



**USAID**  
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SECTOR ENVIRONMENTAL GUIDELINES

# AGRICULTURE

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**Cover Photo:** Lined and unlined canals for irrigated rice in Zanzibar. Photographer: Charles Hernick.

# About this document and the Sector Environmental Guidelines

**This document presents one sector of the Sector Environmental Guidelines** prepared for USAID under the Agency's Global Environmental Management Support Project (GEMS). All sectors are accessible at [www.usaidgems.org/bestPractice.htm](http://www.usaidgems.org/bestPractice.htm).

**Purpose.** The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally sound design and management (ESDM) of common USAID sectoral development activities by providing concise, plain-language information regarding:

- the typical, potential adverse impacts of activities in these sectors;
- how to prevent or otherwise mitigate these impacts, both in the form of general activity design guidance and specific design, construction and operating measures;
- how to minimize vulnerability of activities to climate change; and
- more detailed resources for further exploration of these issues.

**Environmental Compliance Applications.** USAID's mandatory life-of-project environmental procedures require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation via the Environmental Impact Assessment (EIA) process defined by 22 CFR 216 (Reg. 216). They also require that the environmental management/mitigation measures ("conditions") identified by this process be written into award documents, implemented over life of project, and monitored for compliance and sufficiency.

The procedures are USAID's principal mechanism to assure ESDM of USAID-funded Activities—and thus to protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the good name and reputation of USAID.

The Sector Environmental Guidelines directly support environmental compliance by providing: information essential to assessing the potential impacts of activities, and to the identification and detailed design of appropriate mitigation and monitoring measures.

*However, the Sector Environmental Guidelines are **not** specific to USAID's environmental procedures. They are generally written, and are intended to support ESDM of these activities by all actors, regardless of the specific environmental requirements, regulations, or processes that apply, if any.*

**Region-Specific Guidelines Superseded.** The *Sector Environmental Guidelines* replace the following region-specific guidance: (1) *Environmental Guidelines for Small Scale Activities in Africa* ; (2) *Environmental Guidelines for Development Activities in Latin America and the Caribbean*; and (3) *Asia/Middle East: Sectoral Environmental Guidelines*. With the exception of some more recent Africa sectors, all were developed over 1999–2004.

**Development Process & Limitations.** In developing this document, regional-specific content in these predecessor guidelines has been retained. Statistics have been updated, and references verified and some new references added. However, this document is not the result of a comprehensive technical update.

Further, *The Guidelines* are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

**Comments and corrections.** Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: [gems@cadmusgroup.com](mailto:gems@cadmusgroup.com).



**Advisory.** *The Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Guidelines does not necessarily assure compliance with USAID Environmental Procedures or host country environmental requirements.*

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# AGRICULTURE: SOIL AND WATER RESOURCES, INCLUDING IRRIGATION



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 design considerations and monitoring must be an important part of agricultural development programming.

Pumping groundwater for irrigated rice in Zanzibar. Charles Hernick.

## BRIEF DESCRIPTION OF THE SECTOR

Agricultural development has long been a mainstay of USAID's programs throughout the developing world. Helping rural people to develop sustainable and productive farming systems generates income and reduces food insecurity. Given the key role agriculture plays in developing economies, and its importance to rural households' food security, small-scale agricultural development activities targeted at the rural poor are likely to increase. Identifying potential impacts during the planning stages of a project, or during an environmental assessment, allows for alternative methods to be developed, thereby contributing to sustainable agriculture and increased yields.

A number of factors affect agricultural productivity and rural prosperity:

- **Natural resources** (e.g., biophysical framework of soils, water, temperature, and endemic flora and fauna or livestock).
- **Traditional practices.**
- **Government policies** (e.g. land tenure, marketing, animal welfare, labor relations).

### Note

This guideline focuses on crop agriculture and is divided into two sections: dry-land 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 sections of these guidelines, "Integrated Pest Management" and "Safer Pesticide Use." Other agriculture-related issues are addressed in the guidelines on forestry, livestock, and community-based natural resource management.

