement of gullied areas, and building of silt traps or groynes. The cost of these would be wholly met by the government, with landowners responsible for future repairs and maintenance.

Productive works included those leading to a direct benefit for the landowner, usually through increased production. Here, the bulk of the expense would be met by the landowners, even though they were subsidized to some extent by provision of services, such as laying out contour lines, arranging for contractors, and paying for one chisel plowing of eroded land. Individual subcatchments of between 2,000 and 5,000 hectares were delineated and assessed for priority treatment.

Planning and implementing the scheme

Farmers were included at all stages of planning and implementation of the work. When the Soil Conservation Authority was ready to begin work, the broad aims of the project were explained to landowners and their support solicited. Planning began when a majority in a subcatchment favored the project. Landholders were included in planning of both the nonproductive and productive works. Work was phased over a number of years and so fit in with seasonal conditions and what it was possible for the individual farmers to do.

After planning was completed in a subcatchment, each landholder received a map of his property with all planned works and a contract to sign agreeing to carry out certain productive works and to maintain the nonproductive works installed by the SCA. The contract bound the SCA to carry out the necessary nonproductive works and to provide certain services.

The conservation officer who had done the planning was responsible for supervising the implementation of the plan. This personalized service helped to build a feeling of trust between the farmer and the SCA and no doubt played a significant part in the success of the project.

Technology used

Conservation plans had to include measures to control and reclaim the most severely eroded areas and to improve management of the land to break the cycle of excessive runoff and erosion leading to yet more runoff and erosion. The nonproductive works chosen to control erosion and reclaim eroded land included (1) fencing out and planting of trees on badly eroded sites, (2) control of headward erosion in gullies with concrete structures, (3) prevention of streambank erosion with groynes and silt traps, and (4) reclamation of salt-affected areas with fencing and planting of salt tolerant species.

The biggest challenge was to develop, on a large scale, practices that would lead to a more productive but stable form of land use. Fortuitously, it was discovered by the Victorian Department of Agriculture that the soils were deficient in molybdenum. At the same time a simple, quick, and efficient system of pasture improvement had been developed that could be used on all but the steepest and rockiest land. A mixture of superphosphate, molybdenum, and lime was sown with subterranian clover (*Trifolium subterraneum*) and grasses, such as Wimmera ryegrass (*Lolium rigidum*) and Phalaris (*Phalaris tuberosa*), which established quickly and easily. The resulting dense, improved pasture, if properly managed, nearly eliminated erosion, and stocking rates were three to four times those possible on unimproved native pastures. On land too steep or rocky to be chisel-plowed, fertilizer and lime-coated clover seeds were spread from the air, and a good ground cover developed.

An economic evaluation

By the end of the project in the early 1970s, the government had invested more than A $1.2 million, and it was estimated that landowners had spent a similar amount. To appraise the project, an economic evaluation was conducted between 1975 and 1977 by an independent consulting company.

Briefly, this evaluation indicated that the interrelated set of soil conservation and farm development activities carried out at Eppalock was a sound investment for the community as a whole. A net present value (1975) of A $2.91 million, an internal rate of return of 25.4 percent, and a cost-benefit ratio of 2.0 were indicated by the evaluation. Without the SCA's involvement, the soil conservation works and land management practices would have been implemented more slowly, the same increases in production would not have been achieved, and the demonstration value to other areas would have been much less.

Why was the project a success?

By the early 1970s, the SCA's objectives in the Eppalock catchment had been achieved. The severely eroded portion of the catchment—830 square kilometers—had been treated. Only an estimated one-sixth of the previous amount of sediment was reaching the reservoir. The sparse, overgrazed native pastures, which suffered from sheet, tunnel, and gully erosion, were replaced by improved pastures and newly planted trees. Farm production had changed from only wool to fat lamb and cattle production. Farm production had increased threefold in many places, and a more stable land use and an effective system of soil conservation, which could be used as an example in other parts of the state, had been introduced.

Reasons for the success of the project are thought to be the following:

► *The time frame:* A period of 10 years was planned; this was extended two or three years. Even 27 years after the start of the project, a skeleton staff remains, advising and helping farmers.

► *Farmer involvement:* Farmers were fully involved in both the planning and implementation phases. Every effort was made to meet the individual preferences and capabilities of the different farmers. That the works could be carried out over a period of years was extremely helpful.

► *The approach to cost-sharing:* Dividing the works into productive and nonproductive elements, coupled with a simple system of subsidies and services, played a key role in the project's success. The fact that farmers contributed as much to the program as did the state convinced the government that its money was being well spent.

► *Assured funding:* The available sum of A $100,000 annually for 10 years meant the project was able to go ahead with a long-term plan. This is a great advantage over a situation where funds must be appropriated each year.

► *The technology:* The project was helped by some new technology in pasture improvement. This technology would, in all likelihood, have been adopted by farmers eventually, but it is unlikely that such a large area would have been treated so quickly, or that new techniques would have been adopted by so many farmers without the technical advice, services, and subsidies the project supplied.

► *Project organization, administration, and staffing:* A simple, straightforward system of command and communication was established with headquarters. Staff responsibilities were clearly defined, and staff members were not burdened with additional responsibilities. Project staff were general soil conservationists/agriculturists, but they were supported by a core of specialized engineers, agronomists, and soil scientists. There were some staff movements during the life of the project, but these were not frequent or excessive. One officer was responsible for both planning and implementation in a subcatchment. This led to an intimate knowledge of the area and to a close, trusting relationship between conservation officers and farmers.

► *Other factors:* A close working relationship developed between government departments at the field level. Also, there was adequate publicity through local television and newspapers and through a documentary film made by a national television station. Finally, a feeling of pride in the project was created among people living in the catchment area.

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Evolution of soil conservation practices on steep lands in Taiwan

Mien-chun Liao, Su-cherng Hu, Hui-sheng Lu, and Kuang-jung Tsai

About two-thirds of the Island of Taiwan is rugged, mountainous country. The central mountain range runs from North to South. Torrential typhoon rains, steep topography, young and weak geologic formations, and erodible soils are unfavorable natural factors contributing to rapid rates of geologic erosion. In addition to these natural conditions, population pressure, diversified cropping, small size of individual farms, abusive cultivation on hills, and socioeconomic pressure for more land makes the soil erosion problem even worse and more complex.

Experience and expertise of countries advanced in soil conservation are not applicable, so Taiwan must rely on its own research and development for much of the technology used in managing its diverse soils and crops.

The soil conservation program in Taiwan has evolved over 30 years. Because a permanent solution to erosion problems was sought during the early phases, a few "safe" practices were given undue emphasis. Then, a multitreatment approach evolved. In recent years, conservation farm planning has been aimed at saving labor, not only for economy of operation and suitability for mechanical operation, but also to integrate soil conservation with farm management.

Early bench terracing

The design of a soil conservation program depends upon the degree of land problems dealt with and the intensiveness of conservation practices relied upon to meet soil conservation needs. To solve the problems of steep slopes, intense rainfall, a long dry season, highly erodible soils, and thus a tremendous amount of soil loss, bench terraces were adopted.

This oldest of soil conservation practices worldwide was considered the most effective means of conserving soil, despite high construction costs.

Because of low wages in the past, extension of terracing was relatively easy from a labor standpoint. The key problems were a shortage of research findings on bench terracing and an apparent lack of more economical and effective measures to replace it as a practice.

Development of a new approach

Based on the results of a series of experiments and concurrent field observations, the practice of hillside ditching with contour farming was considered an effective method for protecting soil from erosion on both pineapple and sugarcane plantations. After demonstration and intensive extension, this became the standard soil conservation measure for these crops. The combined measure is much cheaper and more easily constructed than bench terraces. Also, the traditional concept of no continuous cultivation of pineapple on the same field changed because of yield increases with the new techniques.

From eastern to central and southern Taiwan, hillside cultivation—the application of agronomic methods of soil conservation combined with hillside ditches—became popular. This approach replaced the extension of only bench terracing for soil and water conservation.

Problems of bench terracing and their solution

Several problems plagued bench terracing. The runoff rate from pineapple plots on reverse-slope bench terraces was greater than with other treatments, and crop yields were lower than on contoured land. The high cost of cropping and transportation, damage to inner rows of pineapple by machines on terraces, interference of multirow planting with field work, as well as high construction costs, all posed problems (*4*).

To deal with these problems, a soil conservation research program was initiated to explore (1) methods to develop bench terracing more economically and (2) economical alternatives to bench terracing.

Among the methods used for gradual formation of bench terraces are the following:

► *Vegetative barriers.* A series of grass barriers are planted on the hillside to accumulate the soil transported downslope. This is an economical way to form bench terraces (Figure 1).

► *Rock barriers, where stone is available.* A rock barrier is used to form terraces. Because of the economic advantages of rock removal and use at the site, rock barriers became one of the major practices on the old alluvial land in eastern Taiwan.

Figure 1. Grass barriers will convert to bench terraces gradually.

► *Hillside ditches.* The improved hillside ditch was actually a terrace, and more would be established later between two built ditches to complete a terrace system.

The method used to replace bench terracing consists of the following:

► *Orchard hillside ditches.* These are more economical to build than bench terraces. Orchards at the intervals varied the spacing of fruit trees grown (Figure 2) (*1*). This practice proved to be labor-saving and effective.

Development of hillside cultivation

Soil and water losses were found to be slight from a cover of bahiagrass in citrus and banana plantations. Bench terraces of the level retention type had almost the same effect as bahiagrass on controlling soil and water loss, but other types of bench terraces were not as effective. Positive effects of cover crops and mulching on citrus plantations provided evidence of the feasibility of hillside cultivation.

Improvement of hillside ditches

The application of hillside ditches on sugarcane plantations in 1956 resulted in lower yields. Then, the design of the ditch was modified into a broad, V-shaped cross-section by Mien-chun Liao. The improved cross-section design proved to be hydraulically sound (*2, 3*). The cross-section is more stable, maintenance cost are low, and soil moisture content in the ditch soils is high.

It was found that the improved hillside ditch could be built by bulldozer, while the hillside ditch with a trapezoid cross-section could only be constructed by hand labor. Most importantly, the ditch bottoms of the improved hillside ditches could be cropped (Figure 3), and they could be used as farm roads for small machines, including transportation and pesticide spraying equipment, and for providing drainage. Because of these advantages, the improved hillside ditches were soon adopted on a large scale in many other countries.

Characteristics of cover crops with potential for orchards

Reduced yield of banana was found to be due to the toxicity of centrosema. Bahiagrass, on the other hand, had no negative effect and was more adaptable than centrosema. Evapotranspiration rate of bahiagrass was greater, but water consumption declined significantly after mowing. Soil hydraulic conductivity was also comparatively high under bahiagrass. Therefore, strip-cover and mulching are recommended.

