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Environmental Guidelines for Small-Scale Activities in Africa (EGSSAA)

Chapter 1: Agriculture: Soil and Water Resources, including Irrigation

Contents

Lacking farm inputs, new technologies or other sources of income, the rural poor often drain the remaining life out of their fragile land, which only worsens their poverty and vulnerability. The linkages among poverty, hunger and environmental degradation are the reasons why environmental oversight must be an important part of agricultural development programming.

1.1 Agriculture Overview

Agricultural development has long been a mainstay of USAID's programs throughout the Africa region. Helping rural people to develop sustainable and productive farming systems generates income and reduces food insecurity. Given the key role agriculture plays in African economies, and its importance to rural households' food security, small-scale agricultural development activities targeted at the rural poor are likely to increase.

Two major factors strongly constrain productivity and rural prosperity in Africa: reduced soil fertility and declining available soil moisture. An estimated 95 percent of Africa's lands face challenges from soils, topography and climate. Soil fertility depletion, in particular, severely limits production in Africa. Yet many responses to this problem are available. Expanding the use of tested management practices, such as watershed management to conserve moisture on hillsides and rock phosphate, nitrogen-fixing tree fallows, and biomass transfer, can overcome/reduce these constraints to crop production. Encouraging profitable alternative land uses such as wildlife farming or forestry is another approach.

Note: This chapter focuses on crop agriculture and is divided into two sections: dryland agriculture management and irrigation management. The first section deals with project design and the environmental impacts of rain-fed cropping. The second looks at environmental impacts associated with irrigated agriculture.

Agrochemical use and its impacts on the human and natural environment are addressed in two completely separate chapters, "Integrated Pest Management" and "Safer Pesticide Use." Other agriculture-related issues are addressed in the chapters on forestry, livestock, and community-based natural resource management.

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The increasing demand for fresh water for domestic and industrial use is another limiting factor to agricultural productivity. It is estimated that, of all the water now being used by humans (2–3 percent of the world's total water), 70 percent is already used for agriculture. Water is a critical source of asset development through livestock and irrigation. Irrigation can boost productivity, but farmers are increasingly in competition with other users, and water deficits will ultimately mean food deficits. Poor irrigation management has lowered groundwater tables, damaged soils and lessened water quality. Wetlands are rapidly disappearing or being degraded.

Again, concerned parties can draw on a wide range of approaches to address African farming's water problems. Water-sparing technologies are available, such as drought-tolerant crop varieties and low-cost drip-and-trickle systems. With a supportive policy and legal framework, irrigation management can be transferred to farmer associations to increase efficiency. And with access to markets, farmers can choose to grow higher-value cash crops.

USAID formally launched the **Initiative to End Hunger in Africa (IEHA)** in 2002 at the World Summit on Sustainable Development in Johannesburg, South Africa. IEHA was created to promote rapid and sustainable increase in agricultural growth and rural incomes as a key solution to cutting hunger and poverty in Africa.

In combating hunger, IEHA recognizes that success requires sustained investments in agriculture-based strategies, programs and policies, together with improvements in health, education, infrastructure, environment and public policy management. IEHA includes a wide-ranging, extensive partnership of African leaders, civil society, donors, private concerns and African governments to work and invest in a smallholder-oriented agricultural growth strategy. See Hhttp://www.afr-sd.org/Agriculture/AgInitiative.htmH for more information.

Indeed, myriad programs address agricultural productivity, by introducing a new technology, an improved input or a new approach into the existing local farming system. However, these farming systems may be unsustainable from an environmental perspective. This is not because farmers do not understand their "environment"—far from it—but because of off-farm externalities, such as market forces or a lack of savings. To feed their families or generate household income, farmers are frequently driven to make trade-offs—shortened fallow periods, lack of crop rotation and other poor land-use measures—which undermine sustainability of the farming system and cause environmental harm. So it is critical that environmental effects be taken into account when planning agricultural initiatives.

Good agricultural practices allow sustainable use of the natural resources—soil and water—needed for crop production. However, with a rising population burden, rural residents are farming on more marginal terrain—sloping lands, infertile soils and areas of low and/or irregular rainfall. The pressure to cultivate marginal lands is often exacerbated by a lack of resources, an inadequate policy framework and poor input supply and market systems.[1] Lacking access to productive technologies, agricultural inputs or employment alternatives, the rural poor often drain the remaining life out of their fragile and marginally productive land, which only worsens their poverty and vulnerability. These linkages among poverty, hunger and environmental degradation are the reasons why environmental oversight must be an important part of agricultural development programming.

This chapter of the *Guidelines* examines natural resources management (NRM) activities that can play a role in fortifying farming systems' sustainability. Soil and water conservation—or on a larger scale, watershed management—can build local farming systems' resilience to climatic extremes and add incrementally to their agricultural productivity through sophisticated use of soil, water and vegetation. Such activities can also buy enough time to allow a more diversified and robust rural economy to emerge capable of generating off-farm employment opportunities. In the long run,

[1] The construction, upgrading or maintenance of "farm to market" roads is dealt with in the chapter on rural roads.

the most sustainable solutions for poverty, hunger and environmental degradation in Africa include options drawing people away from farming on marginal lands into a nonfarm economy.

Potential Environmental Impacts of Agriculture Programs and Their Causes

Natural habitat destruction or degradation. Agriculture can adversely affect a variety of ecosystems. These impacts may come from expanding the area used for crop or livestock production or from using environmentally unsound practices on existing farms. The most common problems include:

- **Degradation of marginal lands**. For a variety of reasons—population pressure, lack of access to land or social equity issues—marginal or degraded lands may be used for agriculture. This new land use may be unsuitable because of inherent constraints on variables such as climate, vegetation, slope, soil depth, soil texture and water availability. Expansion onto these suboptimal lands not only causes further degradation, but also displaces previous land uses (firewood gathering, livestock grazing, hunting, medicinal plant gathering, etc.).

- **Deforestation.** Natural forests are often degraded by encroachment, by

Slash-and-burn agriculture can quickly lead to deforestation, erosion and the loss of soil nutrients, with devastating environmental effects.

excessive or uncontrolled harvesting, by roads dividing them into smaller blocks, or by being cleared for charcoal, crop and livestock production. Slash-and-burn agriculture, where the land is cleared by burning ground cover, replaces the protection given by perennial tree vegetation with short-lived crops that also remove scarce soil nutrients. It is true that when forests are burned to clear the trees for planting, the resulting ash enriches the soil. Unfortunately, these burned areas rapidly lose the initial fertility the ash gives them, and the deforested area—already more liable to runoff, flooding and soil erosion—becomes increasingly fragile. Destruction of forest areas also leaves local populations without the fuelwood, timber, and non-wood forest products they use both to meet household needs and to earn an income.

- **Desertification.** Desertification is the degradation of land in arid, semiarid and sub-humid areas. This process includes deterioration of vegetative cover due to overgrazing, wood cutting, and burning; wind and water erosion resulting from improper land management; and salinization due to improper use of irrigation water. This results in a loss of soil depth and fertility, reduced regeneration and a progressive transformation of the initial ecosystem to a less productive system, culminating in barren desert. In extreme cases, the capacity to support the local population is lost, and residents may leave in search of food and employment elsewhere.

- **Drainage and degradation of wetlands and riparian areas.** Wetlands provide a number of environmental services, including recharging groundwater supplies, acting as natural water-treatment plants, and providing habitats for vulnerable and endangered species. However, wetlands and their edges are often used for agriculture, either in the dry season or after draining. The soils are often fertile at first, and water is available for irrigation. Unfortunately, as wetlands are drained for agriculture or development, the landscape loses its capacity to absorb and control runoff, increasing the potential for downstream flooding. In certain situations, post-drainage aerobic reactions increase the soil's acidity considerably, and the drained land becomes unsuitable for farming.

- **Degradation of coastal areas.** Agricultural activities can degrade coastal areas in a number of ways:
    - Using coastal wetlands for agriculture releases acidic compounds into drainage waters, changes sedimentation patterns and water circulation/drainage, causes loss of protective barriers (mangroves), and increases the likelihood of waterborne diseases.
    - Sand dunes that lose all or part of their vegetative cover to agriculture or livestock grazing can become unstable and expand over previously fertile areas.
    - In industrial-scale agriculture, such as sugar plantations, the fertilizer used can increase nutrient loads and cause eutrophication[2] of estuaries and ponds. This undermines reproduction of commercially important species, including fish, mollusks and crustaceans. In extreme cases, the consequences can include smaller fish yields, fish deaths, destruction of coral reefs, and ecosystem instability or collapse.

Potential Environmental Impacts from Agricultural Development

- Destruction or degradation of natural habitat, including deforestation, desertification and drainage of wetlands
- Loss of biodiversity
- Introduction of exotic and non-native animal and plant species
- Erosion and loss of soil fertility
- Siltation of water bodies
- Reduction in water quality

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[2] Eutrophication is the process by which a body of water becomes enriched with excess dissolved nutrients (such as nitrogen and phosphates) that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.

- Large-scale dams and irrigation schemes that divert freshwater from coastal areas can make estuaries saltier, reduce water circulation and flow, and/or allow saltwater to contaminate groundwater. They may also reduce sediment, leaving less material for beaches and altering patterns of shoreline erosion.

- **Degradation or destruction of protected habitats.** Protected zones may exist as small areas of fragmented habitats surrounded by agricultural land. This undermines the effectiveness of the park by limiting animal migration and supporting unsustainably small wildlife populations. Also, if there is population pressure nearby, people will seek to use the land up to the margins of the protected area and even within it, reducing the park's usefulness as protective habitat.

Biodiversity loss. Increasing homogenization of crops and livestock is replacing diverse varieties with uniform genetic stock. These pure stands may be more vulnerable to a catastrophic disease outbreak, may need more inputs than local crops or livestock to produce well, and may have less market value than better-adapted, more popular local varieties. In addition, farmers generally remove wild plant and animal species from their lands to reduce the negative effects of pests, predators and weeds. However, there are complex interactions between crops and their wild neighbors: certain insects, plants and micro-organisms may play a key role in crop reproduction, maintining soil fertility, controlling pests and floods, and ensuring clean water supplies. Finally, as noted earlier, agriculture can fragment the original landscape, breaking wild species populations into breeding units that may be too small and making them more vulnerable to extinction.

Introduction of exotic species. It is widely accepted that introducing a non-native species to a new ecosystem must be done with great care. Quarantine laws are set up to avoid the potential adverse consequences of such an introduction. Introduced exotic species may spread diseases, out-compete native species for resources, become feral, act as predators or pests, or interbreed with native species. Lack of local competition or predators may give rise to "weed species," such as water hyacinth or Nile perch.

Cropland degradation. Cropland degradation—a decrease in the ability of suitable land to support agricultural production—has two primary elements: soil erosion and loss of soil fertility. Each is described below. As land degradation becomes more severe, farmers often have few options other than to look for another piece of land on which they can earn a livelihood. Expansion onto marginal land is closely linked to a lack of productive potential on existing land.

- **Soil erosion.** Unsustainable practices—such as badly managed open-furrow agriculture, a crop grown in the wrong way or place, deforestation, or draining wetlands—can all cause soil erosion. As the soil erodes, less rainfall is absorbed and the excess runs off. This runoff removes the fertile topsoil necessary for crop production and can have disastrous off-site consequences, including gully formation, landslides, siltation and sedimentation of water bodies, downstream flooding, and damage to productive infrastructure.

  In sub-Saharan Africa, particularly in arid and semiarid areas, the wind can also erode away the soil.