- **International trade agreements.**
- **Public opinion and concerns.**
- **Environmental and climate fluctuations.**

These factors directly influence the quality and quantity of agricultural products produced on individual farms. Changes in these factors over time can enhance or constrain productivity. For example, in Africa, reduced soil fertility and declining available soil moisture, as well as changing temperatures, rainfall patterns, and extreme weather events are major constraints. An estimated 95 percent of Africa's lands face challenges from soils, topography and climate.

Soil fertility depletion, in particular, severely limits production throughout the developing world. Yet many responses to this problem are available. Expanding the use of tested management practices, such as watershed management to conserve moisture on hillsides, applying rock phosphate, planting nitrogen-fixing trees or cover crops in fallows, and transferring biomass, can reduce or overcome these constraints to crop production. Encouraging profitable alternative land uses such as integrating livestock with agriculture, wildlife farming, or forestry is another approach.

### **Feed the Future (FtF)**

Feed the Future (FtF) is the United States (U.S.) Government's global hunger and food security initiative. It supports country-driven approaches to address the root causes of hunger and poverty and forge long-term solutions to chronic food insecurity and under nutrition. Drawing upon resources and expertise of agencies across the U.S. Government, this Presidential Initiative is helping countries transform their own agriculture sectors to sustainably grow enough food to feed their people.

Feed the Future is the U.S.'s contribution to a collaborative global effort that supports country-owned processes and plans for improving food security and promoting transparency. Feed the Future represents a \$3.5 billion pledge to work with partner countries, development partners, and other stakeholders to tackle global food security challenges. Our collective efforts advance global stability and prosperity by improving the most basic of human conditions: the need that families and individuals have for a reliable source of quality food and sufficient resources to purchase it. These efforts, in turn, ultimately advance international security and benefit the American people.

The increasing demand for fresh water for domestic and industrial use is another limiting factor to agricultural productivity and is likely to be exacerbated by temperatures increases, more variable precipitation patterns, and more extreme events, such as floods and droughts, associated with climate change. 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 irrigation. 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, lessened water quality, and caused the rapid disappearance and degradation of wetlands.

Again, concerned parties can draw on a wide range of approaches to address farming-related 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.

In recent years, many communities have also been stressed by changing temperatures, rainfall patterns, and extreme weather events indicative of a changing climate. Climate change is requiring a focus on adaptation, defined as adjustments in natural or human systems in response to actual or expected climate change stresses, which moderate harm or take advantage of beneficial opportunities. Adaptation involves managing current variability and preparing for future changes. By doing so, project managers can improve the likelihood that projects will have long-term success. Project managers can also minimize the project's contribution to climate change by identifying cost-effective ways to minimize greenhouse gas emissions. Many of the techniques that improve the sustainability of small scale agriculture, such as conservation agriculture and agroforestry, can also contribute to climate change adaptation and mitigation.

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 land from an environmental perspective, but because off-farm externalities, such as market forces or a lack of savings frequently drive farmers to make trade-offs in order to continue to feed their families and generate household income. Often, shortened fallow periods, lack of crop rotation, over-tilling and other poor land-use measures undermine sustainability of the farming system and cause environmental harm.

Good agricultural practices allow sustainable use of the natural resources—soil and water—needed for crop production. In some circumstances however, rural residents can be found farming on marginal terrain—sloping lands, infertile soils and areas with low and/or irregular rainfall. The challenge of cultivating marginal land is often exacerbated by a lack of resources, an inadequate policy framework, and poor input supply and market systems.<sup>1</sup> Lacking access to productive technologies, information on weather and climate conditions, agricultural inputs or employment alternatives, the rural poor often drain the remaining life out of their fragile soils. Marginally productive land only exacerbates their poverty and vulnerability.

This section 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 variability and change and extreme events and add incrementally to their agricultural productivity through sophisticated use of soil, water, and vegetation.

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<sup>1</sup> The construction, upgrading or maintenance of “farm to market” roads is dealt with in the rural roads *Guideline*.