This combined practice, consisting of grass mulching on rows of fruit trees and a strip cover of bahiagrass, is as effective for erosion control as a complete cover. The effectiveness of bahiagrass in reducing soil and water losses was proven on slopes ranging from 46 percent to 58 percent, which indicated that replacement of bench terraces with a bahiagrass cover is practical even on these steep slopes.

Bahiagrass has several favorable characteristics: (1) it is easy to plant and has a high survival rate, (2) it grows rapidly and thus covers quickly, (3) there is no root extension to the mulched area, and (4) there is no interference with fruit trees of a clinging stem.

Application of grasses for soil conservation

Planting or leaving suitable grass species on the riser of terraces can be effective in soil stabilization and good for weed control. Bahiagrass is most effective in erosion control.

Centipede grass, Paspalum spp., and bahiagrass are suitable species for waterways. Weeping lovegrass and guinea grass were used on the front and back slopes of hillside ditches for protection. Bermudagrass and Paspalum spp. were used on the bottom of hillside ditches to prevent weed growth.

Figure 2. Orchard hillside ditches serve as farming paths for farm operations.

Figure 3. Planting sugarcane on the edge of hillside ditches can increase production.

Bahiagrass was suitable for planting on farm roads (Figure 4). The number of grass species available for different situations is increasing.

Alternation of major practices

Following are the revisions made in the second edition of the *Soil Conservation Handbook:* "Orchard terrace" was removed because of its interference with machinery operations. "Individual basin" was abandoned because bahiagrass or *Indigofera spicata* could prevent soil loss and reduce runoff. "Orchard hillside ditch," which is a combined treatment of cover crops, mulching, and hillside ditching with grass planting, is promoted in extension programs. Outward-slope bench terracing combined with hillside ditches and bahiagrass planted on the riser is also included for extension.

Formation of a farming system

Soil conservation practices for slopeland farms, mainly orchards, consist of previously adopted bench terraces and newly developed hillside cultivation using hillside ditches. For areas where bench terracing is desired, such as clean cultivation, cash and high-value crop production areas, and high-altitude hill-land vegetable nurseries, consideration should be given

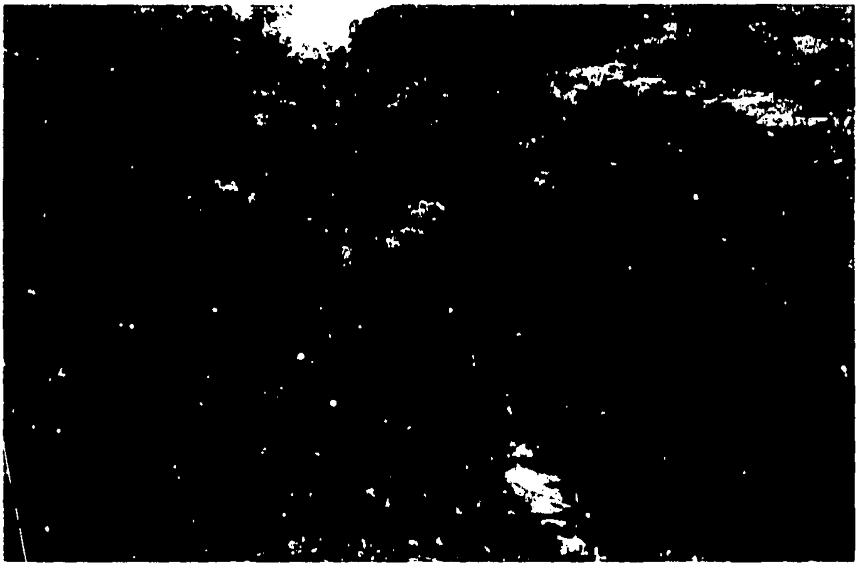

Figure 4. Hillside ditches are stabilized and covered with grass.

Figure 5. Hillside ditches covered with a well-developed stand of grass.

to the layout of road systems for farm machines and to drainage structures and maintenance (*5*).

The new system of hillside cultivation, supplemented with cover crops, hillside ditches with grass planted on side slopes and bottom (Figures 4 and 5), and grass planting incorporated into road systems and grass waterways (Figures 6 and 7), has been applied for overall extension on orchard-dominant slopeland in Taiwan. The systematic installation of these practices is not only effective and economical but can accomplish the objective of labor-saving management through machinery operation.

Conclusion

The design and application of soil conservation practices in Taiwan have been developed into a series of economically effective measures based on the results of long-term observations and experiments. All of the practices applied aim at labor-saving management and the provision of farm road systems, among other things, on modern slopeland farms. Extensive application of grass is a common feature in the practice of bench terrace improvement and new hillside cultivation. Bahiagrass can be used as a cover crop, a waterway crop, and forage as well. Advancement of land use and utilization of the grass resource are simultaneously attained.

Figure 6. Planting grass on farm roads can protect the surface of the road from erosion.

Figure 7. A grass waterway was used successfully on steep slopes.

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Soil conservation in Peru

Jeffrey Vonk

Beginning in 1981, the Peruvian Government, with assistance from the U.S. Agency for International Development, embarked on a pilot project to demonstrate the effectiveness of various soil conservation practices in selected areas of the Peruvian Andes. Soon after the arrival of the project technical advisor, Jerome Arledge, the focus of the project was expanded to shift emphasis from a "testing" activity to an implementation activity. The ultimate goal of the project then became the establishment of a national soil conservation program in Peru.

In addition to the technical advisor and USAID project manager, the project staff consisted of a Lima-based team of technical specialists headed by a project chief. This team assisted the field staff located in 10 different cities in the Peruvian Sierra, from Cajamarca in the North to Puno in the South. Each field office was staffed with two or three paid technicians who were charged with carrying out soil conservation activities in communities within their region. I served as technical advisor to the project after Arledge left the program.

Methodology used

Most people know that Peru has a rich history and tradition in soil conservation that pre-dates Incan times. Unfortunately, for various reasons, many of the Incan terrace and irrigation systems are in disrepair and not in use today. Despite this rich conservation heritage, most Andean farmers needed to be reoriented and trained in the reasons for and use of soil conservation practices in their farming activities.

It is important to understand that the climate of the Peruvian Andes is semiarid. Soil moisture is generally considered the main limiting factor to plant and crop productivity. Erosion control methods generally result in better water management (i.e., more infiltration), which makes more moisture available for plant consumption. This results in immediate and obvious (to the farmer) increases in production. Understanding this, the soil conservation project in Peru followed these basic principles:

- ► Attempt to infiltrate all water where it hits the ground.
- ► Keep all practices simple—the farmer needs to understand and be able to install the practices without a lot of outside technical assistance.
- ► Keep the farmer/landuser directly and actively involved. He or she is the decision-maker and serves as a model for all his or her neighbors.

All conservation practices used in this project were based on the farmer being able to establish a line on the contour. The simplest technology we found to enable the Andean farmer to do this was the basic A-frame level. Once constructed and understood by the farmer, he or she could then establish the contour lines on the farm and, based on these, install the indicated practice(s). In Peru, we used level terraces, infiltration ditches, contour farming, crop rotation (where feasible), and rotational grazing.

All conservation activities throughout the Sierra were community-based. Regional conservationists worked with communities, helping them to organize conservation clubs and women's groups oriented toward soil and water conservation. In most cases, a volunteer soil conservation leader was identified for each community. This person provided leadership for activities in his or her community and was given extra training by paid project staff.

Test-plot methodology was employed by project field staff as a means of selling soil conservation to skeptical Andean farmers. A farmer was normally asked to do a side-by-side comparison, planting a small plot of land in the traditional way and then an equal-sized, adjacent plot using terraces, infiltration ditches, or contour farming.

The crop planted and fertilizer and irrigation practices used (if any) were constant for each plot. The results in nearly every case were dramatic; the conservation plot nearly always yielded more of a crop than the plot planted in the traditional way. This was an effective conservation selling tool because each farmer was involved in his own test plot, and the results were nearly always obvious to the eye without having to take measurements or yield weights. The publication "Impacto de la Conservacion de Suelos y Aguas en la Sierra Peruana," released in April 1986, discusses on a crop-by-crop and practice-by-practice basis the yield increases measured during the 1984 crop year by project personnel. Table 1 consists of data from that publication.

Observations and considerations

Maurice Cook, in his chapter in this book, mentions three aspects or constraints to the successful implementation of soil conservation: information and education, technology, and data.

In the Peru project, an attempt was made to address all of these simultaneously. We placed heavy emphasis on information and education. A media specialist was on staff at the central office in Lima who used all media forms available, both nationally and regionally. Radio was used both for promotional purposes (radio spots) and for announcing regional and national meetings. Newspapers, both local and national, willingly provided space to promote soil conservation, announce meetings, and report the results of the meetings and progress being made in the field.

In the policy arena, the ultimate goal from the beginning was to develop a national soil conservation system and establish that system by law. For this reason, key political figures were always kept abreast of program developments and accomplishments. Special efforts were made to personally brief these individuals and provide them with copies of any manuals, bulletins, and newsletters produced by the project.

A proven technology and methodology was used that allowed for continuous testing, revision, and improvement. It also required active participation by all farmers involved with the program and allowed them, through their own efforts, to evaluate the worth of soil and water conservation practices.

The project in Peru, a government-sponsored program aimed at isolated communities in the Peruvian Andes, also touched on some social and political concerns and values. For the small, isolated high-mountain communities, soil conservation provided a social focal point and activity area.

Table 1. Average crop yields obtained in the Sierra of Peru.

Crop		*Yield on Test Plot (kg/ha)*	*Yield on Treated Plot (kg/ha)*	*Increase*		*Number of Plots*
				kg/ha	*%*	
Level terraces						
Potato	Fertilizer	12,206	17,436	5,230	43	71
	No fertilizer	4,581	11,091	6,550	142	41
Wheat	Fertilizer	2,442	3,603	1,161	48	8
	No fertilizer	723	1,113	390	54	25
Rye	Fertilizer	1,333	1,910	577	43	56
	No fertilizer	740	993	253	34	97
Contour farming						
Potato	Fertilizer	14,312	17,539	3,227	23	99
	No fertilizer	4,750	6,628	1,678	40	15
Corn	Fertilizer	1,121	1,577	456	25	11

Note: Dramatic results were obtained from all crops examined, but the number of repetitions was small in many tests. The complete data can be obtained from the publications cited.

Much of the training and physical implementation of practices was done in group work sessions, providing a community activity that was positive both for the individual and for the community. It was a government-to-people program that provided outreach to the poorest of the poor in Peru's highlands.