Losing Valuable Topsoil—What Erosion Really Means:

Studies carried out in various countries—Jamaica, El Salvador and Taiwan—measured soil erosion rates of 100 to 200 metric tons per hectare per year on slopes less than 25 degrees under smallholder traditional cultivation packages. This is the equivalent of losing up to 10 mm of soil depth in a year or 50 mm (2 inches) in five years. The actual rate of loss at a site depends on the farming system, slope, soil type, and climate. Unless soil conservation is practiced, high rates of soil loss can be expected, especially on steep sites farmed extensively by marginal smallholders in the higher-rainfall areas.

Source: Sheng, 1989.

- **Reduction of soil fertility.** Soil fertility is dependent on three major nutrients (nitrogen, phosphorous and potassium), various trace elements, and organic matter content. A productive soil contains sufficient quantities of each of these factors. The factors can be removed by repeated cropping without fertilization, rainfall leaching, lack of a restorative fallow, and removal or burning of crop residues, either alone or in combination. The subsequent decline in soil fertility often occurs in conjunction with soil erosion, with each problem exacerbating the other.

  Fertilizers can be used to deal with soil fertility problems. But in sub-Saharan Africa, chemical fertilizers are often scarce, expensive or not economical to use. Farmers are reluctant to assume the extra price risk of fertilizers because of the vagaries of the rainfall pattern and the low market prices for the increased yield.[3]

Siltation of water bodies. Eroded topsoil is carried by runoff into water bodies. Once in the slower-moving water, the soil settles, altering the terrain, water depth and water clarity, which can harm fish and bottom-dwelling populations. Siltation can intensify downstream flooding by reducing channel capacity and can also fill the upstream areas behind a dam. One remedy for siltation, dredging, is an expensive process that must be repeated at intervals. Siltation in wetlands and coastal areas can reduce productivity and marine populations. Large-scale siltation impairs shipping and river transport, flood control, the efficiency of dams, fisheries and aquaculture, urban sewage treatment, and drinking water supplies.

Reduction in water quality. Incorrectly applied agrochemicals, fertilizers or manures can migrate from a farmer's field to local water sources, causing environmental harm and adversely affecting human health and activities.[4] Animal manures transported from fields into water bodies through rainfall, runoff or irrigation can pollute local drinking water sources and spread human and animal diseases. Nutrients from manures/fertilizers can also cause nutrient loading in local water bodies, resulting in degraded water quality, reduced wildlife, fish and mollusk populations, and toxic algal blooms. Moreover, such reductions in water quality can impact other uses of water bodies as well, such as drinking water, sanitation, fishing, aquaculture, recreation and tourism, and other farms. The direct environmental impacts of irrigation are discussed later in this chapter.

The effects of policy on the environmental impacts of agriculture. National agricultural and economic policy alters the costs and benefits of particular agricultural investments and practices. Policy can inadvertently discourage environmentally sound agriculture and livestock husbandry practices, or it may unwittingly reinforce others that have adverse impacts on the environment and the land's long-term productivity. Aspects of the policy environment that may cause unintended harm include:

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[3] Paradoxically, farmers may also apply too much fertilizer, apply it too frequently, or use it inappropriately; the excess nutrient may burn the crop as a result.

[4] The impacts of pesticides on the environment are discussed in the *Guidelines'* chapters on integrated pest management (IPM) and safer pesticides.

- **Uncertainties about land tenure.** Without clear title or guarantees of future control of land, farmers have little incentive to practice wise stewardship or invest in conservation practices. Farmers may also hesitate to leave their land fallow for fear someone else may claim it.

Conflicts between herders and farmers often result from uncertain land tenure arrangements and poorly defined land use policies.

- **Subsidies and pricing.** Government control of markets and prices all influence farmers' behavior and production goals. Means of control may include mandated prices of agricultural goods and services, taxes, tariffs and subsidies, import/export quotas, exchange rate policies, and preferences for state-run parastatal marketing. For example, subsidies for inputs such as fertilizers and chemical pesticides can lead to their overuse, resulting in resistant pests, reduced populations of beneficial insects and predators, water pollution, and damage to human and animal health.

- **Resettlement programs in fragile lands**. Traditional (and even improved) farming practices are typically poorly adapted to fragile lands. This is particularly true in lowland tropical areas where higher rainfall quickly leaches nutrients from the soil. Resettlement programs that move people into these areas for agriculture frequently result in unsustainable projects, land degradation and ecosystem damage.

- **A focus on agricultural expansion.** Policies that promote conversion of new lands into agricultural use, instead of measures to intensify yields on existing plots, frequently result in destruction or degradation of ecosystems. This is especially true when the new land's capacity to support agriculture has not been properly or correctly assessed.

- **Nonparticipatory and undifferentiated extension policies.** Extension programs that apply a "package" of new approaches and technologies over large, diverse areas result in sub-optimal or even incorrect techniques for parts of the range of conditions. Ideally, smallholder farmers would participate in adapting packages—e.g., for soil conservation and improved agronomy and livestock management—to their local circumstances**.**

Sector Program Design—Some Specific Guidance

Agricultural activities that are designed and implemented according to sound environmental principles should produce economic benefits for farmers while maintaining long-term land fertility and stability. *To be economically sustainable in the long run, agriculture needs to be environmentally sustainable.* Unfortunately, for reasons already noted, short-term considerations often drive farmers' decisions and choices. Some aspects of environmentally sound agricultural activity design and implementation are discussed in this chapter.

Soil and Water Conservation

Soil and water conservation technologies can both protect land from degradation and reclaim land that has been degraded. Using the correct techniques may make it possible to maintain or even intensify cultivation, or to continue cultivating land that would otherwise become unsuitable for agriculture.

Soil and water conservation technologies may be structural or vegetative; ideally, the two types should be applied in combination (Table 1). All of these measures aim to reduce the rate of runoff and, thus, erosion. These structural engineering or vegetative solutions are usually established on the contour to slow rainfall runoff and contain any soil erosion. Some vegetative measures also have the secondary benefit of improving soil quality.

Table 1: Soil and Water Conservation Technologies

Engineering or Structural Technologies	Vegetative Treatment Measures
Side Hill Ditches or Similar Diversion Structures—very typically separating higher, nonarable land from cultivated land below and diverting runoff **Contour Bunding or Ridges**—built from stones or soil at intervals along the contour as part of the field layout **Grassed Waterways**—carry away runoff channeled by contour structures to a central drainage point without erosion **Terraces**—radical conversion of sloped land into a series of graded steps approximating flat conditions **Small-Scale Terracing**— discontinuous use of terracing, usually small platforms on which trees are planted **Microbasins**—pits or half-moon structures built in a pattern across the slope to hold rainfall, usually in drier areas **Gully Plugs**—barriers built perpendicular to the slope across drainages to slow runoff and contain transported soil	**Strip Cropping or Contour Farming**—plowing and tilling along the contour to trap rain and avoid runoff and erosion **Living Barriers**—e.g., contour hedgerows or grass strips planted along the contour to trap and/or filter runoff and retain soil **Leguminous Cover Crops**—used as green manures or mulches, to fix nitrogen, raise organic matter content, cover the soil and protect it from raindrop impact **Zero or Low Tillage**—crop residues are left after harvest on the site, and the next crop sown with a minimum of disturbance **Adjustments to Agronomic Practices**—include intercropping, improved plant spacing and appropriate crop rotation **Compost Application**—to improve organic matter content and texture of the soil and its ability to infiltrate rainfall **Agroforestry Practices**—admixture of tree crops to crop and/or livestock farming system

Predicting soil erosion. Some soil erosion and/or displacement accompanies any agricultural practice. Physical parameters of the climate and the land's site, slope, soil depth and soil type all affect the potential for runoff and the actual rate of erosion. Assessing the impact of these parameters as they interact and combine requires careful measurement. One way to simplify the assessment process is to use broad land capability classifications, which relate the suitability of a combination of slope and soil depth factors to a particular set of land uses.

Table 2 presents a land capability classification suggested by FAO for small farmers in the tropics (Sheng, 1989).

Table 2: Land Capability Classification Scheme

Slope Class	Slope (%)	Soil Depth (cms)	Land Capability	Major Conservation Treatment	Applicable Tools	Land Use
1	0–12	>15	C1	Mainly agronomic conservation measures; simple terraces on slopes approaching 12%	Large machine or hand	Any crop
		<15	P	Grass cover	—	Pasture
2	12–27	>30	C2	Bench terraces & simple terraces	Medium-sized machine or hand	Any crop
		<30	P	Hillside ditches	—	Pasture
3	27–36	>45	C3	Bench terraces & simple terraces	Hand or small machine	Any crops
		<45	P	Hillside ditches, zero grazing	—	Pasture
4	36–47	>55	C4	Simple terraces & benches	Hand or walking tractor	Annual & perennial crops
		<55	P	Hillside ditches, zero grazing	—	Pasture
5	47–58	>60	FT	Orchard terraces	Hand	Tree crop
		<60	F or AF	Forest cover or agroforestry	Hand	Trees or tree crop
6	>58	All depths	F	Forest cover	—	Forest only

Legend: C = cultivatable land; P = pasture; FT = land for food, fruit and tree crops; F = forest land; and AF = agroforestry.

Classifying an area on the basis of standard land capability parameters—slope, soil depth, and soil quality—and/or actual land use is useful for defining specific intervention units. During design, specific needs and opportunities for each area can be captured, preventing mismatches between land capability and land use. Classification also highlights important interrelationships within the landscape that allow for a more integrated approach to natural resources use and development.

The risk of soil erosion is quantified through models like the Universal Soil Loss Equation (USLE), the Water Erosion Prediction Project model, and the European Soil Erosion Model. These use formulas to determine potential soil losses in terms of tons per hectare per year, based on rainfall, soil erodibility, topography, crop practices and conservation efforts. Models may be valuable in monitoring soil and water conservation efforts, which are typically gradual improvements and incremental reductions in the erosion rate over time. Their formulas, however, require data (such as rainfall intensity or soil erosivity) that may be difficult for small projects to obtain.

Guidance for soil and water conservation projects. Maintaining and restoring soil through soil and water conservation programs can be a lengthy, costly, difficult process, often well beyond the means of small farmers. Understanding certain practical realities about how programs should be designed and implemented can markedly increase their chances of success, make local farming systems more sustainable and increase returns to farmers.

Guidance for Soil and Water Conservation Projects

- Focus on land management, not degradation
- Consider economic impact of conservation on small holders
- Combine soil conservation with improvements in soil quality
- Focus on priority issues
- Avoid "institutionalizing" subsistence agriculture
- Prevent erosion from roads and paths

- **Focus on land management, not degradation.** Degradation is the result of inappropriate land use. To break the degradation cycle, soil and water conservation projects need to move beyond treating the symptoms of degradation to an integrated land management approach. For example, if gullies are forming as a result of overgrazing and excessive runoff, planting trees to rehabilitate the degraded area is not enough. Action must be taken to manage the causes of the grazing pressure, rather than just shift animals to other areas that may be equally fragile.

- **Consider economic impacts to smallholders.** Conservation efforts involve investments and changes that frequently displace other land uses or require production trade-offs. The costs of these displacements and trade-offs are particularly pronounced for smallholders. To achieve the long-run benefits to society of improving environmental stability and assuring long-term productivity, consideration should be given to short- and medium-term incentives that make smallholder participation in conservation schemes attractive. Incentives can include helping farmers to intensify production activities on their better lands.