# 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 be the result of 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 marginal or degraded lands may be used for agriculture. This land use may impose constraints on and be unsuitable for agriculture due to variables such as climate; endemic vegetation; slope; and soil depth, texture, composition, and water availability. Expansion onto suboptimal lands not only causes further degradation, but can also displace previous land uses such as firewood gathering, livestock grazing, hunting, or medicinal plant gathering.
- **Deforestation.** Natural forests are often degraded by encroachment, excessive or uncontrolled harvesting, construction of roads that divide them into smaller blocks, or clearing for charcoal, crop and livestock production. In addition, slash-and-burn agriculture—during which the land is cleared by burning ground cover—replaces the soil and shade protection given by perennial tree vegetation with short-lived crops that, once harvested, remove scarce soil nutrients. It is true that when forests are burned to clear the trees for planting, the resulting ash enriches the soil. In very specific circumstances, such as in areas with minimal population pressure and sufficient time for fields to recuperate, slash-and-burn can serve as an effective system. However, burned areas rapidly lose the initial fertility the ash gives them, so without those specific conditions in place, deforested areas—already more liable to runoff, flooding and soil erosion—become increasingly fragile. Destruction of forest areas also leaves local populations without the fuelwood, timber, and forest resources they use both to meet household needs and earn an income, and disrupt natural ecosystems and wildlife habitat. Local deforestation can contribute to more intense flooding. Therefore, project managers should take particular care to curb practices leading to deforestation in areas where flooding is already a problem or where increased precipitation is a projected impact of climate change. Deforestation also has global implications. Deforestation and forest degradation are the second largest source of greenhouse gas emissions (after fossil fuel consumption), accounting for about 15% of annual global emissions, which makes the loss and depletion of forests a major issue for climate change. Reducing emissions from forest destruction has also been identified as one of the potentially



Slash-and-burn agriculture can quickly lead to deforestation, erosion, and the loss of soil nutrients, with devastating impacts on the environment, wildlife, and local community.

most cost effective ways to reduce the rate of increase of atmospheric greenhouse gasses.

- **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 areas that do not support agricultural activity. 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, regulating the flow of water especially during floods, 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, causes loss of protective barriers including 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.

### Viewing agricultural systems as ecosystems

Ecosystem services are defined as “the benefits provided by ecosystems to humans.” Ecosystem services are the product of interactions between individual ecosystem attributes such as species biodiversity, soil health, ecological functions (processes), ecosystem extent, and physical characteristics. The result is a stream of services including nutrient cycling, pest regulation, an increase in beneficial insects and pollinators, carbon sequestration, and sustained agricultural productivity. Viewed through this framework agricultural ecosystems function as a cyclical or renewable system where one part's waste is another's input. Agricultural ecosystems can be managed to maximize not just crop production, but other services important to the community such as livestock, capture fisheries, fresh water, erosion control, and flood mitigation as well as ecosystem services important globally such as carbon storage.

Focusing on managing agriculture as an ecosystem within a larger ecosystem and community ensures resilience as demand for food production increases with a growing population.

- In industrial-scale monoculture agriculture, such as sugar plantations, the fertilizer used can increase nutrient loads and cause eutrophication<sup>2</sup> of estuaries and ponds, which are breeding grounds for many commercially important species, including fish, mollusks and crustaceans. In extreme cases, the consequences of eutrophication in estuaries can include smaller fish yields, fish deaths, destruction of coral reefs, and ecosystem instability or collapse.
- 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 once-expansive environment surrounded by agricultural land. Fragmented habitat undermines the effectiveness of the park by limiting animal migration and supporting

#### 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 or changes in local hydrology
- Increased GHG Emissions

unsustainably small and decreasing wildlife populations. Also, if there is increasing population pressure in close proximity to the protected area, people will seek to develop the land up to the margins of the protected area and even within it, reducing the protected area's usefulness as habitat.