While working in these isolated communities, one often heard the comment that the soil conservation program was the first Peruvian Government program to reach out and try to help them. In a country like Peru, with anti-government groups like the "Shining Path" guerrillas, which prey on these isolated communities, the political value of this type of program can be immense.

The final subject for discussion is that of the use of incentives to encourage land users to participate. Based on limited experiences with the Peru soil conservation project, as well as observations of other rural "food-for-work" programs, a general recommendation would be to avoid using incentive payments—especially for soil conservation. In those few areas where incentives (either food or monetary payments) were used by the program, farmers basically missed the point for installing and using conservation practices. They tended to do what was necessary to receive the incentive payment rather than to install conservation practices for the good the practices would provide. The focus became the payment rather than resource conservation and productivity improvement. Once the payment was received or the incentive program removed, conservation work normally ceased.

However, if incentives are to be used, they should be something that is a part of the agricultural production system. In other words, stay away from food and monetary payments, and utilize such things as improved seed varieties, fertilizer, and/or farming tools. In this way, at least the payment is tied to the agricultural process, maintaining the focus on resource management.

Summary and recommendations

It is often difficult to look back and judge definitively whether or not a project, such as the soil conservation project in Peru, was a success or not. By the following measures, I would judge the project to have been quite successful. First, it was, by foreign assistance standards, a relatively inexpensive effort—US $1.6 million over a five-and-one-half-year time frame.

Second, it provided improved technology (albeit simple) to a large number of peasant farmers in isolated areas of the Peruvian Andes.

Third, the test-plot methodology and community-based activity allowed for a multiplier effect; that is, the project directly reached many more people than expected, and those people transferred their newfound knowledge to their neighbors. This multiplier effect is demonstrated by the fact that during the first four years of the project approximately 5,000 test plots were established. During the next one year, 2,500 new test plots were established, all with the same level of project staff and resources.

Finally, when USAID funding ended, the Peruvian Government took over the program and continued the activity without foreign assistance. This speaks well for both the value of the activity as well as having the positive effect of keeping political decision-makers informed about the activity.

Recommendations for future action include the following:

► Continue to seek, develop, and use methodologies and technologies that will keep the labor investment to a minimum (e.g., use slow-forming terrace construction methods as opposed to direct construction methods).

► If one is going to depend upon increased productivity and yield as the incentive for using soil and water conservation (as in Peru), one needs to develop a market for that increased production.

► Simple soil conservation technology in developing nations should become the primary and principal technology used by extension agents in the field. Too often, extension efforts focus on attempting to transfer higher technology without first dealing with the basic soil and water resource management problems.

► Use of low-interest credit programs to assist small-scale, peasant farmers is generally ineffective. Most of these farmers are afraid of these programs because they do not understand them and are generally unwilling or unable to learn about them.

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Community participation in soil and water conservation

Davi Nathan Benvenuti

Colonization of the Toledo region in Parana State, Brazil, began in the 1940s when the area was divided into 25-hectare plots. The plots were set out in long, narrow strips from a watercourse at the lower end to a road along the crest at the upper end.

Initially, the areas were cultivated by hand. Stumps of trees or areas of the original forest remained among the fields. But the soil was fertile, the purchasing power of the farmers was rising, and government incentives were directed toward mechanization. These factors, together with the short-term views of the farmers who came to the new region with the dream of getting rich, were sufficient to ensure that in a few years the area that had formerly been forest was transformed into an area of soya and wheat, even on the slopes of the hills and along the margins of the rivers.

At that point the problems began: pollution of rivers, gullying down the property boundaries, serious sedimentation on the roads after every rain, loss of fertile topsoil, and soil compaction with heavy machinery. As a result, farmers' profitability declined, mainly because of their having to increase fertilizer and lime applications and because of lower yields.

Concern for conservation

There arose simultaneously among both farmers and technical staff a concern about conserving what remained and maintaining levels of productivity to cover the high costs of investments that were being made in agriculture.

On September 9, 1976, by means of the Portaria 670 of the Ministry of Agriculture, Toledo was included in the list of Municipios in which soil conservation became obligatory. This was valuable for instilling in farmers' minds the necessity for soil preservation, but the means of undertaking this obligatory conservation was not defined.

A campaign was developed by the technical community with the objective to solve, once and for all, the problems of soil erosion and environmental pollution. Considering the soil characteristics that predominate in the Toledo region—latosols, which are deep, have good internal drainage, and are flat to slightly undulating topography—the first idea was to build terraces in such a way as to retain all the water within the property. This was successful in a majority of cases. But the problems, such as gullies along the property boundaries, damage to roads, and pollution of rivers, continued.

It was then, after many studies and using the experience of technical staff in the region, that the first trial of integrated conservation was implemented in the Municipio of Nova Santa Rosa by the joint action of the Mixed Crop and Stock Cooperative of West Parana and the local extension office. Working together with the group of farmers in the Planalto community, this trial succeeded, which led to plans for applying the system to small catchments.

Conservation in a small catchment

The program of integrated conservation in small catchments envisages the following:

► Construction of slow-absorption terraces, alternating with broad-based terraces, carefully dimensioned and demarcated after a detailed survey of the area, constructed on the dead level, and ignoring property boundaries so as to retain all rainwater on the property. During construction, each gully or old terrace is filled in and eliminated. Both municipal and private roads are studied and realigned or relocated where necessary. Where a road must cross a terrace, a 'bolster' is constructed so that the road does not interrupt the terrace's effect. In places where terraces encounter home paddocks, forests, or deeply cut roads, their ends are closed to prevent any outflow of water.

► Management of the soil after installation of the terrace system. Where a plow pan occurs, subsoiling is essential to increase water infiltration. Liming and organic manuring must be undertaken in the channels to rejuvenate the soil from which the fertile layer has been scraped away to build a terrace. This assures crop uniformity throughout the field from the beginning. Emphasis is also given to crop rotation, a practice fundamental to soil conservation.

► Replanning the property on the basis of capability classification of the soils. This includes establishment of small paddocks on steep slopes and construction of small dams at the heads of streams, which allows for further use of terrace construction equipment, usually bulldozers.

► Reforestation is increased along river margins, lakes, and springs, with a view to protection of the water and to the preservation and recuperation of the region's fauna and flora, in addition to the production of timber for use or sale.

► Treatment of a small catchment does not end with the construction of terraces. On the contrary, it starts there. The work is slow and step-by-step, with a view, fundamentally, to educate the farmers in the proper use and management of natural resources. The objective is to introduce more complex techniques and practices over time, such as direct drilling and making use of the lowland 'varzeas' (wetlands) that up to now have not been put to use. Also, the work includes the increased use of green manuring and other biological manures (compost, dung, etc.) produced on the property or bought at reasonable prices.

A sequence of activities

Making the work known. The first step is to create a conservation attitude among farmers, alerting them to the specific problems of the region and presenting solutions. This can be done in various ways—television, radio, meetings, posters, and visits to farmers. In the Toledo region, this information was already being disseminated efficiently by the extension service of Parana, prefectures, secretariat for agriculture, unions and cooperatives, and technical community, which enabled work to proceed to the second phase. Farmers who were working alone are now grouping together and calling on the technical staff for more information, or even to install the system. Even so, the attempt to make the work known must not stop. Resistant farmers must also be reached, with a view to achieving complete participation in the region.

Preliminary meeting. Once a conservation attitude has been developed among farmers, a desire for more information follows. The second phase of the process is a preliminary meeting in the locality. Such a meeting should be arranged and run by a technical person who has knowledge of a region's specific problems.

During this meeting, all criteria for the system must be clarified. Leaders can be elected to serve as linkages and as a means of stirring enthusiasm on the part of the community group. The purpose of this meeting is not to obtain an immediate solution to the problems. It serves chiefly to clear up doubts, to form a conservation point of view, and to strengthen the ideas already awakening interest in the minds of the most resistant farmers so that these people will join the system of their own free will.

At this stage, a list can be completed of those who occupy the area to be conserved. The major problems to be studied in more detail are listed, together with the names of the most resistant farmers. Then a more concentrated selling campaign can be undertaken with these farmers, using local leaders or neighbors and visits to specific properties.

Together with this list, a map must be made of all the properties together. This gives a better overview and facilitates the survey of the properties to be undertaken later. Airphotos of the area are used, and custom-made, rectified topographic maps of the properties are made. The layout of the river catchment is defined by the marking of contours.

Meeting for firming up the work. After contacts with local leaders and assurance that all the farmers are aware of the advantages the system offers and of the problems, a meeting is scheduled with the property owners who will be involved to firm up work proposals. In this meeting the costs of implementation are discussed, along with types of machines to be used. It is recommended that, on this occasion, the work be contracted out to firms capable of providing the services required. Addresses of the firms in the region are supplied so as to facilitate the contacts by interested people.

At these meetings, all anticipated operations are decided, such as dividing among farmers the costs of terracing and the costs of filling in the gullies at property boundaries, and the delimitation of each stage of work for the next period in the small catchment. A survey is made of those who are to prepare projects that will justify financing the work. The probable costs of implementation are analyzed. It is then possible to fix a date for the beginning of the work, allowing enough time for the necessary survey work on individual properties.

At the same time, arrangements for maintenance of the system, planting of riverside forest, and possibilities for getting on with execution of soil preparation work, planting, and cultivations, or even joint purchasing of machinery, can be discussed.

Field survey. It is important that each property owner participate in the field survey. In the survey the possibilities of changing roadlines, home paddocks, and defining the manner of closing up the gullies are studied, along with the levelling of old terraces and trash lines. By digging pits, any pans in the soil can be detected and the necessity for any subsoiling decided. At the same time, samples can be taken for analysis. During the same survey, the places to be reforested can be decided and the places for possible building of dams, use of wetland "varzeas," and construction of slurry pits can be considered. The details of this survey are carefully written down for the elaboration of future projects and for checking on the work done. After all the individual surveys are completed, the project plan for the catchment as a whole is developed.

Contact with various bodies. After the field survey, it is possible to define the various bodies that will be involved so the necessary actions can be taken. Conditions of financing, financial resources available, interest rates, and repayment periods will be determined in conjunction with the banks. Possibilities for changing roadlines, construction of culverts, road maintenance, and production of forest seedlings (in conjunction with the Institute of Lands, Cartography and Forests and with cooperatives) will be determined jointly with the prefecture.