- **Pair conservation with improvements in soil quality.** Many soil and water conservation programs promote installing vegetative barriers, both live and dead, to contain erosion, plus ditches and trenches to capture transported soil and water runoff and manage the farm/watershed drainage. Typically labor–intensive, these practices benefit production and the farmer community, but only slowly and often with diffuse impact. They should be complemented by actions to enhance soil quality on the farmed plots between the barriers or ditches. The increased productivity that results gives individual farmers a direct payoff on their efforts. Such interventions may be biological or agronomic; examples include conservation tillage and plowing techniques, green manuring, nitrogen-fixing legumes and cover crops, compost and animal manure, crop spacing, intercropping, and improved crop rotations. All can return several benefits: they increase organic matter levels in the soil, improve its fertility, produce better crop yields and help encourage and validate longer-term investments in erosion control.

- **Focus efforts on priority issues.** Although a so-called integrated approach is important, the interventions must be manageable and must target priority problems identified by local communities. Many soil and water conservation and watershed projects fail because they attempt too much. They spread capabilities, expertise and resources too thinly, especially at the field level. Technical staff may understand the mechanics of a given intervention in general, but not the specific adjustments needed for the conditions at a particular site.

- **Avoid "institutionalizing" subsistence agriculture.** Subsistence agriculture on poor lands is not a long-term means to personal and community economic development. Farmers have aspirations beyond soil and water conservation or increased agricultural productivity. They wish to secure opportunities for their children, see broad development of rural infrastructure, and have access to economic opportunities. Soil and water conservation projects need to be wary of simply reinforcing and maintaining an inequitable status quo.

- **Recognize the contribution of roads to soil erosion.** One cause of soil erosion is a misaligned road, track or path, which channels and concentrates runoff and leads to soil erosion and gully formation. An FAO study conducted in El Salvador in the late 1970s found that as much as 25 percent of the erosion in upland watershed areas was caused by poorly designed roads and paths. Agricultural programs often include farm-to-market roads to improve market access for products; it is vital that such roads be designed in an environmentally sound way. See the chapter on rural roads in these *Guidelines*.

Tied ridges like these can be used to catch runoff, prevent erosion and conserve top soil and soil fertility.

Other Considerations in Agriculture Program Design

Promote farmer and community participation. Managing natural resources and the environment is most often a social act involving both individual and collective choices about the sharing and wise stewardship of resources. It is essential for farmers and communities to take part in designing agricultural development activities, in judging the chances for harmful environmental impacts, and in controlling and mitigating such impacts.

The most important impacts to avoid are those that directly affect the health and well-being of human populations. In the agriculture sector, these include soil erosion and soil fertility depletion, which reduce the farming system's productivity; lowered water quality and quantity; agrochemical contamination; and damage to human health from irrigation system development. Avoiding or minimizing these impacts generally involves education and behavioral changes in the way people farm. Without agreement and buy-in from the participant community, farmers may make less than optimal environmental choices because they seek short-term returns without looking at longer-term costs.

Building local skills, systems and commitment to environmental review and resolution can lead to real development results. Such activities (a) increase local people's capacity for analyzing problems and finding collective solutions; (b) build greater self-reliance; and (c) enable communities to justify support for their needs within civil society and to the government.

Special Considerations for Project Design

- Promotion of farmer and community participation
- Characterization of site conditions for best mitigation and monitoring results
- Protection of watersheds and riparian buffer zones, including springs, stream and river banks, and wetlands
- Management of exotic animal and plant species
- Promotion of use of agroecological techniques

Characterize site conditions. Many small-scale agricultural development activities occur in areas with heterogeneous (non-uniform) site conditions. Such conditions make planning activities more difficult. Choosing the most appropriate set of interventions in these areas depends on accurate, detailed area or site description **(characterization)**. Characterizations in turn are based on *geographic information*. The most basic tool is a georeferenced map at a suitable scale (1:10,000 or better) on which is plotted field survey data. Geographic Information Systems (GISs), Global Positioning Systems (GPSs) and high-resolution, small-scale satellite imagery (e.g., Ikonos imagery) are efficient and effective means for obtaining and managing basic geographic planning information. Georeferenced databases make it substantially easier to monitor programs' impacts, whether the focus is on measuring results or ensuring that mitigation measures are doing their job.

Protect watersheds and riparian buffer zones. It is extremely important to ensure that agricultural activities do not undermine communities' potable water supplies. Although the chapter on water supply and sanitation in these *Guidelines* deals with these issues in depth, agriculture project design should consider these water quality and quantity issues:

- **Protection of springs and seeps.** Groundwater springs and seeps[5] are important rural water sources and need special safeguards to ensure they remain viable, sanitary sources of potable water. Typically, a spring is the result of water infiltrating the ground, running along an impermeable rock or soil layer, and emerging at the surface. Springs usually occur in ravines or gullies, fed by a catchment basin. Often, a community may protect the spring by leaving vegetation in the fringe area immediately around it. Unfortunately, contaminants can still enter through the catchment area that supplies the water. Effective protection of the spring or seep requires ensuring that there is a protective vegetative cover over all of the steeper areas on the slopes above the spring.

- **Protect riparian areas.** Riparian (waterside) areas and wetlands require similar protective efforts. Such areas serve many important ecological functions and often have multiple uses. They need protection to insure clean water supplies, such as buffer strips along stream margins. How wide these strips must be depends on soil, slope and land use. Narrower buffers may be acceptable if, along fields fronting on a watercourse, people put in berms, bunds or filter strips (e.g., vetiver grass or similar vegetative barriers) to keep the direct runoff out of the stream.

Manage exotic species. A project should carefully review what has happened in the past when a particular nonindigenous species has been allowed to enter a similar ecosystem before planning its use or risking introducing it by accident into a project area. Plant quarantine and *phytosanitary* (plant health) regulations should be strictly observed.

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[5] A seep is a type of wetland where water flows to the surface in a diffuse flow.

Use agroecological techniques. Under agroecology (or ecoagriculture), lands are managed for both agricultural production and biodiversity conservation (see Altieri, 2002). Using agroecological techniques, farmers can protect wild species and conserve habitat while also increasing farm production and incomes. Agroecology uses the following strategies:

- **Reduce habitat loss by increasing agricultural productivity and sustainability on already-farmed lands.**
  By increasing production in fertile areas, the pressure to farm marginal land or clear new land is reduced. Increased production may translate into a demand for labor that might otherwise be involved in lower-paying, locally unsustainable practices (such as making charcoal or brick). Techniques include:
  - using improved seed;
  - using multiple cropping;
  - using fertilizers, manures and irrigation and replacing old or inadequate irrigation systems;
  - rotating crops; or
  - introducing cash crops to supplement incomes and pay for soil improvements.

- **Enhance wildlife habitat on farms and establish corridors linking uncultivated areas.**
  Most larger farms contain some areas unsuitable for production, such as riverbanks, waterways, irrigation canals, roads, drainage ways, windbreaks, borders, uncultivated field strips, and woodlots. These areas are useful as animal habitats, particularly for species that do not require large areas for nesting, food and protective cover. Techniques for enhancing habitats include:
  - Planting windbreaks and woodlots using a mix of tree species. Some are preferred food sources for birds and other animals. Wooded areas can also connect forest patches.
  - Consider using uncultivated areas in fields for bird habitats. By planting these areas with plants suitable for birds, erosion is reduced and the birds may eat harmful insects.

- **Establish protected zones near farming areas, ranches, fisheries and parks.**
  This strategy helps to prevent inappropriate uses of these areas and contributes to watershed protection. The zones can also provide income-generation opportunities. Potentially, the buffer zones around natural parks can be partially managed by local communities (see the chapter on community-based natural resource management in these *Guidelines*).

- **Mimic natural habitats by integrating perennial plants.**
  Natural environments include myriad annual and perennial plants. Designing farm landscapes that reproduce natural ecosystems helps to conserve water

Agroecological Techniques

Using the following agroecological techniques, farmers are able to protect wild species and conserve habitat while also increasing agricultural production and incomes:

- **Reduce habitat loss by increasing productivity of already-farmed land.** This includes using improved seeds, multiple cropping, better use of fertilizers, crop rotation and using cash crops to finance soil improvements.
- **Enhance wildlife habitat** on farms and establish wild corridors between uncultivated areas.
- **Establish protected zones** near farming areas, ranches and fisheries.
- **Mimic natural habitats** with perennials.
- **Use farming methods that reduce pollution.**
- **Enhance habitat quality** on farmlands with proper farm resource management practices.

and soil nutrients and provides wild animal habitats. Techniques for recreating natural habitats include:

- Planting trees in pasture. Trees provide shade for cattle, habitats for birds, and timber, firewood and other products for farmers.
- Creating agroforests to shelter annual crops (see the chapter on forestry and agroforestry in these *Guidelines*.)
- Growing shade-loving cash crops, such as shade-grown coffee.
- Flooding rice fields during fallow periods to mimic wetlands. These environments harbor fewer predators than natural wetlands, making them safer habitats for birds and amphibians.

"In eastern Zambia, 3,000 farmers began to use improved, two-year tree fallows that nearly tripled annual net farm income from maize, their most important crop."

Source: McNeely and Scherr, 2001.

- **Use farming methods that reduce pollution.**
  Techniques for pollution prevention in farming include:
  - Planting buffer strips between farms and water bodies.
  - Practicing integrated pest management (IPM) (see the chapters on IPM and pesticides in these Guidelines).
  - Practicing organic farming, which uses no synthetic chemicals, antibiotics or hormones. **NB:** Organic produce needs certification before it can be sold as such in the export market.
  - Leaving rows uncultivated during contour plowing. Natural vegetation grows in these unfarmed areas, reducing soil erosion, providing organic matter for the soil, and serving as animal habitats.

- **Adapt farm resource management practices to enhance habitat quality around farmlands.**
  Managing habitat quality around farmlands can help to prevent crop losses due to external activities, such as deforestation and wetlands depletion. Techniques for managing habitat quality include:
  - Practicing low-tillage agriculture. Low- and zero-tillage techniques reduce soil compaction, improve conditions for beneficial organisms such as earthworms, and use the cover crop to replenish soil nutrients and prevent erosion.
  - Improving irrigation efficiency.
  - Allowing fields to lie fallow to replenish soil nutrients. Planting fast-growing trees and shrubs in fallow fields can increase food security.
  - Practicing sustainable forestry (see the chapter on forestry in these *Guidelines*).

Mitigation and Monitoring Issues

Monitoring is needed to ensure that the desired results—whether improved productivity, social welfare, or minimal environmental impacts—are actually being achieved. Impact monitoring is

Mitigation and Monitoring Issues

- Ensure community and farmer involvement in mitigation and monitoring
- Design monitoring programs to handle complex situations
- Plan to include analyses of the economic and environmental impacts of monitoring and mitigation
- Use proper, efficient monitoring tools, including well-organized data sets, control plots, stream and weather monitoring stations, photo and video records, and monitoring of technology adoption and dissemination.

complicated by variations in the site conditions, which may reflect natural variability, past use, or differing decisions made by individual farmers. Documenting pre-project baseline conditions is critical to determining if mitigation is working and results are being achieved; however, results of project interventions may take many years to appear.

Participatory mitigation and monitoring: Community involvement in monitoring the impacts and results of the program helps to build capacity among farmers and local organizations, and helps the project achieve long-term success. Farmers should be involved in defining and analyzing their problems, identifying potentially adverse impacts, designing and implementing mitigating activities, and measuring success in terms of participant satisfaction and other indicators.

Drawing conclusions about the success or failure of their efforts reinforces the notion of accountability, both within the community and with respect to the program staff. It also strengthens organizational management skills, creates better understanding of the causes and effects of environmental impacts, and helps avoid the problems of top-down project programming.