## BIODIVERSITY LOSS

Increasing genetic homogenization of crop and livestock species replaces on-farm diversity (e.g., diverse varieties) with uniform genetic stock. These pure stands may be more vulnerable to a catastrophic disease outbreak and may need more off-farm inputs to produce well. Farmers may remove endemic plant and animal species from their land to reduce the negative effects of pests, predators and weeds. However, there are complex interactions between crops and their wild neighbors: certain native insects, plants and micro-organisms may play a key role in crop reproduction; maintaining soil fertility; controlling pests, weeds, erosion, and floods; and ensuring clean water supplies. The loss of pollinators

<sup>2</sup> Eutrophication is the process by which a body of water becomes enriched with excess dissolved nutrients (such as nitrogen and phosphorous) that stimulate the growth of aquatic plant life (e.g. algae), usually resulting in the depletion of dissolved oxygen.

due to pesticide overuse or misuse and loss of habitat (extent or quality) is an issue that reduces or prevents crop reproduction as well.<sup>3</sup>

## 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 become invasive, spreading diseases, out-competing native species for resources, becoming feral, acting as predators or pests, or interbreeding 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 that expose soil such as full tillage or tillage without the use of green manures,<sup>4</sup> badly managed open-furrow agriculture, deforestation, or draining wetlands—can all cause soil erosion. As the soil erodes, less rainfall is absorbed and excess rainfall runs off, removing the fertile topsoil necessary for crop production and imposing disastrous off-site consequences, including increased eutrophication (as described above), gully formation, landslides, siltation and sedimentation of water bodies, downstream flooding, and damage to productive infrastructure. Soil erosion may be exacerbated by temperature increases, more variable precipitation patterns, and more extreme events, such as floods and droughts, associated with climate change.
- **Reduction of soil fertility.** Soil fertility is dependent on three major nutrients (nitrogen, phosphorous and potassium), various trace elements, soil biodiversity (including microbes, beneficial soil bacteria, and earthworms), and organic matter content. A productive soil contains sufficient quantities of each of these factors. The fertility of soil declines with the removal of any of these factors, and with practices such as 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.

### Losing valuable topsoil— What erosion really means:

Studies carried out in various countries including 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 or sloping sites farmed extensively by marginal smallholders in the higher-rainfall areas.

Source: Sheng, 1989.

<sup>3</sup> UNEP. 2007. Global Pollinator Decline: A Literature Review.  
[http://www.grid.unep.ch/products/3\\_Reports/Global\\_pollinator\\_decline\\_literature\\_review\\_2007.pdf](http://www.grid.unep.ch/products/3_Reports/Global_pollinator_decline_literature_review_2007.pdf)

<sup>4</sup> Sullivan, P. ATTRA. 2003. Overview of Cover Crops and Green Manures.  
[http://www.clemson.edu/sustainableag/IP024\\_covercrop.pdf](http://www.clemson.edu/sustainableag/IP024_covercrop.pdf)



Chemical fertilizers can be used to deal with soil fertility problems. But in many developing countries, chemical fertilizers are often scarce, expensive or not economical to use. Other practices that increase soil fertility include using organic fertilizers, such as animal manure, planting cover crops after the growing season, intercropping, or using green manure.

## SILTATION OF WATER BODIES

Eroded topsoil is carried by runoff into water bodies and soil settles in slower-moving water, 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 AND LOCAL HYDROLOGY

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.<sup>5</sup> Even when applied correctly, the scale of application (i.e. the size of the farm or the number of farms in a watershed applying agrochemicals, fertilizers, or manures may result in pollution. 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 and 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.



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

Changes in local hydrology may stem from land use change (e.g., from native vegetation to crops) and on-farm water management practices. These changes may result in a loss of water regulating ecosystem services. These changes may negatively impact downstream water users who depend on minimum flows or seasonal floods for their activities. These changes may be exacerbated by temperatures increases, more variable precipitation patterns, and more extreme events, such as floods and droughts, associated with climate change.

## THE EFFECTS OF POLICY ON THE ENVIRONMENTAL IMPACTS OF AGRICULTURE

National agricultural and economic policies alter the costs and benefits of particular agricultural investments and practices. Poorly designed policies can inadvertently discourage environmentally-sound agriculture and livestock husbandry practices, or it may unwittingly reinforce others that have adverse

<sup>5</sup> The impacts of pesticides on the environment are discussed in the *Guideline on integrated pest management (IPM) and safer pesticides*.

impacts on the environment and the land's long-term productivity. Aspects of the policy environment that may cause unintended harm include:

- **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. It is important to consider gender and other social issues associated with tenure. For example, in many areas, women are more likely than men to lack tenure, as are poorer populations.
- **Agricultural subsidies/payments and pricing.** Government control of markets and prices all influence farming practices and production goals. Means of control may include mandated prices of agricultural goods and services, taxes, tariffs and subsidies, import and export quotas, exchange rate policies, and preferences for state-run parastatal marketing. Subsidies, payments, and price controls may have positive or negative effects on the environment. For example, agricultural 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. However, payments for conservation/land set-asides may have beneficial effects on ecosystems and their related services, such as water purification and regulation, habitat for commercially important animals (for hunting or fishing).
- **Resettlement programs in fragile lands.** Traditional (and even sustainable) 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 accurately assessed.
- **Non-participatory 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

### SOIL AND WATER CONSERVATION

Soil and water conservation practices 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. All of these measures aim to reduce the rate of runoff and 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.

Since soil erosion may be to be exacerbated by temperature increases, more variable precipitation patterns, and more extreme events, such as floods and droughts, associated with climate change, soil and water conservation techniques can be useful for climate change adaptation and can also help increase soil carbon.

## SOIL AND WATER CONSERVATION TECHNOLOGIES

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

## 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.

## LAND CAPABILITY CLASSIFICATION SCHEME SUGGESTED FOR FAO FOR SMALL FARMERS IN THE TROPICS (SHENG, 1989).

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 models 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.

- **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. Discussion and training and the identification of alternatives are required to modify the practices that lead to such circumstances in the first place.
- **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.
- **Pair conservation with improvements in soil quality.** Many soil and water conservation programs promote installing barriers of live vegetation and organic matter 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 as 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.
- **Avoid “institutionalizing” subsistence agriculture.** Subsistence agriculture on poor lands is not a long-term means to personal and community economic development. Farmers have

### 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
- Consider climate change impacts where appropriate

aspirations beyond soil and water conservation or increased agricultural productivity. They wish to secure opportunities 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.** A misaligned road, track or path channels and concentrates runoff and leads to soil erosion and gully formation. An FAO study conducted in El Salvador 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. For a more detailed discussion, see the rural roads *Guideline*.
- **Consider climate change impacts where appropriate.** Since soil erosion may be exacerbated by temperature increases, more variable precipitation patterns, and more extreme events, such as floods and droughts, it is important to consider these impacts when planning soil and water conservation projects. Helping a farmers or communities better manage current variability in temperature and rainfall can ensure preparedness for more significant adaptations in the future.

## OTHER CONSIDERATIONS IN AGRICULTURE PROGRAM DESIGN



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

**Promote farmer and community participation.** To ensure proper environmental management farmers and communities should be pro-actively involved in designing agricultural development activities, in judging the chances for harmful environmental impacts, and in controlling and mitigating such impacts. It is important to consider how to effectively engage women and other potentially marginalized social groups in community discussions as they have different roles and responsibilities in agricultural production and respond to incentives differently. If the roles and needs of women and other potentially marginalized social groups are not adequately considered as part of the consultation and buy-in process this may undermine uptake of environmentally beneficial practices. For example, if training is not designed to accommodate women's participation, they may not learn the skills necessary to implement a new practice.

The most important impacts to avoid are those that directly affect the income and health of human populations. Soil erosion and soil fertility depletion reduce the farming system's productivity; lower water quality and quantity; and cause agrochemical contamination. These impacts can be avoided or minimized by employing the soil and water conservation technologies discussed above and educating farmers in behavioral changes that can increase well-being, increase crop resilience to changes in weather, and provide income security, such as more diverse agricultural systems. For example, a system growing three types of crops is more likely to survive drought than a simple monocrop (i.e., maize only) system.<sup>6</sup> 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 and benefits.

### 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.

Building local skills, systems and commitment to environmental review 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.