Writing up the projects. After making the plan, budgets can be prepared. These budgets are presented in a form prescribed by the Banco do Brasil S/A. The principal items include: (a) identification of the property; (b) income from agricultural activity; (c) inventory of livestock and equipment; (d) technical project for agricultural activity for the period of financing; (e) calculation of costs, defined according to each different operation, to be incurred in the implementation of the conservation system; (f) calculation of capacity to repay, definition of forms of payment, and payback period (usually 1.5 to 2 years); (g) recommendation of adequate technology, as much in the methods of implementation as in the type of machinery to be used, along with the form of construction, maintenance, and management of the system as a whole; and (h) statement by technical staff on the viability of the investment and the benefits it is expected to bring.

Executing the work. Construction work must begin at the upper end of the land.

Spacing of terraces: The equation used for areas of purple latosols is $VI = 0.14\ S + 0.8$, where VI is the vertical interval in meters and S is slope in percent. For slopes of 3 percent or less, VI is 1.22 meters.

Location of terraces: The terraces are set out on the level contour, not permitting the lateral movement of water from one property to another. These are also started at the top of the slope. Stakes are set about 20 meters apart, or nearer if the land is irregular. Each line is marked with a plowcut, and the stakes removed, avoiding problems with stakes being moved or removed by other people.

Choosing the type of terrace: The association of terraces most used are as follows: up to 3 percent slope, only broad-based terraces; 3 percent to

8 percent slope, one "murundum" (high broad-based) to two broad-based terraces; 8 percent to 12 percent slope, one murundum to one broad-based terrace; and 12 percent and above, only murundums.

In cases where the soil is compacted, it is important to subsoil areas on which terraces are to be constructed. Subsoiling improves the output of soil-moving machinery. After terrace construction, it is essential to subsoil along the terrace channels so as to facilitate infiltration and to permit adequate crop root development.

Planning of municipal and local roads: Where adjustments are necessary, planning is done jointly with the prefecture. In-farm and between-property access roads are located exactly on the contour wherever possible. Where this is not possible, it is necessary to minimize the roads that cross terrace lines, although it is always necessary to leave a broader crossing of the murundums at one of the property margins to allow for entry of machinery into the fields.

Checking the activities: The presence of a technician is essential during construction to make sure that the work conforms to specifications and recommendations.

Coordination and technical assistance in maintenance of the system. The Banco de Brasil requires three supervisory visits during the period of financing. For the types of work to be undertaken, however, three visits are insufficient. This is especially so in the first year when changes in soil preparation and natural resources management on the property are encouraged.

Management of terraces: After construction, terraces must be managed in such a way that they do not lose their efficiency. It is possible to cultivate them annually and thereby avoid weeds. Equipment exists for cleaning murundums mechanically. Also, people are alerted to the need for maintaining broad-based terraces during seedbed preparation for each crop.

Management of the soil: This system of conservation ensures that all cultivation is done on the level contour, but it is important that during each visit advice is given on improved farming methods, such as green manuring, organic manuring, and direct drilling.

Reforestation: Part of the plan is the reforestation of river margins, springs, and dams with a minimum strip width of 10 meters. Windbreaks to protect homesteads and home paddocks are also included. Native tree species should be introduced to achieve better ecological balance in the region.

Evaluation. Each stage must be evaluated so as to correct faults before passing on to subsequent stages. In the end, the program as a whole must be thoroughly evaluated to ensure that it operates within the proposed objectives.

Integration. To achieve the expected success of the program, total integration is necessary, both of the community and of institutions. All must work together and with the same objectives.

An expanded program

After the experience in the Toledo region, the work was expanded to the entire region of West Parana. With the results obtained, the state government launched a state program in 1982 that embraces the entire State of Parana. This has produced excellent results, with the involvement of diverse secretariats of the state. The program, called "The Program of Integrated Management of Soil and Water of the State of Parana," is coordinated by the Secretariat for Agriculture, and all of the secretariat's units are involved. The program also has the cooperation of the Association of Agricultural Engineers of Parana, which is the technical coordination agency responsible for training technical staff.

At the regional and Municipio levels, coordination of the work as well as elaboration of projects are the responsibility of the extension service. Together with other organizations, both at the municipal and the state levels existing in the municipality, the extension service is technically responsible for the implementation, supervision, and follow-up of the work undertaken.

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Watershed management in Java's uplands: Past experience and future directions

Achmad M. Fagi and Cynthia Mackie

As one of the most densely populated islands in the world, Java encompasses only 7 percent of Indonesia's land area but contains 100 million people, about 60 percent of the total population. A central range of volcanoes covers approximately two-thirds of the island in hilly, mountainous terrain more than 200 meters above sea level. From 1960 to 1980, the population density on cultivated land jumped to more than 1,000 per square kilometer in some areas. It is now estimated to be 700 to 800 per square kilometer in many areas.

Continuous population pressure has led to an expansion of subsistence agriculture. Such agricultural systems and poor conservation practices are viewed as a major cause of soil erosion and land degradation. The high sedimentation rate in Java's rivers threaten lowland plains mostly in the northern coastal parts of the island, where irrigated rice is grown.

With an increasing awareness of the linkages between upstream land use patterns and the downstream water supply for irrigated rice, and to improve the livelihood of upland farmers, the government of Indonesia has devoted considerable attention to watershed management.

Various strategies have been used to meet this challenge. Currently underway is a research program, the Upland Agriculture and Conservation Project, a joint effort by the government of Indonesia, the U.S. Agency for International Development, and the World Bank.

Present status of Java's watersheds

At present, 33 watersheds in Indonesia are considered to be in a critical state of land degradation. The government has given priority to 13 densely populated watersheds. Among these are the Jratunseluna watershed in Central Java (Jratunseluna is taken from the names of its five major rivers:

Table 1. Average sediment contribution over selected watersheds in Java.

Selected Samples of River Watershed	*Sedimentation Rate (t/ha/yr)*
Brantas, East Java	34
Kalikonto (pre 1979)	34
Kalikonto (1979-1981)	10
Karangkates	34
Jratunseluna, Central Java	
Jragung	38
Lusi	21
Citanduy, West Java	
Citanduy	37
Cimuntur	30
Cikawung	19
Ciseel	15
Range in Java	9-120
Range outside Java	<1-11

the *Jra*gung, *Tun*tang, *Se*rang, *Lu*si, and Juw*ana*) and the Brantas watershed in East Java.

The Jratunseluna watershed is home to about 5.9 million people. It covers 790,000 hectares, of which 105,000 hectares are considered critical land. About 12 million people live in the Brantas watershed, which covers 1.18 million hectares, 150,000 hectares of which are in a critical condition. These two watersheds are the target areas of the UACP, launched in 1984-1985. This effort represents an expansion of the improved approach used earlier in the Citanduy Project in West Java.

Upland agriculture is one of the most marginal of farming practices in Indonesia. Crop yields are usually low because of severe production constraints, especially soil erosion and consequent poor soil fertility. Erosion has received special attention because it influences downstream river characteristics. Sedimentation of waterways represents a serious environmental problem in Java, where there is a great dependency on irrigation for lowland rice production. In addition, all rivers in Java are dammed for hydroelectric power, flood control and other purposes. Although there is little historical data, it appears the rate of sedimentation in the major river systems has increased steadily since the upland forests were converted to plantations during the Dutch colonial administration.

The sedimentation rate in Java's rivers may be among the highest in the world (Table 1). This is due to a combination of the natural erodibility of the soils, the rugged terrain, and land use practices. Table 2 lists the rate of erosion for different vegetative covers on Andosol soil with a 10 percent slope in Ciparay, West Java.

Strategies for watershed management

Previous approach (pre-1980). More than a decade ago, the government of Indonesia began devoting considerable effort to upland management. Primary objectives are to reduce the high sedimentation rates in waterways and to improve the livelihood of upland farmers. This renewed attention comes after a long, successful campaign to increase the production of major food crops. Indonesia has now achieved self-sufficiency in rice, following an impressive annual rise in rice production averaging 4.5 percent over the past 10 years. This success has sharpened the awareness of the threats posed by soil erosion, declining land productivity, floods, and drought to the sustainability of past agricultural advances.

Starting in 1976, new programs were initiated to counter this trend. Reforestation programs were initiated on both state and private land. The major thrust on state land has been to allow annual cropping by subsistence farmers for the first few years of timber plantation establishment (e.g., teak, pine) in return for planting and maintenance of tree seedlings. This program has had limited success because of the poor quality technical inputs (such as seed), the lack of cooperation by farmers (who prefer to cut the tree saplings when they start to compete with food crops) (*4*), and poor economic incentives to participate.

Reforestation of private land (called the regreening program) is funded

Table 2. Erosion levels and runoff under various vegetative covers on Regosol soil, 10% slope, Ciparay, West Java.

Crop Cover	*Erosion (t/ha/yr)*	*Runoff (%)*
Potatoes planted up-and-down slope	136.1	17.3
Grasses	0.2	0.7
Contour potatoes planting	43.5	14.3
Onion	11.0	6.2
Onion planted on terrace	3.1	4.7
Forest	0	2.0
Trees without shrub	29.1	33.0
Trees without shrub, mulched	1.0	9.0
Shrub, mulched	0.4	7.3
Trees, cultivated underneath	27.1	36.8
Trees, cultivated and mulched	6.8	13.1

Table 3. Effects of soil and water conservation techniques and cropping patterns on soil erosion and runoff in Oxisols, Citanduy watershed, West Java (1984-1986).

Soil and Water Conservation Techniques	*Cropping Patterns*	*Erosion (t/ha/yr)*	*Runoff (m^3/ha/yr)*
Bench terrace Cultivated areas	Upland rice + cowpea + corn – cowpea + soybean – peanut + corn	1.5	21,646
Risers	Brachiaria grass		
Ridge terrace Cultivated areas	Cowpea + corn + Brachiaria – cowpea + corn + Leucena	5.7	49,635
Ridges	Brachiaria grass		
Individual terrace with Gliricidea strip	Centrocema + corn – cowpea corn + Brachiaria grass	9.6	48,732
Farmer's technique Cultivated areas	Upland rice + corn + cassava	12.6	42,634

by the Ministry of Forestry and administered by provincial and district governments. It originally focused on disseminating fuelwood and other tree crops for farmers to plant in their upland fields. The response was disappointing; farmers frequently cut trees when they began to interfere with food crops or planted the trees in their home gardens. Marketing prospects also proved uncertain, particularly because many of the tree species produced low-value products.

The regreening program was more recently revised to focus on bench terracing on the more gentle slopes (less than 50 percent) and accompanying food-crop-based cropping systems. Several foreign assistance projects were initiated to help develop a technological package for upland areas and to promote more integrated watershed management planning. This was demonstrated in the Bengawan Solo River Basin in Central Java, supported by the Food and Agriculture Organization (*3*). Subsidized demonstration farms, the dissemination of seedlings and other inputs for expansion areas, and on-farm research were undertaken.