Accordingly, program proponents should schedule routine monitoring and evaluation sessions with the participants as a prelude to preparing the formal year-end mitigation and monitoring reports required by USAID. Semi-structured encounters with farmers (which should also include an opportunity for ad hoc responses by participants) may address environmental issues that need special monitoring, such as ensuring that:

- project practices do not lead to erosion, clearing, or conversion of marginal lands not suited to agriculture;
- soil conservation measures are actually reducing and/or arresting erosion and runoff problems;
- any livestock development activities are not leading to overgrazing or making it worse; and
- interventions meet the community's expectations so residents will continue to replicate them as designed.

Monitoring for complex situations: As shown above, many variables can affect productivity growth and environmental impacts in agricultural development activities; trying to account for them all can make monitoring burdensome. Efficiencies can be achieved by simultaneously monitoring for performance and environmental impact. For example, programs may record the number of participants involved or the size of the area treated, though not as indicators of program performance or environmental impacts. In certain cases, productivity, yields and social welfare changes can act as proxy indicators of environmental stability and program sustainability. Plans for combined performance and impact monitoring should also ensure that data from the monitoring will be analyzed; the analyses can feed back into improved program design.

Economics and environmental impact monitoring: Under marginal conditions, development programs aimed at improving agricultural productivity and/or containing environmental degradation tend to raise production costs. Project planners must carefully examine the real costs and benefits of the project from the farm household perspective **(microefficiency)**. This is particularly important when labor-intensive conservation interventions are proposed.

Rural people, especially those coping with difficult subsistence conditions, are typically very rational about economics and risk. If benefits come too slowly, are too intangible over the near term, or are insignificant compared to the marginal costs of interventions, farmers are unlikely to continue them. Thus proposed interventions should aim to have a rapid, beneficial impact on productivity, household food security or opportunities to generate income.

Project planners and managers must also establish realistic costs for unit area treated **(macroefficiency)** during initial or pilot efforts. Two factors must be considered in a macroeconomic assessment: the costs to society of *not* reversing the degradation or increasing farm productivity, and the magnitude of the problem across the region where the program is operating.

In other words, if the costs of continuing environmental degradation are high both on-farm and off-site, then government and its partners (NGOs and donors) can better justify high costs per unit area. Nonetheless, before launching an expensive plan, they also have to consider the size of the problem: How many hectares in the program area would have to be treated to begin to have a real impact on the degradation?

Tools for monitoring: Collecting quantitative data and other information for monitoring purposes can be both costly and time-consuming; the tools listed below can help to make it a more efficient process.

- ***Data organization.*** Sound baseline data sets are essential to monitoring of any kind, whether the goal is to detect adverse environmental impacts or to quantify project results. Classifying the program or community area into distinct treatment blocks, along with GPS and GIS technologies, can be useful in making quick surveys of changes in vegetation or land-use patterns when compared to baseline conditions.

- ***Formal control plots for soil erosion.*** Assessing the benefits of soil and water conservation technologies may require controlled test plots to be set up that ensure a minimum number of variables for reasoned analysis of cause and effect. Often, these test plots are found on agricultural research stations. If not, depending on the program, it may be necessary to set them up and collect the data to measure and demonstrate impact.

- ***Stream-gauging and meteorology stations.*** Soil erosion is typically proportional to rainfall, and without localized data, it is difficult to draw conclusions about the efficacy of erosion control measures. The importance of accurate meteorological and hydrological data for agricultural development cannot be overemphasized. Almost any program can justify a small weather station—or, in the case of small-scale irrigation or watershed management, a stream-gauging station. The data collected are useful in helping to define the impact of weather on crop productivity and environmental stability. Development of the monitoring plan must also recognize realistic needs. For example, providing the program's technical staff with rain gear and boots (so they can get out in the rain) can help them to understand erosion through firsthand observation.

- ***Photo and video records and technologies***. The intricate nature of applying soil and water conservation technologies across a mosaic of farm fields makes it extremely difficult to measure results. While sampling techniques can help to overcome this constraint, a number of modern technological advances are well-suited to collecting and managing data on changing site conditions. Seasonal conditions in the program area can be recorded using digital photography and videography, ideally taken from the same vantage points and at the same points in the agricultural calendar. Using GPS and GIS equipment can make it easier to survey for changes in site conditions or land-use patterns that indicate whether soil and water conservation technologies have actually taken hold. These tools can also enhance projects' ability to train staff and participants and can be used to demonstrate results for public relations purposes.

- ***Technology adoption, dissemination, and maintenance*****.** One of the most appropriate proxy indicators of the success of soil and water conservation technologies is farmer satisfaction with the application. This is easily detected by gauging adoption rates, the extent of the technologies' spread to other farmers, and the degree to which the farmers carry out the ongoing maintenance that is often critical for maintaining optimal impact.

Specific Mitigation Measures

Table 3 provides specific guidance for mitigating and monitoring adverse environmental impacts for activities in agriculture. Although the mitigation and monitoring measures suggested below are geared to several distinct categories of sector activities, program implementers also need to be aware of the implications and constraints (as well as potential beneficial outcomes) of the policy framework in which they are working.

Table 3: Impact Monitoring and Mitigation for Small-Scale Agriculture Sector Activities

Category	Problem	Root Cause	Mitigation Measure
Land degradation	Loss of soil from agricultural land	Water- and wind-induced soil erosion	Improve overall farming system Match land use to land capability Apply appropriate soil and water conservation measures
	Loss of soil from marginal areas	Water- and wind-induced soil erosion combined with inappropriate land use	Reduce pressure on marginal areas through alternative income sources and/or changed land uses Encourage revegetation of degraded and marginal areas to reduce runoff
	Soil infertility: significant increase in fertilizers necessary for crop production	Nutrient exhaustion due to farming techniques	Rotate crops Allow land to lie fallow Intercrop with legumes or other nitrogen-fixing species Practice low-tillage farming Combine crop and tree production (agroforestry)
	Overgrazing leading to erosion, vegetation loss and gully formation	Noneconomic reasons for large herds (e.g., prestige, marriage dower) Lack of alternative fodder sources	Increase average animal productivity through health and nutrition Improve market options for culls Improve grazing management systems Improve communal land management
	Land barrenness: sand dunes encroaching on productive agricultural land	Desertification due to climate change, poor land-use practices and farming techniques	Use trees, grass, grass mats, or mesh to stabilize dunes and prevent their spread Plant vegetative windbreaks to reduce soil erosion from wind Revegetate denuded areas to reduce soil erosion from runoff Take other conservation and prevention measures, such as more efficient use of fuel, improved dryland farming, and livestock improvement programs, to reduce crop and herd quantities and improve quality
Runoff from land use	Polluted and eutrophic lakes and rivers Low fishery yields	Poor water quality caused by being downstream from livestock farms; agrochemical and fertilizer use on cropland	Vegetate areas around fields to prevent nutrient runoff from croplands Vegetate riparian areas to prevent erosion along stream banks, leaving 50-m-wide strips between waterways and croplands Collect agricultural wastewater from intensive livestock operations in holding lagoons

	Pollution of exposed wells and springs	Increased incidence of waterborne disease	Implement minimum setback limits for grazing and agriculture around water sources Ensure that wellheads and springs are properly constructed and protected
	Contamination of environment, especially soil and water	Subsidies for farm inputs Inappropriate input packages	Improve training of farmers in input use, especially chemicals Train providers and venders of agricultural inputs
Siltation	Flooding and decreased navigability of rivers and waterways	Deposition of silt in rivers and water bodies from erosion	Revegetate critical watershed areas and apply soil and water conservation measures to the upstream areas for better erosion control
	Flooding and soil erosion after rainstorms	Watershed destabilized due to deforestation and reduced area or capacity of wetland	Revegetate degraded and marginal areas to reduce runoff Vegetate riparian areas to prevent erosion along stream banks Maintain condition of existing wetlands and construct additional artificial wetlands if appropriate
	Changes to river deltas, coastlines, and estuaries	Destruction of coastal areas from erosion and siltation	See above measures for erosion control along river and critical watershed areas Protect mangroves from agricultural and other uses
Degradation of protected habitats	Destruction in and around protected areas and parks	Poor land-use policies that foster unsustainable use of protected lands	Institute community-based natural resource management (CBNRM) to manage park lands
Biodiversity loss	Decrease in wild plant and animal species	Biodiversity loss due to habitat destruction and competition from foreign species	Use ecoagricultural techniques Create corridors connecting protected habitats Revegetate areas in and around fields to create habitat Use appropriate native plant and tree species Obey plant and animal quarantine rules

1.2 Irrigation

Brief Description of Sector

Irrigation is used in arid and semiarid regions to counter drought, to supplement water requirements in areas where total seasonal rainfall is poorly distributed during the year or variable from year to year, and to prolong the effective growing season to permit multiple crops per year instead of a single one. In areas where traditional rain-fed agriculture has a high risk of crop failure, irrigation helps to ensure stable production.

Irrigation systems are used on 14.3 million hectares in Africa, although the number of irrigated areas varies widely among countries. According to FAO's Aquastat database, Egypt, Sudan, South Africa, Morocco, Madagascar, Nigeria, Algeria, Libya, Angola and Tunisia account for more than 80 percent of the water-managed areas. Where rainfall is less scarce, as in many in equatorial African countries, irrigation is used for off-season cropping, for rice cultivation, to produce high-value crops like vegetables, or as a supplemental water source in wetlands and valley bottoms.

Weirs like this are used to divert water from a river to irrigate farms. They can have significant effects on the hydrology and quality of the river flow.

There are many obstacles to increased irrigation in sub-Saharan Africa. The region has limited and diminishing freshwater resources. In a number of areas where water is scarce, such as Southern Africa, planning is not possible due to the absence of any regional agreement on the use of potential resources. Even where water resources are available and adequate, other conditions may hinder irrigation development. These include unfavorable topography and soils; distant markets; inadequate infrastructure, training and management; and lack of credit or extension services. Moreover, the many environmental problems associated with irrigation (see next section) should encourage project planners to approach it with caution.

Types of Irrigation Systems

- Diversion systems, to divert a river or stream flow for irrigation use
- Spate systems, which rely on occasional flooding of a stream or river to collect water
- Spring systems, drawing water from springs and groundwater
- Storage systems, which rely on water captured by small dams
- Lift systems, using pumps or other mechanical means to move water from water source to fields
- Sprinkler systems, which mechanically move water from a source for dispersal over a field
- Center pivot systems, a specialized sprinkler system rarely seen on small farms
- Drip, or trickle irrigation, which applies small amounts of water directly to the ground close to the roots of a plant

Small-scale irrigation projects in Africa typically irrigate 100 hectares or less. Surface and gravity-flow irrigation are the most widely used techniques, although sprinkler systems are used on the larger commercial farms in Zimbabwe, South Africa, Kenya, Zambia and various countries in North Africa. Expansion of other systems such as trickle, drip, or treadle pumps has been slow. Surface irrigation schemes include:

- **Diversion systems.** Diversion or off-take systems divert a portion of river flow for irrigation use. These systems use a natural river or stream flow, diverting it into a canal system and, possibly, a storage tank. Diversion systems can operate with or without a control structure at the head of the system. Occasionally, a structure is constructed in the watercourse to increase the amount of water that may be diverted. Primary canals, sometimes lined, transport water from catchment areas to the flatter croplands below. Diversion systems can deliver irrigation water during the dry seasons and/or supply supplemental irrigation during rainy periods.