**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 geo-referenced 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 guideline on

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<sup>6</sup> UN Framework Convention on Climate Change. Risk management approaches to address adverse effects of climate change - Economic diversification. 2013. [http://unfccc.int/cooperation\\_support/response\\_measures/items/5003.php](http://unfccc.int/cooperation_support/response_measures/items/5003.php)

water supply and sanitation in this series deals with these issues in depth, agriculture project design should consider the following water quality and quantity issues:

- **Protection of springs and seeps.** Groundwater springs and seeps 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 and are 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 yield services/uses important to the local community. They need protection to ensure 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 to introduce it into a project area. Plant quarantine and *phytosanitary* (plant health) regulations should be strictly observed.

**Grow crops in greenhouses** if water resources and beneficial insects and pests can be adequately managed. Greenhouses can help maximize crop production and use less space. Because it is controlled environment, water recycling can help conserve water in areas where water resources are scarce. For marginal lands in particular, greenhouses may be a more sustainable agricultural systems compared to others.

**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:

- **Increase sustainable agricultural productivity on already-farmed lands to reduce habitat loss.** By sustainably 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 timber, 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.

**“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



- Planting higher value crops/varieties that can be sold to export markets.
- **Enhance wildlife habitat on farms and establish corridors linking uncultivated areas.** Larger farms may have 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 community-based natural resource management *Guideline*).
- **Mimic natural habitats by integrating perennial plants.** Natural environments include a diverse selection of native annual and perennial plants. Designing farm landscapes that reproduce natural ecosystems helps to conserve water and soil nutrients and can attract beneficial species (e.g., pollinators, insectivores). Techniques for recreating natural habitats include:
  - Planting native trees in pasture. Trees provide shade for cattle, habitats for insect eating birds, erosion control on sloped landscapes, prevent run-off of excess nutrients, and can provide fruit, timber, firewood and other products for farmers.
  - Creating agroforests to shelter annual crops (see the section on forestry and agroforestry in this *Guideline*.)
  - Growing shade-loving cash crops, such as shade-grown coffee (which typically creates more revenue per pound).
  - 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.
- **Use farming methods that reduce pollution.** Techniques for pollution prevention in farming include:
  - Planting buffer strips of native plants between farms and water bodies.
  - Practicing integrated pest management (IPM) (see the sections on IPM and pesticides in this *Guideline*).
  - Practicing organic farming, which uses no synthetic chemicals, antibiotics or hormones. Organic farms and produce need 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 corridors.
- **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 wetland 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 a cover crop to replenish soil nutrients, create channels in the soil for crop roots, and prevent erosion.
- Improving irrigation efficiency.
- Allowing fields to lie fallow to replenish soil nutrients. Planting fast-growing fruit trees and shrubs in fallow fields can increase food security.
- Practicing sustainable forestry (see the forestry *Guideline*).

## CLIMATE CHANGE

### PLANNING FOR A CHANGING CLIMATE

Crops and arable lands are vulnerable to changes in temperature, precipitation, water availability, and seasons. Over the past few decades, many agricultural systems have been altered by changes in climate and these trends are expected to continue in the future. In fact, many recent crop failures caused by atypical weather extremes (e.g. drought, flood) and seasonal temperature and precipitation shifts and variability are consistent with expected changes in climate. Climate change can also impact the diseases, pest infestations or invasive species that can effect crops. With the exception of crops grown in greenhouses, most are exposed to climate stresses, such as changes in temperature or precipitation patterns. Because many crop systems are planned and operate on a short-term basis (several months to several years), there are regular opportunities to plan ahead for exposure to an altered climate.

**In the context of EIA, mitigation** is the implementation of measures designed to eliminate, reduce or offset the undesirable effects of a proposed action on the environment.

**In the context of climate change, mitigation** is an intervention to reduce the sources or enhance the sinks of greenhouse gases in order to limit the magnitude and/or rate of climate change.

Project managers should focus on incorporating information from historical records, recent trends, and future projections. The timeframe of projects should reflect the type of investment being made. For example, projects to plant annual crops may have a shorter timeframe than agroforestry efforts, agricultural research or longer-term investments that use agricultural inputs. Future projections should also take into consideration environmental thresholds that, if surpassed, could cause rapid ecosystem change. Note that near-term projections are more reliable and less uncertain than long-term emissions and climate predictions. In many cases managing for greater uncertainty rather than specific trends may be most appropriate.