Present approach (post 1980). That early effort has led to development of a model farm system in the Citanduy Project funded by USAID. The system is based on an intercropping of cassava with corn, upland rice, and peanuts, using improved varieties, and on the feeding of Brachiaria and Setaria grass to goats and sheep. Grasses are planted on terraces (risers) (*1*).

In the case of Citanduy, the dryland terrace system has spread throughout the basin and measurably reduced the rate of surface soil erosion (Table

3). However, the export price for cassava has risen sharply of late, which is inspiring farmers to return to their previous system of land cultivation. This reversal calls into question the extent to which underlying problems and constraints facing farmers in the uplands are being addressed. The watershed management efforts have also been plagued by poor coordination with local government, leading to delays and conflicting extension programs. A further problem has been reliance on a single farming model for a diverse set of physical and socioeconomic conditions. The siting of project activities, for example, has often proved inappropriate for both technical and economic reasons.

Experiences from the Bengawan Solo and Citanduy Projects have inspired a more comprehensive approach in the UACP for improved management in the Jratunseluna and Brantas watersheds. Realizing that upland agriculture faces more complicated environmental, biotechnical, socioeconomic, and institutional constraints, integration of activities and responsibilities has been encouraged at the national, provincial, and district levels.

In the field, farming systems research and sustainable upland farming systems were started at the same time and will end in the same period. Prime concerns of the research are to develop site selection criteria and soil and water conservation technologies, as well as mechanisms for

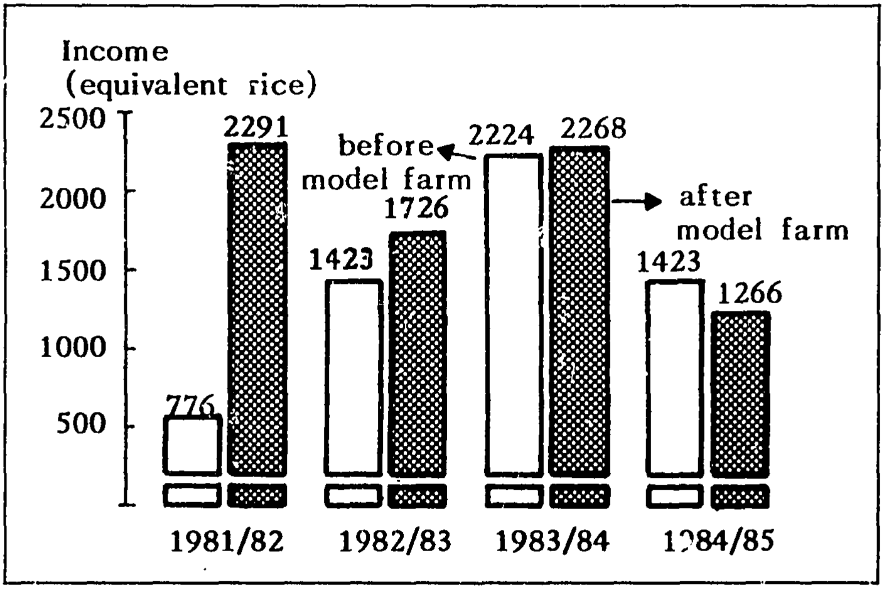

Figure 1. Comparisons of farm income before and after model farm, Citanduy watershed, 1981-1982 through 1984-1985.

Table 4. Farming systems, including soil and water conservation packages, tested at family systems research sites, Jratunseluna watershed, Central Java and Brantas watershed, East Java, 1985-1986, 1986-1987.

	Effective Soil Depth					
	>90 cm		*90-40 cm*		*>40 cm*	
Slope (%)	*Low Erodibility*	*High Erodibility*	*Low Erodibility*	*High Erodibility*	*Low Erodibility*	*High Erodibility*
<15	B*	B	B	B	C	C
15-30	B	B	B	C	C	C
30-45	B	C	C	C	C	D
>45	D	D	D	D	D	D

*B, bench terrace: 75% food crops, 25% perennial crops plus livestock.
C, ridge terrace: 25% food crops, 75% perennial crops plus livestock.
D, contour alley cropping, nearly 100% perennial crops.

technology transfer aimed at the adoption and expansion of sustainable farming systems.

Some results and their evaluation

An evaluation of the farming system model demonstrated on the model farm in the Citanduy watershed has had uneven success. Crop production after the model farm was developed was much higher than before the model farm in 1981-1982. From 1982-1983 through 1983-1984, the production gap narrowed; in 1983-1984 the gap was negative (Figure 1). It was reported recently that the productivity on successful model farms declined sharply after a few years.

Figure 1 suggests that bench terracing may reduce surface soil erosion at the expense of soil fertility. Based on this result, slope, effective soil depth, and erodibility were used to improve farming system models (Table 4).

The research conducted to date suggests the criteria system is still imperfect for classifying land and recommending appropriate soil conservation technologies. In particular, the appropriateness of bench terracing does not seem to be predictable by the slope, soil depth, and erodibility criteria only.

Economic analysis of cropping system models developed on two land categories in Klari showed that introduced cropping patterns in bench terraced plots with gentle slopes (less than 45 percent) increased productivity. Contour alley cropping in plots with steep slopes (greater than 45 percent) had low productivity because a thick canopy of trees reduced space for food crops. Variation in productivity was observed within the bench terraced plots, indicating heterogenuous soil fertility.

A contrasting pattern of soil erosion was observed at the Srimulyo farming system research site, Malang, and the Sumberkembar farming system research site, Blitar, which are located in the Brantas watershed. Bench terraces resulted in lower soil erosion than ridge terraces at both sites. However, bench-terrace expansion in Sumberkembar should be done with care because it has a high risk of collapsing after a long period. This is because of the high limestone content in the subsoil and because montmorillonite clay causes instability.

Not all farmers have uplands suitable for bench terrace farming systems. Therefore, a more holistic solution has to be explored, rather than focusing exclusively on the uplands. This may be done by improving production potentials of other agricultural resources. Figure 2 shows that upland

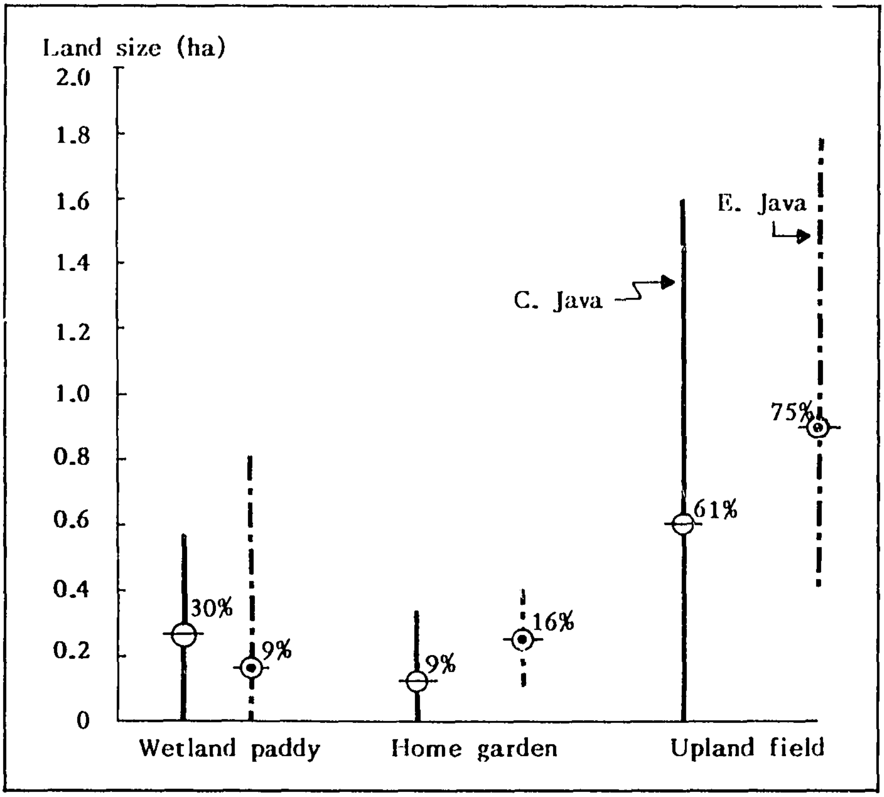

Figure 2. The range in land holdings (average of 12 communities), each in Jratunseluna watershed, Central Java, and Brantas watershed, East Java. Proportion of total land owned for each field type is shown by percentages.

farmers also have wetland paddy and home gardens, which are more stable in terms of soil erosion and productivity.

Future directions

Watershed management in Java poses tremendous difficulties because of the island's high population density, rapid rate of soil erosion, and the diversity of physical and socioeconomic conditions. The experience gained in Indonesia to cope with this challenge is pertinent to other Asian counties and elsewhere in the humid tropics. The following research issues are emerging as the most important to tackle if farming systems research is to provide UACP with the necessary information and guidance to stimulate soil conservation and to improve farm income.

Developing suitable farming system models for different upland conditions. The concept of a single agricultural package that can be easily disseminated throughout the uplands has proved unrealistic. Instead, the great variability in topographic, soil, and other physical conditions needs to be accounted for in planning a system. Of special importance is the development of better criteria for determining appropriate soil conservation technologies in the uplands. Additional field studies are needed to develop alternatives to bench terracing on problematic soils. Of particular interest is the potential of different leguminous cover crops for land stabilization and fodder production.

More attention to "indirect" means of watershed protection. The importance of upland fields as one component of a larger farming system is convincing us that more attention needs to be placed on lowering the risk of agricultural intensification. This requires a reconsideration of where agricultural interventions should be focused, including the potential for improving home garden and sawah production. This would meet upland household subsistence and other financial needs without increasing pressure on critical uplands. For this reason, we are devoting more attention to low-input agroforestry and silvipasture systems that can stimulate rural industries in, for example, postharvest processing.

Understanding household decision-making. One of the recurrent weaknesses of watershed management programs in Java has been the lack of understanding about why farmers are not always eager to adopt superior soil conservation technologies that promise to increase upland productivity. We are discovering that conventional surveys cannot provide the answer without supplementary studies that take a problem-oriented approach. For example, a study of labor mobility will elucidate how off-farm activities by households affect agricultural decision-making. Another topic of importance is the allocation of labor within upland households. The role of women as managers of tree crops or as collectors of fodder, for example, still needs to be investigated. This will facilitate the extension program so that the appropriate household members are contacted.