- **Spate systems.** Similar, but less sophisticated, spate systems use occasional flood-level flows in a watercourse. They are typical in arid areas with intermittent streams that only flood during high rainfall. This type of system, which is sometimes called "wild flooding," depends on climate and topography for the opportunistic capture and spreading of floodwaters (see Prinz and Singh, 1999).

Under USAID Reg. 216, irrigation, no matter what the scale, is considered to fall within the "class of actions normally having a significant effect on the environment" (216.2[d]) and therefore requires a formal environmental assessment.

- **Spring systems.** Spring systems use water from natural springs, often collected overnight, to irrigate crops. Spring waters are typically divided among irrigation, livestock and household needs. The area irrigated is usually small, and irrigation water is often carried by hand.

- **Storage systems.** Storage systems are another simple form of small-scale irrigation, capturing water from a stream and storing it behind a dam for use during the dry season. Outlets in the dam channel the water into canals leading to irrigated perimeters downstream, typically in the same valley. Earthen dams are the most common storage system used, and pumps may be used on larger dams.

- **Lift systems.** Lift systems involve using manual or mechanical pumps to raise water out of a river course or well in combination with a surface irrigation channel. Such systems can be used to feed surface irrigation systems or sprinkler systems. They may also be combined with a storage tank into which the water is pumped to increase delivery pressure. Hand- or foot-operated treadle pumps, which originated in Bangladesh, are being seen increasingly in Africa, especially on small vegetable farms near urban centers.

- **Sprinkler systems.** Gravity-driven sprinkler systems are common in some highland areas, often being used for producing horticultural (garden-type) crops. This type of system captures water from a spring or diverts it from a river or stream high up in the catchment, sometimes storing it in a tank, and carries it via PVC pipes for dispersion over a small plot of land. These systems can be used for either supplemental irrigation or dry-season use.

- **Center-pivot irrigation system (CPS).** A specialized sprinkler irrigation system for large flat areas, the CPS is seen occasionally on the largest farms; such systems are capital-intensive and not typically applicable to smallholder conditions.

- **Drip irrigation.** Drip irrigation, sometimes called trickle irrigation, involves dripping water from small pipes onto the soil very slowly (2–20 litres/hour). Water is applied close to plants so that only the soil around the plant gets wet, unlike surface and sprinkler irrigation, where the whole soil surface is wetted. Depending on the crop and the climate, crops are watered every one to three days, which maintains a high moisture level in the soil while minimizing water loss from evaporation. Drip irrigation is often used for vegetable production; however, the initial cost of a drip irrigation system may be prohibitively high for smallholders.

Potential Environmental Impacts

An array of adverse environmental impacts may be associated with irrigation, and some of the most severe may be in newly irrigated areas. Modifications to existing irrigation projects may also generate new, unanticipated impacts, which vary according to the stage of implementation. For example, specific health and other social risks may occur during irrigation construction that relies on migrant laborers living in temporary and unsanitary accommodations. Also, after years of operation, cumulative impacts may emerge that could have only been predicted through environmental impact assessment.

Soil salinity. Intensified agricultural production on irrigated lands can reduce soil fertility over time by making it more salty (saline). A high level of salt in the soil limits what crops can be grown, reduces crop germination and yields, and may make soils more difficult to work. Excessively saline soils force farmers to abandon fields. Salts build up in soils in four main ways:

- Irrigation water contains salts. Water is taken up by plants or evaporates into the atmosphere, but the salts accumulate. Flatter, low-lying areas, water tables with a low hydraulic gradient, or low-permeability soils are most susceptible. Depending on what is happening upstream, the water source itself may become more saline over time, increasing the salinization rate of the soil. Also, systems that reuse the drainage water during water shortages make salt accumulate faster.
- Artificial and natural fertilizers may not be fully absorbed by plants, leaving salts which accumulate in the soil.

- Salts may occur naturally in the soil, and adding extra water through irrigation mobilizes them. This problem is often severe in desert or arid regions where natural rainfall is inadequate to remove the salts from the root zone by leaching.
- If the water table is high, water will rise through capillary action and evaporate, leaving salt in the upper layers and on the surface of the soil. Excess irrigation can also raise the water table and is often associated with salinized arid regions, where large areas of once-arable land have become unusable.

Potential Environmental Impacts of Irrigation

- Increased soil salinity
- Alterations to hydrology and watersheds
- Increased erosion and sedimentation
- Threats to human health
- Damage to water quality for all users
- Damage to sensitive ecosystems, such as rivers, wetlands and coastal estuaries
- Disruption of local socioeconomic arrangements
- Inefficient use of scarce water resources
- Cumulative and area-wide effects on environmental quality

Excessive salt can cause irreversible damage to the soil structure, particularly in clay soils. In areas with acid sulphate soils, such as tropical coastal mangrove swamps, irrigation removes cations (positively charged ions) from the soil and reduces the availability of nutrients to plants. As an acid sulphate soil dries out, the change in pH also decreases the organic content and may release elements that can have toxic effects on the ecosystem.

On islands and in coastal areas, saline intrusion into groundwater sources is a major problem associated with drawing water for irrigation and drinking water. If too much groundwater is drawn, salt water can enter the aquifer. Not only will this have a major impact on other aquifer users, but the entire coastal ecosystem, particularly plants and fisheries, will be affected.

Hydrology. Diverting water for irrigation affects watersheds by altering rivers' flow regimes (patterns of flow volume) and affecting the depth of the water table. Without irrigation, rivers may experience large seasonal variations, flooding during the rainy season (flood regime) and carrying small water volumes during dry seasons (low-flow regime).

- **Low-flow regimes.** Irrigation takes water from the already limited supply available during low-flow regimes. This may leave too little water for downstream uses such as drinking water, hydropower, transportation, and other irrigation projects. In addition, reduced water quantity often translates into reduced water quality, because there may not be enough water to dilute pollutants to acceptable limits. Turbidity also increases as flows are diminished. If the river is linked to wetlands or an estuary, reduction in water volume or quality may harm critical animal habitats, fisheries, and flora as well as drinking water supplies.
- **Flood regimes.** Irrigation reduces river flooding, which may be helpful in that it lessens the potential for property damage and loss of life. On the other hand, irrigation also alters natural irrigation and fertilization of flood plains, disrupting traditional agricultural practices. Fisheries and aquaculture projects in estuaries and coastal areas may be harmed by reduced floodwaters. Diverting floodwaters leaves less water to recharge groundwater supplies and wetlands. Furthermore, floods are important for transporting sediment downstream. When they are reduced, the decrease in flow may contribute to greater siltation upstream, making rivers less navigable.
- **Dams.** Reservoirs are often used to supply irrigation water during dry seasons, provide power, and prevent flooding. Like other water diversions, dams worsen low-flow states and add to the potential

adverse impacts of reduced flooding. Creation of new dams may require local populations to relocate and deprive villages of farmlands or forests. Shallow reservoirs can become clogged with weeds, impeding water flow and preventing livestock from reaching drinking water. Reservoirs may also be breeding grounds for vectors carrying diseases like malaria, schistosomiasis (bilharzia) and river blindness.

- **Water table.** Lowering the volume of water in rivers has a similar effect on groundwater levels. Less river water means less groundwater recharge and lower water tables. This may make springs and wells dry up, leaving people to collect water from more distant sources, or it may make water less potable, possibly increasing the risk from diseases such as guinea worm, schistosomiasis, dysentery and typhoid. Long-term reductions in water table levels can lead to land subsidence (slumping).

  Conversely, problems such as irrigation canal leakage and over-irrigation lead to waterlogging and raise groundwater levels on and around farm plots. Waterlogging implies higher numbers of waterborne pathogens (organisms that cause disease), afflicting plants, livestock, and humans.

Erosion and sedimentation. Because irrigated land is already wet, it may be less able to absorb rainfall. Runoff from irrigated croplands during a storm can thus be heavier than runoff from unirrigated areas, carrying sediment and any farm chemicals into water bodies. The effects of sedimentation on rivers are compounded by any changes in flow regimes caused by irrigation structures. Increased sedimentation upstream can also clog irrigation intakes, pumps, filtration operations and in-field channels downstream.

Poor design, construction and placement of water inlet points for irrigation can all erode the soil at the head of an irrigated field. The eroded soil may accumulate in the middle or at the tail ends of the field where the water moves more slowly, interfering with in-field water distribution.

Human health. On one hand, irrigated agriculture can improve human health through greater food security, better nutrition, improved local infrastructure and higher incomes that allow access to medicines and health services. On the other hand, irrigation also supports many waterborne diseases in both humans and animals, including malaria, schistosomiasis, dengue, bancroftian and lymphatic filariasis, river blindness, loiasis, roundworm, tapeworm, guinea worm, yellow fever, sleeping sickness, cholera, typhoid, hepatitis and leishmaniasis.

For example, stagnant or low-flow water bodies, such as clogged irrigation canals, waterlogged fields and rivers under extremely low-flow regimes, breed malaria-carrying mosquitoes and the snails that transmit schistosomiasis. Lowered water tables in arid regions can increase the incidence of sandflies, which transmit leishmaniasis. Using polluted wastewater for irrigation can spread roundworms and tapeworms in both livestock and humans. Finally, pollutants, including pesticide residues, excess nutrients from fertilizers, and saltwater intrusions in groundwater, all threaten drinking water sources, leading to increased sickness and death.

Water quality. As mentioned earlier, irrigation can affect downstream water quality by reducing the amount of water available to dilute contaminants and by potentially increasing agrochemical pollution.

- **Toxic substances.** Modern agriculture uses a variety of toxic and potentially toxic substances. Pesticides and herbicides can endanger human and animal health, persist in nature, and interfere with natural pesticide controls (such as predatory insects).[6] Applying too many agrochemicals can cause many of these elements to build up in water. Use of sewage or industrial wastewater can spread disease and contaminate soils and food; sewage sludge may also contaminate soils with heavy metals, which can have toxic effects on ecosystems and human health.
- **Nutrient pollution.** Commercial irrigated farming projects normally use fertilizers, but overusing them puts excess nutrients in the ecosystem. Nitrates, which are water-soluble, are quickly transported into rivers and estuaries. Phosphates attach to soil particles, but may eventually seep through to contaminate groundwater or be carried in rainwater runoff to rivers, streams and lakes. As phosphate concentrations rise, they may stimulate rapid growth of aquatic vegetation and algae. Excess nitrates in water sources can be toxic to aquatic life and young children. Also, if human excreta is used as fertilizer or deposited in irrigated fields, rainwater runoff may transport them into open water bodies where they may spread diseases such as cholera, hepatitis and worms.
- **Anaerobic effects.** Loading water bodies with nutrients encourages algal blooms, which deplete life-giving dissolved oxygen and harm aquatic life and fisheries. These conditions are most severe in shallow and slow-moving water bodies, such as reservoirs and low-flow regime rivers. Reservoirs may also become anaerobic (i.e., lacking oxygen) near the bottom due to decaying organic matter. When organic matter decomposes under these anaerobic conditions, the process yields hydrogen sulphide, methane and ammonia, all of which are poisonous to humans and aquatic organisms.

Impacts on ecosystems. Diverting water for irrigation leaves less for downstream ecosystems, including wetlands, mangroves, and coastal estuaries. Discharge water from irrigated fields may contain more salt, less dissolved oxygen, more pollutants, and a heavier silt load than the incoming flow. It also tends to be warmer than receiving rivers and streams. These changes can encourage weed growth and harm fish and bird populations.