Planning for climate change requires an understanding of the relationship between climate, crop growth, hydrologic cycles, and the agricultural economy. To the extent possible, planning should consider the unique climate **sensitivities** of specific crops, soils, and landscapes; for example, some crops require very narrow temperature ranges while others can tolerate higher or lower temperatures. Some crops may be more resilient than others when facing a changing climate and some locations may be at lower risk of impacts like increased storm intensity, rainfall, drought, or temperature. Climate change impacts may be more severe if other non-climate stressors—like increased human withdrawal of water, erosion, nutrient loss, or development-caused flooding—make crops more sensitive. Some crop varieties may no longer be economically viable as they are increasingly affected by changes in climate, diseases, pest infestations, or invasive species. Ultimately, improving access to information about crop options and

providing or improving weekly and seasonal weather forecasts for farmers can improve their ability to anticipate and adapt to probable impacts.

## ADAPTING TO CLIMATE CHANGE BY MINIMIZING VULNERABILITY THROUGH PROJECT DESIGN

A particular agricultural system's vulnerability to climate change is the degree to which it may be unable to cope with a changed climate. Vulnerability is a function of exposure, sensitivity, and adaptive capacity. While exposure and sensitivity, as discussed above, refer to physical attributes, adaptive capacity refers to the capacity or potential of people to:

- Adjust to, rebound from, or cope with the consequences of climate variability and climate changes
- Moderate potential damages
- Take advantage of opportunities

Elements of adaptive capacity include:

- Access to information
- Access to financial, technical, human resources
- Social capital and cohesion
- Redundancy of transportation and information systems
- Economic diversification

Project managers working with communities heavily dependent on agriculture for food and income can help improve resilience to **climate change in a number of ways**. To mitigate climate change impacts, project managers can employ a number of management strategies including those described below.

Projects can be designed to focus on sustainable agriculture management practices that ensure resiliency and regeneration capacity of crops and food security for the community. Land use planning efforts to determine which areas are most suitable for agriculture and which crops will be most successful, provisions to protect critical farmland from development, planting crops or cover crops year-round to prevent erosion, planting multiple varieties of resilient crops, managing canopy height for tree crops, developing alternative livelihoods can be particularly important as a means to buffer the effects of extreme climate events and enhance adaptive capacity. In some cases, collecting payments from the community prior to the growing season in exchange for food after harvest have been successful. This method provides the essential capital to fund the significant start-up costs to farmers at the beginning of the growing season. This keeps farms in production, allows farmers more flexibility to implement sustainable practices, and guarantees food for the community. Farmers should also be encouraged to insure their crops. Further, well-managed farmland provides a natural buffer against natural disasters such as landslides, floods, and soil erosion, all of which are expected to increase and incur significant costs as global temperatures rise.

From a **risk management** perspective, it is less costly to adapt to the potential direct and indirect impacts of climate change on crops and people than to continue practicing "business as usual." Doing so reduces vulnerability, maximizes the chance of successful yields, facilitates crop ecosystem and community adaptation to climate change, and can increase community resilience.

## POTENTIAL CLIMATE CHANGE IMPACTS THAT COULD AFFECT AGRICULTURE PROJECTS

DIRECT IMPACTS	INDIRECT IMPACTS	POSSIBLE ADAPTATION RESPONSES
ILLUSTRATIVE EXAMPLES	ILLUSTRATIVE EXAMPLES	ILLUSTRATIVE EXAMPLES; ADAPTATION RESPONSES SHOULD BE TAILORED TO LOCAL CIRCUMSTANCES
<ul style="list-style-type: none"> <li>• Reduced yields</li> <li>• Soil erosion</li> <li>• More crop pests &amp; disease</li> <li>• Decreased soil fertility</li> <li>• Heat stress for human field workers</li> <li>• Food and crop spoilage due to heat and moisture conditions</li> </ul>	<ul style="list-style-type: none"> <li>• Reduced nutrition</li> <li>• Reduced incomes</li> <li>• Food insecurity</li> <li>• Migration</li> <li>• Reduced access to markets</li> </ul>	<ul style="list-style-type: none"> <li>• Conservation agriculture: low till, diverse rotations, cover/tree/shrub crops more resilient to drought</li> <li>• Sustainable intensification: more crop per drop, kg of fertilizer, hectare of land, etc.</li> <li>• Salt and heat tolerant varieties</li> <li>• Efficient drip/micro-irrigation of higher value crops</li> <li>• Farmer managed natural regeneration of trees, grasslands, fish stocks, mangroves</li> <li>• Farm-based rainfall capture and infiltration</li> <li>• Heat management techniques for farm workers</li> <li>• Improved post-harvest management techniques</li> </ul>