The diversity of existing agricultural systems in the uplands remains poorly documented. An inventory of agroecosystems and existing tree cropping and silvipasture practices will help identify how upland communities are now managing their natural resources. This inventory will employ the agroecosystem analysis and rapid rural appraisal techniques developed by KEPAS (Agroecosystems Study Group) to create a typology of agricultural practices. By using a problem-oriented approach, the inventory process is also expected to reveal the key environmental and socioeconomic constraints to sustainable agriculture in the uplands, particularly to agroforestry and silvipasture systems on the most critical lands. Particular attention will be given to analyzing the "best" and "worst" land use practices in the project areas. The "best" practices will help guide on-farm and field laboratory research and provide clues to the costs and benefits of different agroforestry and silvipasture systems. By understanding why farmers use "worst" practices, specific steps can be taken to overcome these constraints.

Economic aspects of agroforestry/silvipasture. Special attention is needed with respect to the economic prospects of different perennial crop commodities and livestock raising. The agroforestry and silvipasture elements of the upland farming systems are the least well-known, but the most important for ensuring long-term soil conservation and agricultural sustainability. There are high risks associated with tree crop research because of the long lag time between planting and research results. If the research is misdirected, many years of effort are lost. There is an imperfect understanding of current patterns of fuelwood and fodder collection by upland households. This information is critical, as well as that about commodities, if research is to test appropriate species and practices.

A related issue is how to improve the economy of scale of perennial crop production so that upland farmers are producing enough of a particular product to serve the demand of a local factory or market. Presently, a chaotic array of crops is planted, and there are poor connections between small-scale farmers and rural industries. One strategy we are exploring is the possibility of localized zones (perhaps on the scale of sub-districts) of tree crop specialities. This approach has to be carefully balanced against the need to avoid the risks of monocultures. The prices of many tree crops, such as coffee, historically have fluctuated from year to year, bringing hardship to farmers who rely too heavily on one commodity for income. There is also a need to reappraise the economic policies that act as constraints to small-scale commercial production of tree crops. Price supports, the lack of credit, and other policies seem to act as disincentives for farmers.

Overcoming institutional constraints. Among the greatest challenges we face are the many institutional constraints to cooperative research and development in the uplands. The problems of upland conservation cut across sectors and involve inherent conflicts between the goals of different government institutions. It is becoming evident that farming systems research must take active measures to overcome these constraints rather than just passively observe them. The technical expertise in Indonesia is difficult to draw from because of historical rivalries between different disciplines, most notably agriculture and forestry. The exchange of information between universities and government research programs is also weak. We are actively exploring mechanisms to overcome this problem by concentrating on cooperative efforts in the field and technical workshops.

A similar difficulty arises with interaction between researchers and extension agents. The research component of UACP is managed by the Agency for Agricultural Research and Development, a line agency. Extension efforts are administered by provincial and district governments. By physically locating research sites adjacent to model farms (or even on them), as well as by organizing joint training programs for junior staff, we hope to break down some of the traditional barriers of communication between research and extension.

Summary

Most of Java's watersheds are in a critical state. Immediate actions have to be taken to prevent more losses due to severe sedimentation of rivers and reservoirs and consequent reduction of water supply for rice and electric power, flood damage, and drought hazard. Surface soil erosion reduces soil fertility and land productivity, which, in turn, incites upland farmers to further open virgin land for food cultivation, fuelwood, grazing, and so forth. Most importantly, negligence of upland farmers who are poorer than farmers staying in lowlands with better living facilities may increase social and security problems.

Previous approaches used to improve watershed management and utilization (reforestation and regreening) were unsuccessful. Through better understanding that food security and cash are prime concerns of upland farmers, a farming systems approach has been followed in the Upland Agriculture and Conservation Project, which is jointly funded by the government of Indonesia, USAID, and the World Bank. The main objectives are to increase farm income and reduce soil erosion. Integration of activities and responsibilities of various government agencies is initiated at the national, provincial, and district levels.

The Agency for Agricultural Research and Development, Ministry of Agriculture, is responsible for development of farming systems and soil and water conservation technologies. Land slope, effective soil depth, and erodibility are used to select the most suitable soil and water conservation techniques in combination with optimum composition of food crops, perennial crops, and silvipasture-livestock systems.

Preliminary observations on various combinations of conservation techniques and cropping systems indicated that the criteria used were still imperfect. The appropriateness of bench terracing did not, in particular, seem to be predictable by slope, soil depth, and erodibility criteria.

In most locations, however, preliminary data showed that land suitable for bench terrace farming systems was most productive, but not all farmers have uplands for such systems. Therefore, a more holistic solution must be explored, rather than focusing too exclusively on the uplands. Income does not derive from uplands only, but it is a total from upland, wetland paddy, and home gardens. The latter two are relatively more stable in terms of productivity.

The UACP is relatively short-term (until 1991), while the areas to be covered are large. For the purpose of expanding sustainable upland farming systems, an inventory of agroecological potential, site selection criteria, improvement of conservation criteria, and mechanisms for the adoption of technology are the focus of research.

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The Natural Resources Management Project in Honduras

Frederick Charles Tracy

Honduras, the second largest country in Central America with an area of 112,088 square kilometers, is also one of the poorest in Latin America in terms of people's standard of living. The rural population, which constitutes almost two-thirds of the country's approximately 4 million people, is growing at an annual rate of 3.3 percent. Owing to this growing population and the expansion of export commodities (bananas, beef, and sugar) that have displaced corn production on flat land, smaller landholders have been forced onto marginal land, especially hillside areas. In these areas the well-being of rural families as well as natural resources are degenerating because of inadequate conservation practices.

The pressure on hillside land in the central and southern regions of Honduras increases with each passing day. Although some farmers use one or more improved techniques, a majority still employ traditional agricultural systems. The lack of incorporation of conservation practices has resulted in severe degradation in the upland watersheds of the region. Investigation has shown that rural farmers worry little about the soil erosion problem and rarely understand the cause-and-effect relationships involved. This indicates the necessity of an intensive campaign to raise consciousness before prescribing conservation activities.

Soil conservation in Honduras

In the last 10 to 15 years, numerous projects have promoted soil conservation in Honduras, as in the neighboring countries of Guatemala and El Salvador. Hundreds of farmers have received training and tried one or another conservation practices on their land. These experiences have clearly demonstrated that farmers are capable of learning and applying conservation practices, substantially reducing soil erosion on their fields and realizing significant yield increases within their production systems. However, exploitation of marginal hillside land remains not only a national problem but an increasingly regional concern as well.

Strategy of the Natural Resources Management Project

The principal focus of the soil and water conservation component of the Natural Resources Management Project is the transfer to the farmer of the understanding and skills to incorporate appropriate soil and water conservation practices into his production system. Analyzing the experiences of other projects in the region, certain criteria have been identified that are aimed at maximizing farmer participation in the learning process, trial, and adoption of conservation practices at the farm level. The most important criteria for a conservation program include:

- Participation by the farmer in the analysis, selection, and realization of the practices.
- Use of practices that are compatible with the farmers production system and produce rapid, positive results.
- Use of a practical training system, easily understood by the farmer and readily transmitted to other farmers by him.

A procedure for the conservation of a field

The basic principal in implementing conservation systems is to not present a fixed package but rather a selection of practices from which the farmer can select the combination that best fits the conditions of his land and his personal resources. Soil conservation practices for small hillside farms should integrate conservation structures and agronomic measures to protect the soil and sustain or improve its productive capacity (Figure 1).

On small hillside farms, the most important conservation structures can be grouped into three categories: barriers, ditches, and terraces. The structures used in the Natural Resources Management Project include live barriers, hillside ditches, individual terraces, drainage canals, rock walls, narrow-base terraces, bench terraces, and rock check-dams. The agronomic measures most widely accepted by farmers are contour cultivation, application of organic fertilizer, conservation tillage, and agroforestry practices.

Application of the conservation methodology: Some results

A soil conservation methodology incorporating this procedure has been implemented since 1984 in a majority of the project area. Results of a questionnaire involving 170 farmers/participants on the impacts of the Natural Resources Management Project showed that beneficiary farmers had achieved a high level of learning in the technical and practical aspects of erosion control measures. For example, 97 percent of the farmers acknowledged that the principal advantage of conservation structures is not an increase in productivity but the control of erosion. Also, 75 percent of those responding felt capable of marking contour lines for the construction of ditches and terraces.

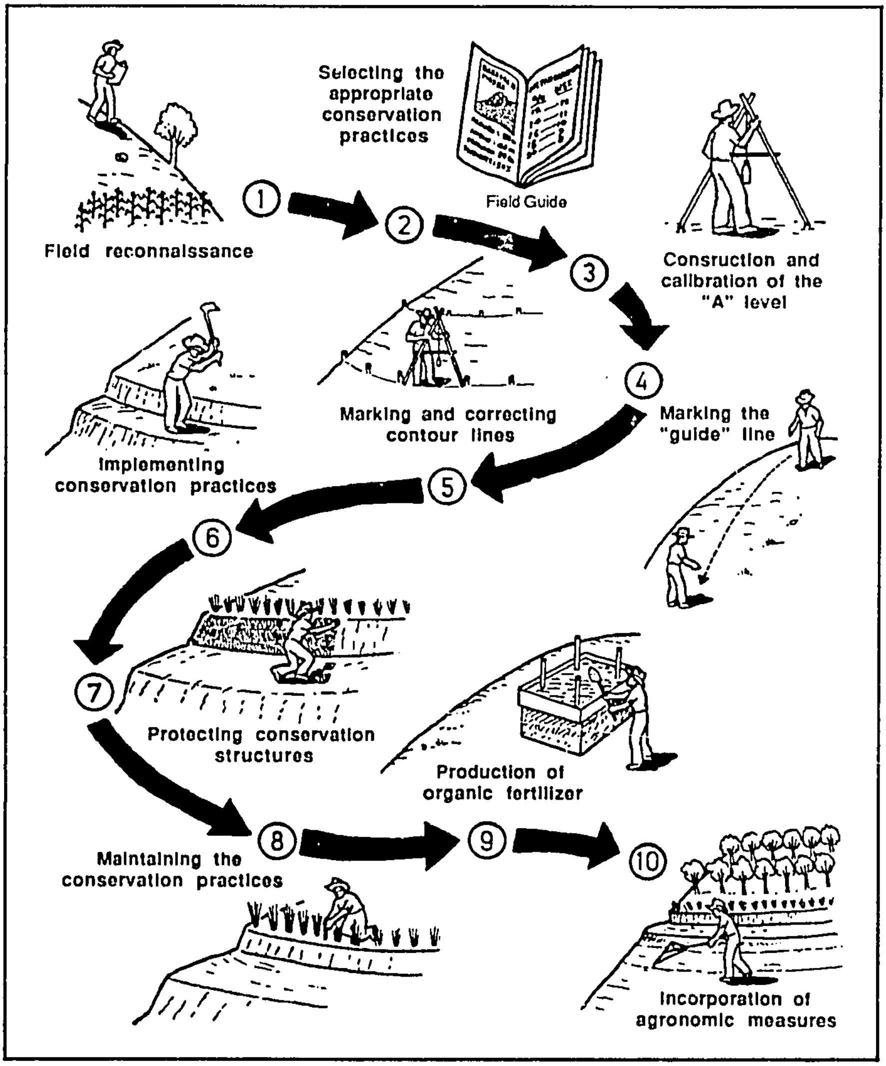

Figure 1. Systematizing the conservation of hillside fields.