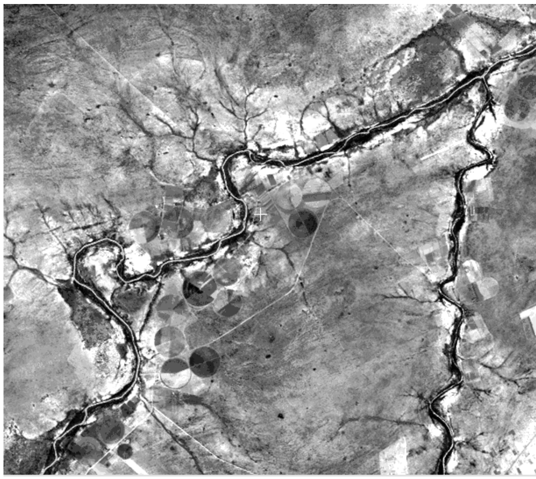
Less water downstream in wetlands decreases the recharging of local groundwater and hampers wetlands' natural water treatment functions. A long-term reduction in water flow to wetlands will cause them to shrink and will alter the composition of wetland vegetations. These changes in flora cause loss of animal habitat, flood protection, and coastal erosion buffers. Mangroves, in particular, require large volumes of fresh water and sediment

[6] For a discussion of pesticides' effects on water quality, see the sections on IPM and safer pesticides in these *Guidelines.*

to protect coastal areas and make them flourish and to support commercially valuable spawning grounds.

Increased erosion and consequent siltation of water bodies damages fisheries and aquaculture. Land clearing for irrigated agriculture, particularly for monoculture crops, may destroy sensitive and important animal and plant habitats. As discussed earlier in this chapter, wetlands are often deliberately drained and used as sites for irrigated agriculture because of their high soil fertility, but while the fertility is often short-lived, the wetlands' environmental benefits are lost for good. Larger areas of irrigated monoculture are especially prone to crop pests and diseases. Waterborne vectors of human and animal diseases (snails, mosquitoes, etc.) may also be encouraged. All of these impacts may harm local species that use wetland habitats, as well as migratory bird populations.

Socioeconomic impacts. Although irrigation is usually introduced to improve economic conditions and support development, it may wreak social and economic havoc. New irrigation schemes can disrupt communal land-use rights and highlight discontinuities between traditional and legal land rights. Individual water rights may need to be negotiated, particularly for small plots. Changes to field layouts may be necessary and some cultivated land may be lost, which will require adequate compensation. Even successful irrigation projects can harm downstream users by reducing water volumes and/or quality.



Irrigation systems, such as the dark, circular center-pivot lands and other systems visible in this photo, can have a significant impact on water quality and add extra competition for the use of scarce water resources.

Moreover, successful irrigation projects tend to result in *induced settlement* and *in-migration.* Disrupted communities and displaced settlers may be more likely to exhibit behavior that puts them at high risk for HIV/AIDS. In addition, this growth is typically unplanned, without adequate provision for potable water supply, waste disposal, housing, roads or other services. Public health in settlements can actually *worsen* as a result of an irrigation project. Larger, denser populations in a newly irrigated area undertake related activities with environmental impacts of their own, such as more agriculture, grazing, and harvesting of forest products. This phenomenon, called the Hinterland Effect, must be planned for before beginning any irrigation project.

Irrigation generally benefits landowners more than tenants or communal land users. While women and children may benefit from higher income and improved nutrition, they may also lose access to lands traditionally used to collect fuelwood or grow vegetables. Also, irrigation projects may involve pastoralists with little or no experience with irrigation farming techniques. They are less likely to benefit from such projects than are outside investors or entrepreneurs who hire the workers as tenant farmers.

Inefficient use of scarce water resources. As a result of poor site choice—e.g., sloping lands that increase runoff—scarce water resources may be used inefficiently. There may be major leakage and evaporation from canals and storage dams, as well as poor water management by farmers within the scheme; these problems are particularly acute under arid or semiarid conditions. Poorly maintained canals result in water losses and the growth of vegetation in the canals, with noticeable effects on efficiency, distribution and leakage.

Cumulative and areawide impacts. Before creating a new irrigation project, it is crucial to consider the cumulative impacts of other NGO/donor projects in the watershed. Although a single project may only divert 1 percent of a river's flow for irrigation, many such projects using the same river may severely alter its flow regimes and negatively impact downstream users. The importance of leaving adequate flows for drought or low-flow regimes cannot be stressed enough. When too much water is diverted, rivers can be reduced to a series of stagnant pools of water along the riverbed where mosquitoes breed and spread disease.[7] Also, excessive diversion of water may have unforeseen impacts on biodiversity by exacerbating conditions that already threaten local populations of endemic species.

Traditional Irrigation in Africa

Throughout Africa, farmers irrigate shallow, seasonally waterlogged depressions, called *dambos*. Also known as *banis, bolis, fadamas, marais, and vleis,* these wetlands are variable in soil and water regimes over a short distance. Good farmers use bed size and height, plus different crops and cultivars, to manage this diversity. By contrast, large-scale interventions often focus simply on removing the water and lowering the water table, without considering the negative impacts these changes cause.

Properly managed dambos can yield twice as many crops per unit of land and water as mechanical irrigation systems, and less expensively. Dambo cultivation can also benefit the watershed, since no extra groundwater is necessary, watershed downstream flows are not affected, and wetland habitats for biodiversity are conserved.

Source: McNeely and Scherr, 2001.

Sector Program Design—Some Specific Guidance

Designing an irrigation system from the ground up, or rehabilitating an existing one, demands attention to a multitude of factors—social, economic and technical. It is essential to take local, national and regional experience in the sector into account, and to involve knowledgeable local staff in preparing for the project. Considerations include, but are not limited to:

- capacity of land and water resources to support irrigation;
- optimum scale of the scheme;
- crops best adapted to the soils and seasonal water availability;
- sources of extension information, technology and input supply for the scheme (tools, seeds, machinery, etc.);
- output markets for increased production;
- role of the community in managing the system;
- farmers' experience with irrigation farming techniques; and
- whether population has to be relocated to the project area to supply the scheme with workers, impacting on local health and increasing demand for housing, health, education and other services.

Complete success in irrigation development is elusive, and large-scale changes should not be undertaken lightly. Even minor modifications to such traditional wetland management schemes as *dambos*, *marais* and *bas-fonds* (see box, left) can cause major problems.

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[7] For photos and examples, see T.M. Catterson et al. (1999).

Community involvement. Community and farmer participation in planning and designing new irrigation schemes (or rehabilitating existing ones) is critical to minimizing adverse socioeconomic impacts and maximizing community benefits. User feedback on particular needs for extension, marketing and credit will also help to generate community involvement and support for infrastructure changes, and it can be the key to successful development and implementation of annual mitigation and monitoring plans.

Some sample questions to consider when soliciting community input for a new irrigation project are:

- What are current land tenure arrangements?
- How will the project guarantee equitable access to irrigated lands? Equitably shared benefits from production?
- Are there differences in men's and women's roles and relationships that may affect the long-term future of the scheme and the environment?
- Will there be adequate access to markets?
- Will farmers have enough demand for their production?
- What is happening to the quality of the soil in the area? What are existing and future soil maintenance needs (e.g., will soil fertility decrease due to intensive cropping and nutrient leaching)? What changes have farmers observed in the last 30 years?
- What is the potential for soil salinization or other long-term, cumulative effects?
- Are there any current pest problems?
- What is the condition of the potable water supply? Are there potential health issues?
- What is the current incidence of malaria? Bilharzia?
- Is there potential for introduction of nonindigenous seed, etc.?
- What are the long-term prospects for maintaining canal and irrigation structures? Who will maintain them? How? Who will pay for maintenance?
- What are the cumulative effects of similar irrigation schemes? Are other potentially unsustainable land-use practices occurring in the watershed (such as charcoal or brick making)?

Irrigation Sector Program Design Principles

Incorporate community involvement in planning and operation

Design for local soil conditions

Account for water availability

Design for local crop conditions and varieties

Plan for operation, maintenance and management of the project

Ensure that the design accounts for health risks

Follow environmentally sound construction practices

- What are possible secondary impacts—particularly induced settlement? Is there adequate provision for drinking water, waste disposal and other services for settlers?

- What realistically may happen when the project ends? What will the project area look like in 30 years?

Design for soil conditions. Choose an irrigation system suited to the type of soil available. Low-quality irrigation water should not be used on clayey soils, but might be used on more permeable sandy soils where pollutants will not accumulate. In high-salt situations, salt-tolerant crops should be chosen. In addition, salt levels in the soil should be reduced through such mitigation measures as adding gypsum to either the irrigation water or the soil before irrigating, or growing a catch crop[8] of a salt-tolerant plant such as *Sesbania*. Construct adequate groundwater drains (either pipe/tile drains or deep ditches) to control the water table.

Soil erosion causes sedimentation of reservoirs, irrigation intakes and pumping stations, requiring expensive, annual desilting. Soil erosion rates, however, can be predicted and planned for, based on soil type, field size, structure drop size, slope, and field layout. Leveling fields before planting will reduce soil erosion, as will constructing field bunds. To stabilize soils, farmers should always plant vegetation on bunds and on areas around control structures and new irrigation construction. (See guidance on controlling soil erosion in the chapter on agriculture above and in the references.)

Design for water availability. It is very important to install stream-gauging stations or water-level gauges to collect a historical record of regular and lean conditions. Without such information, it is difficult to plan for additional irrigated fields and new crops, or to determine if maintenance or new infrastructure will be required. This information is also needed to develop and establish legal agreements between farmers and communities over water use and distribution. Any major irrigation scheme must have this hydrological data in hand from the start to ensure a good plan. Local personnel should be trained to use stations or gauges to record measurements.

When creating a new irrigation project, it is wise to start with a smaller area for irrigation in Phase 1, using conservative estimates of water availability. As more data about low-flow conditions become available, the irrigated area can be expanded to match the water supply. Be aware that growth of both population and industry in the area will, over time, create competing uses for surface water and groundwater.

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[8] A catch crop is a quick-growing crop sown between seasons of regular planting to make use of temporary idleness of the soil or to compensate for the failure of a main crop. Examples of catch crops include rapid-maturing vegetables as radishes or spinach (planted between rows of slower growing crops); quick-growing crops such as rye, millet, or buckwheat; or an annual legume, such as soybean, which can be used as fodder or plowed under to increase soil fertility. (Source: *The Columbia Encyclopedia,* sixth edition, 2001.)

Gravity-flow irrigation uses gates, siphons and checks to evenly distribute water in a field. Other systems, such as overhead, drip or trickle, while they grow more crop per unit of water, are more capital-intensive. These require availability of the systems themselves and of spare parts, as well as crop prices that allow returns from the increased production to justify the investment.

If soils require leaching beyond what occurs naturally during rainy seasons, extra water will be required and should be budgeted for over and above crop requirements. Saline drainage water should be disposed of properly, either to the ocean through dedicated channels or to evaporation ponds.

Design for crop conditions. Irrigation systems should control where, when and how much water is supplied to promote yield and enhance the economic efficiency of crop production. Watering requirements, both volumes and frequencies, will change based on time-variable crop needs. System design should aim for optimal growing conditions in a specific plot or season while protecting the fields against long-term degradation.

Design for operation and management. Regular maintenance will be necessary to keep irrigation canals free of weeds, reduce effects of sedimentation, and prevent wasteful leaks. Farmers and communities must devise and implement a workable approach to operation and maintenance *before* any irrigation program is undertaken. System design should include who will be responsible for maintenance, monitoring, and regular operations.

Operation and maintenance (O&M) questions to be answered before project launch include:

- Who will be responsible for O&M?
- When will irrigation take place?
- How will fair delivery be determined?
- Who will be responsible for developing and implementing the mitigation and monitoring plan?
- How much will O&M cost?
- Who will pay for O&M?
- Who will manage the funds for O&M?
- How will appropriate use of the funds be guaranteed?

Design for health risks. Surface, contour, and furrow irrigation typically present more health risks than sprinkler, central pivot, or drip irrigation schemes. Contamination of groundwater and surface waters by pesticides and fertilizer can likewise imperil health. The risk of such contamination should be assessed and design and operation measures taken to minimize this risk.

Dam and reservoir design. To prevent anaerobic conditions in reservoirs, clear out organic matter like trees before filling, and design multilevel dam outlets to make sure downstream waters are sufficiently oxygenated.

Reservoirs and irrigation canals can also be used for aquaculture and as bird habitats. Aquaculture in canals can help to control weeds while providing a source of protein and income. Bird sanctuaries and wildlife parks can be established around reservoirs to protect wildlife and stabilize shorelines against overuse and erosion.

Follow environmentally sound construction practices. Constructing irrigation works involves a whole set of construction-related environmental concerns, including worker sanitation, location and management of borrow pits, construction of access roads, etc. (see the chapters on small-scale construction, roads, and water and sanitation in these *Guidelines*).

Environmental Mitigation and Monitoring Issues

Mitigation and monitoring plans should be created to protect sensitive ecosystems and protected areas from changes in flow regimes or water quality. Effective planning of irrigation projects demands a sound environmental baseline (e.g., stream flow, groundwater levels) as well as ongoing monitoring of critical conditions.

Planning environmentally sound small-scale irrigation. Because of the importance of small-scale irrigation activities in the food security efforts supported by USAID in Ethiopia in the late 1990s, a Programmatic Environmental Assessment (PEA) of these activities was carried out (see Catterson et al., 1999). One of the PEA's outcomes was development of a *Checklist for Planning Environmentally Sound Small-Scale Irrigation (SSI) in Ethiopia*. Because of the breadth and variety of the SSI program in Ethiopia, it is likely that this checklist could be successfully used in other African countries. The *Checklist* is included as an appendix.

Table 4 provides specific guidance for mitigating and monitoring adverse environmental impacts for irrigation activities.

Table 4: Mitigation and Monitoring Table for Irrigation Impacts

Category	Problem	Root Cause	Mitigation Measure
Soil problems	Waterlogged soil	Overwatering; inadequate drainage	Use good irrigation management, matching water demand and supply by location. Provide drainage and line canals in highly permeable areas to prevent leaks. Redesign irrigation infrastructure to reduce waste; use sprinkler or drip irrigation systems instead of gravity-flow systems. Encourage farmers to value water resources by establishing a system of water user fees tied to consumption.
	Salt buildup on irrigated land	Irrigation system does not adequately leach salts from soils	Design system to allowing leaching with excess water. Alternate irrigation methods and schedules. Install and maintain subsurface drainage system. Adjust crop patterns (fallow times, crop selections, etc.) to prevent further salt buildup. Incorporate soil additives. Add gypsum to either the irrigation water or the soil before irrigating. Plant salt-tolerant catch crops such as *Sesbania*.
	Crops wilting or dying	Changes to soil chemistry, including acidification and alkalization	Monitor soil chemistry. Identify indicator plant species. Consult soil scientists. Apply soil nutrients, conditioners and chemicals where feasible.
Water problems	Crops not growing over entire irrigated field	Intrafield distribution system is malfunctioning	Maintain irrigation canals. Clear weeds. Line canals against leaks. Encourage farmers to value water resources by establishing a system of water user fees tied to consumption.
	Dry wells for drinking water and irrigation	Groundwater depletion	Reduce off-take or pumping to allow natural aquifer recharge. Encourage farmers to value water resources by establishing a system of water user fees tied to consumption.

Water problems, cont.	Salt water in wells for drinking water and irrigation	Saline intrusion in coastal aquifer due to excessive groundwater pumping	Reduce groundwater pumping to allow natural freshwater to recharge the aquifer, in order to lower salt concentration in the aquifer.
	Water quality problems for downstream users	Discharged irrigation water is saline or contaminated	Treat irrigation drainage water before release.
	Reduced water quantity for downstream users, waterways and wetlands; intermittent streams run dry.	Too much water diverted for irrigation Poor understanding of stream flows and available water	Reassess water available for irrigation; may need to irrigate a smaller area. Use pipes instead of open canals to prevent water loss from evaporation. Promote local and regional watershed management. If available, consider using treated wastewater for irrigation, leaving freshwater resources for other users.
Health problems	Increased incidence of water-related diseases	Stagnant waterways providing breeding grounds for disease vectors Inappropriate design causing suitable conditions for vectors Shared use of water for irrigation and home use	Periodically flush slow or stagnant waterways with water from dams to remove snails (which cause schistosomiasis). Note that this is effective only for a few hundred meters from where the water is released. Clear clogged irrigation canals. Control mosquitoes, snails and blackfly along reservoirs by periodically fluctuating water levels, making shorelines steeper, and removing weeds. Periodically drain waterlogged fields to prevent mosquitoes. Train women in health issues.
Social problems	Increased inequity	Inequitable access to irrigation waters or crops	Design and manage system to improve access by “tail-enders” (users whose fields are farthest from the water source). Establish and enforce a volume-based water fee. Improve system management, including maintenance of main canals.
	Hinterland effect	Increased migration into area due to successful project	Ensure adequate social and other infrastructure to meet needs of immigrants.

Water transport and storage problems	Weeds growing in reservoirs, irrigation canals, and drains	Siltation or blockages reducing flow	Mitigate weeds in reservoirs, canals and drains by using linings, shade, intermittent drying-out periods, mechanical removal, and weed-eating fish and insects. The removed weeds may also be used for composting, biogas generation, and fish and animal feed.
	Poor water quality downstream from a dam	Insufficient water flow from dam, or poor-quality water behind the dam	Use dam operations to maintain minimum flow conditions to dilute pollutants. To prevent anoxic conditions in reservoirs, clear organic matter, such as trees, before filling.
Ecosystem problems	Damage to downstream ecosystems from reduced water quantity and quality	Too much water diverted for irrigation or storage Saline intrusion at coasts	Use dam operations to mitigate changes in flow regimes of rivers and prevent weeds and diseases.

1.3 Resources and References

Internet Sites Pertinent to Environmental Review of the Agriculture Sector

- The New International Invasive Species Compendium: http://www.cabi.org/isc

  Invasive species are among the largest causes for reduced food production and post-harvest losses, and they can be major vectors for human and animal diseases. For example, in sub-Saharan Africa the UN estimates the cost of the invasive witchweed is responsible for annual maize losses amounting to $7 billion; and, overall losses to invasive species may amount to over $12 billion for Africa's eight principal crops.

  This data base/compendium was partially funded by USAID and USDA along with a number of other donors, and it is now available to anyone with access to the internet. Developed in partnership with CABI (formerly the UK's Commonwealth Agricultural Bureaux, but in 1986 it became a public international organization).

  This is a living compendium and will grow over time. At the start it includes:
    - Datasheets on over 1500 invasive species and animal diseases.
    - Basic datasheets on further species, countries, habitats and pathways
    - Bibliographic database of over 65,000 records (updated weekly)
    - Full text documents (updated weekly)

- U.S. Environmental Protection Agency, Public Information Center (3404), 401 M Street, S.W., Washington, D.C. 20460; tel. (202) 260-2080: http://www.epa.gov

  Environment and biodiversity conservation issues, as well as the relationships between natural resources management and agricultural productivity, have become important topics considered by the 16 international research centers that form the Consultative Group for International Agricultural Research (CGIAR): http://www.cgiar.org

- The UN Food and Agricultural Organization (FAO) Aquastat Web site: http://www.fao.org/nr/water/aquastat/main/index.stm

- Conservation Agriculture in Europe: http://www.ecaf.org/English/First.html (good definition of conservation agriculture in executive summary)

- UN Environment Program (UNEP) Programme on Success Stories in Land Degradation/ Desertification Control: http://www.unep.org/desertification/successstories/

- Good Web site under the University of Pennsylvania's African Studies Center: http://www.sas.upenn.edu/African_Studies/About_African/ww_food.html

- FAO. Agriculture Food and Nutrition for Africa: A Resource Book for Teachers of Agriculture: http://www.fao.org/docrep/W0078E/w0078e00.htm

- FAO. The State of Food and Agriculture 2001: http://www.fao.org/docrep/003/x9800e/x9800e00.htm

- About desertification: http://cals.arizona.edu/OALS/ALN/aln40/WebResources.html

- International Development Research Centre (IRDC). This Canadian institution is a constant source of information on sustainable agriculture in the developing world: http://www.idrc.ca/en/ev-1-201-1-DO_TOPIC.html

- Swedish International Development Agency (SIDA). A major international donor supporting soil and water conservation development programs in many countries: www.sida.org

- Revised Universal Soil Loss Equation project version 2: http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=175643

- U.S. Global Change Research Information Office, Geoindicators report: http://www.lgt.lt/geoin/

Tapping the U.S. Comparative Advantage in Soil and Water Conservation and Sustainable Agriculture

- U.S. Department of Agriculture (USDA) listing of agencies, services and programs: http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?navtype=MA&navid=AGENCIES_OFFICES

- USDA's Sustainable Agriculture Research and Education (SARE) Program is an emerging program administered by the Cooperative State Research, Education and Extension Service (CSREES). Although targeted at farming conditions in North America, the conceptual approach and many of its findings can be applied in sub-Saharan Africa: http://www.sare.org/publications/index.htm Some of its more noteworthy publications include Building Soils for Better Crops, The Small Dairy Resource Book, Managing Cover Crops Profitably and Source Book of Sustainable Agriculture. It also operates a free e-mail discussion group; to subscribe, send a message to listserve@sare.org, and in the body of the message, write "subscribe sanet-mg."

- The USDA's Natural Resources Conservation Service Web site offers links to a broad spectrum of information about its programs and information sources related to soil, water and natural resources conservation: http://www.nrcs.usda.gov/

- The Soil and Water Conservation Society of the United States is an international organization with programs and publications of interest to those in Africa concerned with soil and water conservation and watershed management: http://www.swcs.org

- The Alternative Farming Systems Information Center offers information resources for farmers and extension agents: www.nal.usda.gov/afsic/csa

- Another site providing assistance, publications and resources free to farmers, extension educators and other agriculture professionals is the Appropriate Technology Transfer for Rural Areas (ATTRA) network: www.attra.org

- The Cornell University-managed Agricultural Network Information Center, or AgNic (www.agnic.org), is an unparalleled guide to quality agricultural information on the Internet from the National Agricultural Library, land-grant universities, and other institutions. It includes access to Cornell's Soil Health Portal (http://mulch.mannlib.cornell.edu), which uses a distributed database technology.

- The Sustainable Rural Development Information System (SRDIS), cosponsored by Columbia University, the Center for International Earth Science Information Network (CIESEN), and other partners (http://srdis.ciesin.org/), is another specialized online library of Internet-based resources.

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- FAO Soils Bulletins include several titles of particular interest to soil and water conservation, including No. 4, Guide to 60 Soil Water Conservation Practices; No. 13, Land Degradation; No. 30, Soil Conservation in Developing Countries; No. 33, Soil Conservation and Management in Developing Countries; No. 34, Assessing Soil Degradation; No. 44, Watershed Development with Special Reference to Soil and Water Conservation; No. 49, Application of Nitrogen-Fixing Systems in Soil Management; No. 50, Keeping the Land Alive: Soil Erosion, Its Causes and Cures; and No. 53, Improved Production Systems as an Alternative to Shifting Cultivation.