The challenge of transferring a conservationist mentality to farmers and providing them with the knowledge and skills to modify inadequate land use practices continues to be very real, especially on marginal hillside land. Conservation systems must be further simplified; greater emphasis placed on practices that produce higher, more secure yields (i.e., mulching, green manuring, productive live barriers, and agroforestry); and greater effort placed on transferring knowledge and skills to farmers.

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Erosion research on steep lands in the Dominican Republic

Rafael A. Veloz and Terry J. Logan

Water erosion in the Cordillera Central of the Dominican Republic is severe because of cultivation by small subsistence farmers of soils on slopes from 20 to 50 percent. Slash-and-burn techniques are used to clear the land, followed by clean cultivation of mixed annual crops.

Conservation practices are seldom used, although conservationists have been experimenting with a number of cross-slope practices, such as rock walls, grass strips, and hillside ditches. Terraces are not suited to these soils because of their shallow depth (often less than 30 centimeters).

A soil and water loss study

An experiment was established in 1984 to measure runoff and erosion in the Rio Ocoa watershed of the southern Cordillera. Ten plots, each 15 meters long and 3 meters wide, were established side-by-side on a shallow soil (20 centimeters deep, loamy mixed iso-hyperthermic Typic Troporthent) with a 30 percent slope.

The treatments consisted of a mixed cropping system of groundnuts (*Arachis hypogea*), maize (*Zea mays*), beans (*Phaseolus vulgaris*), and pidgeon pea (*Cajanus cajan*) with clean cultivation and the following conservation practices: rock wall, grass strip (*Cymbopogon citratus*), hillside ditch, and hillside ditch with grass strip. Other plots included mixed cropping with clean cultivation but no fertilizer, mixed cropping with no tillage, mixed cropping with minimum tillage, pasture (*Panicum maximum*), and bare soil.

Surface cover a key

A total of 58 events were sampled in 13 months, during which time cumulative rainfall was 1,530 millimeters. Table 1 summarizes soil and

Table 1. Soil and water losses from 10 cropping/conservation treatments, Cordillera Central, Dominican Republic.

	Treatment			Cumulative Runoff (mm)	Soil Loss (tons/ha)
Plot	*Crops*	*Tillage*	*Conservation Practice*		
1	Mixed (no fertilizer)	Typical	None	166	187
2	Mixed	Typical	None	102	133
3	Mixed	No-till	None	11	2
4	Mixed	Minimum	None	45	46
5	None	Bare plot	None	579	1,254
6	Guinea grass	None	None	19	3
7	Mixed	Typical	Rock wall	142	163
8	Mixed	Typical	Grass strip	121	133
9	Mixed	Typical	Hillside ditch	171	127
10	Mixed	Typical	Hillside ditch/ grass strip	111	81

water losses on the 10 treatments.

These preliminary results show that rainfall erosion is great on these clean-cultivated, steep soils in the Cordillera of the Dominican Republic (and certainly on the steep lands of Haiti as well). The only viable approach to erosion control on these steep, erodible soils appears to be maintenance of surface cover, either by conversion to pasture or through residue management. The conservation practices alone do not reduce soil loss to anything near acceptable limits. The question that must be answered, therefore, is whether residue management alone provides sufficient erosion control or whether, when this treatment is taken to the field, additional practices are required to make it effective.

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Soil erosion and conservation on steep volcanic soils of Santiago Island, Cape Verde

L. Darrell Norton

Soil and water losses on Santiago Island, Cape Verde, are severe because of the island's steep slopes and intense, erratic rainfall. Those soils with an erosion hazard are on steep slopes and very shallow, generally less than 1 meter to bedrock. Many areas once cropped have been abandoned due to the loss of the entire soil profile. Infiltration in these areas is negligible, and catastrophic runoff occurs often.

In areas where cultivation is still possible, hand tilling and planting maize (*Zea mays* L.) disturbs the soil and leaves it very loose. After emergence, weeds are removed and stones are placed in small piles. The areas between the stone piles are smooth and susceptible to splash detachment and overland flow. Surface sealing is extensive, making the infiltration rate very low.

Current efforts to control runoff and soil erosion start at the bottom of a watershed with the construction of large check dams and gabions to retard runoff and sediment discharge into the channels. Control work ends with the construction of small rock walls or calderas on the contour for planting trees. Overland flow often concentrates and small gullies develop. These coalesce to form larger gullies with a flow energy sufficient to breach the structures. In 1984 half the check dams on Santiago Island washed out in one catastrophic rainfall event. Removal of sediment deposited on roads and repair of washed-out roads are major financial burdens on the Cape Verdean government.

Three paired watersheds with different practices were established and monitored for soil and water losses by Food and Agriculture Organization scientists (*3*). The universal soil loss equation was applied to the study watersheds by Mannaerts (*2*). He found that estimates using the USLE were inconsistent with actual watershed data, even using a sediment delivery ratio.

In a new study now underway, three computer models that operate on the IBM personal computer were chosen, in addition to the USLE, for testing the effects various conservation practices are having on a watershed. These models are ANSWERS [Areal Nonpoint Source Watershed Environment Response Simulation (*1*)], Guess [Griffith University Erosion Sedimentation System (*4*)], and EGEE (Ephemeral Gully Erosion Estimator (*5*)].

In addition, five sets of standard Wischmeier runoff plots have been established on the Mannaerts watersheds to gather soil and water loss data for input in the models. The treatments in these plots stress rough tillage for more surface storage and leaving the stones undisturbed for surface cover. This new study is just getting underway. Results will be reported as they are forthcoming.

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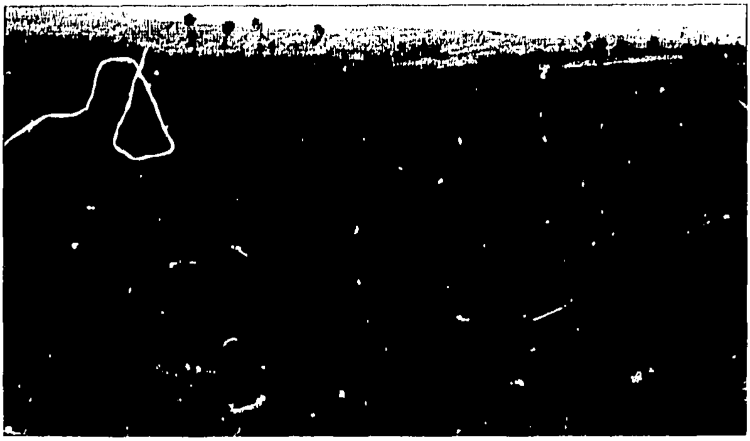
VI

SUMMARY



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Soil and water conservation on steep lands: A summary of workshop discussions

D. W. Sanders

The conservation-on-steep-lands workshop in San Juan, Puerto Rico. was a particularly lively workshop in which every participant became involved in the discussions. Many different aspects of soil and water conservation on steep lands were raised. These varied from broad methods of approach and fundamental principles to debate on the relative benefits of some specific practices. But the recurring themes that ran throughout most of the discussions were to be found in these questions: How can soil and water conservation be applied more effectively on steep lands? What are the factors that lead to successful soil and water projects? Conversely, what are those factors that can lead to failure?

Following is a summary of the main points that came out of these stimulating discussions.

Some general conclusions

First, no matter whether we are dealing with high or low rainfall regimes, densely or sparsely populated zones, sophisticated and advanced farmers or poor subsistence peasants, the basic principles and approaches need to be much the same. On the other hand, the necessary practices to bring about soil and water conservation tend to be site-specific.

The criteria for successful projects can, therefore, be applied under any conditions. However, there is no simple package of conservation practices that can be taken and applied anywhere or everywhere; these need to be carefully developed to suit the particular ecological, economic, social, and political circumstances in which they are to be applied.

Second, a close and often intricate relationship usually exists between the different forms of land use in any area. This is particularly so in developing countries, where land users, be they arable farmers or graziers, or foresters, may have different rights and may use the same land in different ways. For example, in many parts of Africa and the Middle East, a landowner only has control over his land while a crop is growing. Once the crop is harvested, anyone may bring his or her animals to graze the residues. This, of course, may make desirable practices, such as stubble mulching, difficult if not impossible. This points to the necessity for carefully considering local customs, traditions, and relevant laws in developing and implementing projects, wherever they may be.

Third, in most countries there is now growing and sometimes fierce competition for land for different uses. In Ethiopia, for instance, only 3 to 4 percent of the land remains under forests, although the demand for fuelwood and timber for building is rapidly increasing. In some other countries more than 10 percent of the land is now taken up for buildings, roads, airports, and other forms of nonagricultural use. Such factors are leading to increased competition for land and a need for all governments to evaluate carefully their land resources, assess their present and future requirements, and then carefully plan for the wise and rational use of the land that is available. Failure to do this will only lead to land exploitation, degradation, and poverty.

Fourth, water management must be seen as one of the keys to soil conservation on steeply sloping land. While generally the aim must be to increase infiltration, due attention must also be paid to the safe disposal of excess water. Particular care must be taken on those soils that are subject to mass movement or that are vulnerable to leaching. There is also the special case of crops that require good drainage, for example, yams that workshop participants saw grown on ridges on very steep slopes in Puerto Rico.

Fifth, the effects of macroeconomics on farmer behavior and, consequently, land use were stressed. Although this subject is normally well outside the control of the normal field practitioner, he or she should always bear in mind the effects that a change in the price of a particular crop, the shortage of a vital input, or the lack of a market can have on the way a farmer responds.

General approaches to soil and water conservation

There was general agreement that few land users are interested in soil and water conservation from the standpoint of controlling or preventing erosion. Directly or indirectly, the land user, whether he or she be involved in growing crops, livestock production, or forestry, is interested in biomass production from the land. However, the most effective way of controlling and preventing erosion undoubtedly is to ensure that the land is densely covered with vegetation.

The logical approach to soil and water conservation, therefore, lies in assisting the land user to produce and to manage biomass effectively. This leads to the conclusion that soil and water conservation should be looked upon and tackled as the desirable side effect of improved land use and of biological production.