- FAO Web site: Intensifying Crop Production with Conservation Agriculture. http://www.fao.org/ag/ags/AGSe/General/Cont1.htm. A Web site with excellent publications and case studies, including:
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Irrigation-Related References

- These brief guidelines cannot begin to cover the diversity of small-scale irrigation systems found in Africa, which occur across a variety of ecological, social and geographic settings. Examples include dambos, in southern Africa, the marais in the upland areas of Rwanda and Burundi, bas-fonds in West Africa, and other wetland areas, including the West African coastal mangrove systems bolanhas where rice is produced. Extensive literature collections on these specialized topics can be found in Africa (Zimbabwe, South Africa, Nigeria, Cote D'Ivoire, Egypt, Morocco) and at universities and other institutions worldwide. We hope the references here will lead the reader to these other sources-some broader, some more specialized.

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1.4 Appendix: A Checklist for Planning Environmentally Sound Small-Scale Irrigation (SSI)

Introductory Note

This checklist for environmental planning is based on small-scale irrigation (SSI) work done in Ethiopia and was designed to assist NGOs there in environmental review of small-scale irrigation activities. If done correctly, using the checklist will accomplish several things:

- users will have identified potential negative environmental impacts associated with the proposed site;
- users can certify to USAID that they are aware of these impacts and have taken the appropriate steps to avoid and/or mitigate them;
- the completed questionnaire and the information it contains, submitted as part of an IEE, will enable USAID environmental officers to verify that the determination is valid and the activity can be approved; and
- everyone involved in the small-scale irrigation activity, including USAID staff, will be aware of which specific elements of the activity require monitoring.

It should be noted that this checklist is not intended to give scores or rankings or to compare one proposed small-scale irrigation site with another. It is further assumed (as specified below) that the provisions for supervision, inspection and monitoring related to the typical mitigation needs of small-scale irrigation will be in place. The checklist is intended chiefly as a guide to ensuring that issues related to the environmental soundness of SSI are addressed iteratively throughout the planning and design steps.

Each item on the checklist needs to be considered and the information duly recorded. Doing so will make it easier to prepare the IEE (or amended IEE); it may also be possible, depending on the outcome of using the checklist, to append it to the IEE itself, allowing the IEE to deal in a more summary fashion with the usual categories of required information. Users are encouraged to add any other information or categories of data that emerge as important in preparing the plan for development of the specific scheme.

To successfully use this checklist, the basic studies, measurements and community consultation regarding the feasibility and design of the proposed activity should have already been carried out. The checklist can also serve as a tool for structuring the consultation needed with the community and any water user associations about:

- the basic design of the SSI site;
- the potential for negative environmental impacts;

- the roles, rights and responsibilities of the different parties (community, water users, project staff, partners, government agencies) in addressing these impacts; and
- the agreements to be achieved among all parties to ensure the sustainability of the activity/investment.

This template does not cover all the potential precautionary measures, nor all possible issues related to the feasibility of small-scale irrigation at every site. Finally, it is not intended to be a substitute for planning and designing the SSI activity.

Note: The abbreviation “masl” used in the checklist = meters above sea level.

Environmental Planning for Small-Scale Irrigation: A Checklist

1. Small-Scale Irrigation Site Identification and Characteristics (fill in the blanks)

Date project planning began: ____

Expected completion date:__________ Present status:____

Site/community name: ____

Location (region, district, village):____

Approximate altitude of scheme:_________________(masl): Agro-ecological zone: __________________

Project Design by:____

Brief project history (proposed by, how identified, by whom):____________________________________

____

Community concurrence:__________ How reached:____

Water user association (WUA) established? [yes/no]:________ Name:_______________________________

How established:____ Date:______________

Number of beneficiary participants in WUA:_________________________

Number of males:____________________ Number of females:_______________________

Percentage of total community to be included in scheme:____________________________

Area to be irrigated:_________________(hectares)

Type of irrigation (spring, diversion, storage, spate, or lift):_______________________

Average size of household irrigated plot:______________ (hectares)

Previous use of irrigated area:____

Is this (check all that apply): a new scheme:________, rehabilitation of traditional scheme:________, upgrading of traditional scheme: ________, rehabilitation of modern scheme: ________

Proposed crops: wet season: ____________________________, dry season:___________________________

Average household holdings outside the scheme:____

Other major infrastructure or investments linked to SSI: ____

____(e.g., roads, potable water, watershed management)

What is the total cost of the scheme?: ___________; broken down by cash costs:___________ food aid cost equivalents (if applicable):___________; community contribution in labor and in kind:___________

Estimate the costs in either US dollars or local currency. Include all necessary investments required for the scheme to operate. Food aid costs can be calculated by multiplying the number of person/days of labor by the equivalent value of the day's ration. Community contribution can also be factored into the calculations, including contributed free labor, if any, and the estimated value of the materials provided (stone, sand, soil, etc.).

What is the expected unit cost per hectare of irrigable land within the command area during the dry season?__________$/hectare.

What percentage of the annual operating budget does the project cost represent, for the district:__________, for the local area:__________, for the program of the project organizer:__________?

Sketch map included: (to scale at 1:10,000 or larger)

2. Analyzing the Basic Parameters

Prepare a brief narrative response for all of the headings below that apply to this site.

Water Resources Availability

- How much water (liters/sec) is available for irrigation purposes?
- Is there a historical record of river/stream hydrology (yes/no)? If so, how was it compiled?
- If not, how was amount calculated? Briefly describe method. (An additional sheet showing calculations should be added.)
- Are there upstream users of the water, or could there be? Explain.
- Are there downstream users, and how do they use water?
- Are they actively pursuing irrigation, and are they using water for potable water supply or for animal consumption? Estimate their requirements (liters/sec).
- How were downstream users consulted?
- What percentage of stream flow will be abstracted during lean (low-flow) periods?

Other Uses and End Users

- Has the potential usage by people or animals been factored into the calculations of water use within the scheme? If so, how?
- Will the scheme attract additional herders and their animals in search of water, including from beyond the present community?
- Is there a need for maintaining minimum ecological flow during the lean season? If not, why not?
- What precautions are being undertaken to guard against unnecessary leakage/evaporation within the scheme?
- Describe the methods by which government staff, WUA officials and the users themselves will measure/know about the annual/seasonal/periodic water availability.

Catchment Status

- What is the estimated size, in hectares, of the catchment that supplies water to this scheme?
- What are the present land uses of the catchment? A sketch map may help to illustrate this point.
- What is the condition of the catchment (good or natural, slightly degraded, moderately degraded, highly degraded, being rehabilitated)?
- Do the present activities include rehabilitating/improving the catchment? If so, what will this entail?
- What percentage of the catchment will be treated each year, and by whom?

3. Estimating Crop Water Requirements

Prepare a brief narrative response for all of the headings below that apply to the site.

- What crops will be planted and in which season?

- What are crop water requirements per hectare?
- An additional sheet describing likely crops and their water requirements in different seasons could be added.
- What is the source of information for the crop water requirements? Describe.
- Which publications are the basis for this estimate of crop water requirements, or how else were these amounts determined (see bibliography)?
- What will be the likely percentage mix of the project's main crops during the wet season and the dry season?
- How will the size of the area under irrigation change from wet season to dry season?
- Are there expectations/intentions about building up the command area during the break-in stage of implementation? (Explain.)
- Are these crops that are familiar to the users or already being grown by them?
- In years of poorest rainfall, what will be the estimated area of irrigable land, and how will the cropping pattern change during the dry season? (Explain).
- What are the expectations regarding production increases, in good rainfall years (percent increase) and in poor rainfall years (percent increase)? What would be the worst-case scenario? (Explain).
- Give some examples of the expectations regarding increases in yield, by crops.

4. Farm/Scheme Land and Water Management and Conservation

Prepare a brief narrative response for all of the headings below that apply to the site.

- Do the proposed users have experience with SSI?
- Will there have to be land redistribution? (Explain—regularly/annually/periodically?)
- What sort of water management technology will be used within the irrigated plots?
- Will the users be able to maintain the fertility of their irrigated plots, and how will they do so?
- What is the average slope of the land within the command area?
- Will soil conservation measures within the scheme be required? If so, briefly describe them.
- Are there indications of salinity problems in similar SSI schemes nearby?
- What did the measurements of water quality (grams/liter) and soil salinity (salinity class) reveal?
- Is salinity likely to become a problem in this scheme? If so, what measures will be taken to manage the problem? Describe.

5. Postconstruction Follow-Up and Technical Assistance

- Where will the farmers get extension support from—government or private sources?
- Are there extension agents available?
- Have the extension information sources been specifically trained in irrigated agriculture, and have they received training specific to this site and its operations?

- Do the information sources need transport to reach the scheme, and do they have it?
- Is there an operations manual to guide these extension services?
- What other services will be provided by the information sources? Input supply? Marketing? Pest and disease diagnostic services? Other?
- Briefly describe any training provided and planned for the WUA officers and users.
- Is there a water user's fee system, and what are its principles? Briefly describe.
- Briefly describe the operations and maintenance requirements of the scheme and who will be charged with its implementation.
- What level of technical assistance from the project designers will be required by the WUA during the start-up phase of the irrigation activities?
- Have the necessary resources (staffing and budgetary) been set aside for this purpose?

6. Water-Related Disease Hazards

Because of the importance of environmental health, particularly in the hotter, lower altitudes, the project designer should provide, if possible, a citation of the environmental health study findings as a supplement to the response to this section of the Checklist.

- Has an environmental health assessment been part of the planning for this scheme? If so, briefly discuss its results.
- Is a health baseline data set available for the community, and what are its most important quantitative findings? Provide a list.
- Briefly discuss expectations regarding community vulnerability to water-borne diseases.
- Briefly discuss expectations regarding public awareness of environmental issues.
- Briefly explain the status of health services in the community, and describe any plans for upgrading these services.
- What percentage of the community has access to potable water, and where do they normally obtain it, in the wet season and in the dry season?
- Does the program of the project designer in this community include a potable water supply component? Briefly describe.
- Is there a community-specific nutritional baseline available?
- What are the household-level nutritional goals of the scheme? Describe.
- How will these goals explicitly be achieved? Describe.
- What measures will be taken for providing potable water to the workforce during construction and for training the workforce on water-related disease hazards? Describe.

7. Displacement and Land-Use Changes

- Will there be displacement of farm plots as a result of scheme construction? If so, briefly describe (no. of households affected/area of land affected).
- Will the command area change/shift as a result of rehabilitation or upgrading? If so, briefly describe.
- What measures are planned to account for these displacements/changes? Describe.

- What percentage of the command area is likely to be devoted to cash crops? Which crops will they be?
- Where and how will these cash crops be marketed and by whom? Describe.
- What are the expectations regarding prices for these cash crops, transport and marketing costs, and returns to the farmers? Describe with as much quantitative data as possible.

8. Monitoring Plans

- What indicators will be monitored to ensure that activities are not leading to unforeseen adverse environmental impacts?
- Which of the planned mitigative measures (see below) will require further specific monitoring to be sure it is effective, and how will this be done?
- How will environmental monitoring be linked to performance monitoring to avoid needless duplication of efforts and meet reporting requirements?

9. Mitigative Measures Planning

- Identify the specific adverse environmental impacts foreseen during planning and describe the mitigative measures for each.
- How have the costs of these measures been factored into the feasibility considerations for the scheme in question?
- Will there be resources available for post-construction mitigation measures, and who will provide them?