The question then arose as to what circumstances would induce the land user to change, not just his or her attitude, but his or her behavior so that the required changes in land use and increased vegetative production are achieved. From the discussions it would seem that, short of coercion, the land user will only change his or her usual practices if he or she perceives that the changes will minimize risks, increase income or make yields more reliable, and/or reduce inputs, be these inputs of money or labor.

The prime efforts of the soil and water conservationist should, therefore, be channelled into assisting the farmer to increase and manage the vegetation that he or she produces on the land.

While the production and management of vegetation is of paramount importance, the supplementary need for physical conservation measures must not be forgotten or underrated. For example, in many circumstances it is impossible to produce crops on steep slopes without the use of at least some physical conservation structures.

Criteria for success

Many workshop participants were keen to examine and discuss the factors that they believe played an important part in attaining the objectives of the projects in which they had been involved. From these discussions it was possible to develop a list of factors that it was generally agreed were needed if a project was to succeed. Similarly, it was possible to gather a number of factors that it was generally claimed would hinder or even prevent a project from succeeding. While these factors are given below with a little detail, it is worth mentioning that factors most cited as essential elements for success in many presentations and discussions were the need for long-term programs, flexibility in project design, and the need to involve farmers at all stages of planning, implementation and maintenance.

There was general consensus that the following factors must be taken into account if any soil and water project is to meet with a reasonable degree of success:

► The project or program must be long-term. Short-term projects seldom achieve much. The reason is that successful soil and water conservation practices involve the introduction of changes in farmers' behavioral patterns. (The point was made that it is not enough just to influence attitudes; actual behavior patterns must change.) Because change is a process, time is important.

► To ensure the full participation of the farmer (and local administration), the project must address needs that are perceived by the farmer to be relevant and important. It was stressed that in doing this appropriate forms of communication must be used. (It was interesting to hear that forms of mass media, like television, had been relatively ineffective in getting farmers to adopt conservation practices).

► A project, to succeed, must offer short-term benefits to the farmer. Farmers frequently cannot afford to wait for long-term benefits from their activities and are seldom prepared to undertake soil and water conservation for some altruistic or off-farm benefit that does not affect them directly.

► The need for flexibility in a project was stressed by many participants. It was suggested that any project should frequently and regularly review its own progress and then change and adapt its program as it proceeds. Such a procedure implies a built-in system of monitoring and evaluation. A number of participants warned against starting projects that set out with rigid objectives and target figures.

► Projects tend to be successful when they only attempt to expand gradually and systematically. The rate of expansion must depend upon the rate at which land users are prepared to change and the facilities and manpower of the project.

► Although there was not a clear consensus of views on the subject, it would seem that the existing land tenure system can have an effect on the success or failure of a project. Obviously, a farmer who is likely to be evicted from the land he or she is working is not likely to be interested in investing heavily in conservation practices. On the other hand, participants did report on successful activities in different countries where various land tenure systems are in operation. Perhaps the lesson to be learned from this is that any soil and water conservation project must be fully aware of and understand the local land tenure system and then tailor its program to fit in with that system.

► Full use should be made of existing organizations and administrative structures. and projects should aim at developing these. Several participants warned against projects that aimed at establishing new units within governments. These units frequently collapse at the end of a project. It was recommended that projeccts should make full use of nongovernmental and volunteer organizations where possible; through these, projects can be helped to expand and to attain continuity.

► The actual conservation practices presented must be seen by farmers as ways of minimizing their risks, increasing returns, reducing labor, or taking the drudgery out of farm life. Furthermore, the suggested practices should normally fit easily into the prevailing farming systems and be within the physical and managerial abilities of the farm family. This does not mean that completely different farming systems should not be considered if they are likely to be effective and acceptable to the farmers.

Conversely, it was agreed that failure is likely to result if soil and water conservation projects and programs:

- Do not adequately consult the farming community.
- Do not consider the short-term needs of farmers.
- Do not provide for maintenance and follow-up to conservation works.
- Attempt to expand the program too rapidly.
- Do not have flexibility.
- Create political antagonism.

Although most, if not all, of the criteria needed for a successful project may appear obvious, it was clear from the discussions that few projects do in practice start with a design that meets all of these requirements. On the other hand, most projects appear to contain at least one of those factors that make success difficult.

Soil and water conservation practices for steep lands

Although soil and water conservation practices were discussed to some extent, the only clear conclusion that could be drawn is that practices tend to be site-specific and must be tailored to fit into local farming systems, markets and supply systems, customs, and environmental conditions.

Agroforestry was discussed in some detail. From these discussions it would appear that agroforestry does have potential under all agroecological conditions, even though some object to the term agroforestry as inappropriate and would rather just talk about the use of trees and shrubs in farming. In any case, before agroforestry is generally accepted by farmers, a number of problems will have to be overcome. These include:

- The need to emphasize the "agro" aspects of agroforestry. Normally, this is the farmer's prime concern. Trees must be managed in a way that they will be useful to farmers; this may mean that traditional forestry practices and advice may have to be changed. For example, farmers are usually not interested in thick logs of wood, such as foresters traditionally aim to produce. The farmer's requirement may be relatively thin poles for building, fencing, and firewood. This implies the earlier and more frequent harvesting of trees and selecting varieties that will coppice.
- The need to develop agroforestry systems that farmers perceive to

be both useful and within their physical and managerial capacities. This may mean making more use of multipurpose trees and varieties that will produce at least some fruit or timber in the short term.

► The need to overcome problems of land tenure and land use rights in some countries. Farmers who do not have long-term tenure on their land are unlikely to be interested in planting trees. However, it may not be practical to try to introduce agroforestry systems in those regions where farmers do not have the power or right to control grazing on their lands.

► The need to overcome some practical problems in some countries. For example, suitable varieties of seedlings must be available at a reasonable price near where they are to be planted, and farmers may need advice and assistance on how to best plant and then manage the young trees.

► The need to develop new markets if the introduced agroforestry systems result in the production of, for instance, more fruit than the farmer's family can consume.

► The need for more research on species to overcome some of the problems now being encountered. For example, both eucalyptus and mangoes have frequently been advocated for use in agroforestry systems, but participants mentioned cases of farmer resistance to these two species because eucalyptus tends to compete with crops for moisture while mangoes produce too much shade.

There was general agreement that in conservation more emphasis should be placed on *water managment*. So important is this subject that some participants suggested that we should talk of water and soil conservation instead of soil conservation or even soil and water conservation.

A number of participants mentioned the need to design conservation measures, both vegetative and physical, in such a way that maximum or even total infiltration is achieved. On the other hand, other participants warned of the problems of increased water infiltration leading to mass movements and possible deleterious effects on yields of crops requiring good drainage. It also appeared from the discussions that not very much is known yet about the effects of leaching on terraced lands in high rainfall areas.

Related to this was another problem that has worried soil conservationists for a long time: how to safely and cheaply dispose of excess water from steep, terraced lands. A number of solutions were suggested, including the use of precast concrete channels. Regrettably, most effective solutions are too expensive for farmers unless some high-value crop is grown on the terraces.

Water harvesting would seem to be a topic requiring more research and development. It was pointed out that vegetative measures as well as physical works should be looked at as a means of harvesting water. An interesting case from Indonesia was described by one participant where the infiltration rate of vertisols had been increased by filling the soil cracks with crop residues during the dry season. This counteracted the effects of surface sealing, allowed greater infiltration and storage of water, and led to a marked increase in crop production. So effective has this technique been that one island has changed from being an importer to an exporter of rice.

Soil sealing in particular and deteriorating *soil structure* in general are increasingly being recognized as major causes of excessive runoff and erosion. The point was made, therefore, that soil conservation measures must aim at increasing soil fertility by improving both the physical and chemical properties of soils. With good management, this should lead to a greater production of biomass, leading, in turn, to reduced runoff and erosion. In relation to this, some delegates stressed the importance of such practices as mulching and the use of compost to build up soil organic matter.

The problem of erosion caused by *overgrazing* was discussed in some detail. In many developing countries this has proved to be the most difficult problem for soil conservationists to overcome. It clearly is a subject that requires special attention.

A number of approaches to dealing with the problem of overgrazing were debated, such as stall feeding and "cut and carry," which have appeared promising. It was agreed that more attention must be given to other possible practices, such as controlled rotational grazing, contour ripping, and the reseeding of degraded grazing land.

The value of *fences and hedges* was emphasized. It would seem that the economics of fencing needs to be looked at more closely, while more work needs to be done on selecting and introducing suitable varieties of plants for hedges.

Extension is important if soil conservation practices are to be adopted. The need for effective forms of communication was stressed. Each extension message put across must be relatively simple and always within the grasp of the target audience.

Use of food aid, subsidies, and credit

Food aid, subsidies, and credit schemes have been used in the past and still are being used to encourage farmers to adopt soil conservation practices. In retrospect, it seems that the results from using these three incentives have been varied and often disappointing. Some participants claimed that farmers had become dependent on food aid in some projects and that little had been achieved in the way of erosion control while agricultural production had decreased. In other cases, farmers have come to expect government subsidies for carrying out soil conservation works and will not even carry out the necessary maintenance unless they are paid to do so. Credit schemes have often proved expensive to administer and ineffective. Nevertheless, it appears from the discussions that there is a place for all of these forms of assistance. The lesson to be learned is that food aid, subsidies, and credit schemes must all be well thought out, administered properly, and implemented with care and sensitivity if they are to be effective. If used in the wrong way, they can all prove to be counter-productive.

The catchment approach

Should soil and water conservation be approached on a catchment or watershed basis, or should the emphasis be placed on the individual farm and farmer? Alternatively, should conservation works be planned to coincide with administrative boundaries?

All three views were expressed by different participants during the workshop. The traditional approach to watershed management was criticized by some for its top-down approach and the fact that it ignores the particular needs and capabilities of the individual farmer. The view was also put forward that the catchment or watershed concept was meaningless to the individual farmer. On the other hand, the problems of dealing with perhaps hundreds of smallholdings individually in a reasonably short time were pointed out by other participants. Other participants also put forward the view that a village or administrative area was the unit that should be used for planning purposes because this was understood by the people and meant that administratively the work of a project could become easier.

In conclusion, it could perhaps be said that if emphasis is placed on biological and agronomic measures, rather than on physical practices, to achieve soil and water conservation, these approaches need not be mutually exclusive. The aim may ultimately be to treat a whole catchment, but this may best be done by working progressively from the individual farm units.

If any scheme is to succeed, however, great care must be taken that the decision-making unit, whether it be at the farm level, village level, or political-administrative level, is never ignored or bypassed.

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