## MINIMIZING GREENHOUSE GAS (GHG) EMISSIONS AND MAXIMIZING SEQUESTRATION

Depending on the operational methods used, farmland can either be a source or sink of GHGs. About 12 percent of global GHG emissions result from activities linked to agricultural activity, such as fuel use for transportation and equipment, and the production and overuse of nitrogen fertilizer. In addition, agriculture contributes to climate change because it is a major driver of land use change. When forests and other carbon-rich ecosystems are converted to agriculture, the carbon dioxide they store in their trunks, leaves and soils is released into the atmosphere. About 15% of global emissions come from deforestation. Decreasing use of fossil fuel inputs also helps to mitigate emissions impacts. Methane emissions can also be reduced from rice paddy fields by draining the fields during the growing season—a practice that can also conserve water and increase yields. Ruminant livestock (cows, goats, and sheep) are also a source of methane emissions. The provision of relevant climate change mitigation information and technical assistance to countries and stakeholders can decrease agriculture’s contribution to climate change.

Conversion of forest land for agriculture is the largest driver of deforestation globally, and this practice removes a potential source of carbon sequestration. Conversely, some agricultural practices can store carbon in agricultural biomass and soil, and certain practices can help prevent the carbon already stored



in agricultural landscapes from escaping into the atmosphere. Increasing soil carbon is doubly beneficial because it can enhance productivity and resilience to climate change. These practices include avoiding clearing new land for agricultural use, improving and utilizing already degraded lands for planting crops, conservational tillage practices or “no-till” practices, planting cover crops to keep carbon in the soil after the growing season, implementing crop rotations, and composting.

## 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 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. It is important to understand that there should be a strong social component to community involvement, including engaging men, women, children, and the elderly, as well as other social groups that may have different roles in agricultural production and labor. Understanding the different roles that various social groups play in agriculture can help increase the effectiveness and sustainability of project interventions. Community members should be involved in defining and analyzing 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;
- Project measures are not negatively impacting women or other vulnerable groups unintentionally;

### 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 social 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.

- Climate variability and change are not undermining project interventions;
- Any livestock development activities are not leading to or worsening overgrazing; 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 (disaggregated by sex) 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 perspective of all members of the farm household (**micro-efficiency**). This is particularly important when labor-intensive conservation interventions are proposed, and where burdens could fall unduly on women or other vulnerable groups.

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 (**macro-efficiency**) during initial or pilot efforts. Two factors must be considered in a macroeconomic assessment: the costs of *not* reversing the degradation or increasing farm productivity, and the magnitude of the problem 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.

## 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. Collection of relevant social data, such as gender and livelihood information should be considered. Classifying the program or community area into distinct treatment blocks, along with GPS and GIS data, 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. 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 take data measurements 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 by men and women, 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

The following table 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.

## IMPACT MONITORING AND MITIGATION FOR SMALL-SCALE AGRICULTURE SECTOR ACTIVITIES

Note: Many of the problems listed in the table below may be affected by climate change, or may impact climate. The associated mitigation measures may be particularly helpful for increasing adaptive capacity, or for decreasing sensitivity or exposure to potential climate changes.

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
Land degradation	Loss of soil from agricultural land	Water- and wind-induced soil erosion <i>Can be exacerbated by increase in extreme events associated with climate change, such as more frequent and/or severe floods and droughts</i>	Improve overall farming system Match land use to land capability Apply appropriate soil and water conservation measures Consider and plan for climate impacts Adopt agricultural practices such as conservation agriculture that enhance resilience Encourage stakeholder (men and women)-led land use planning and agricultural practices to take climate variability and change into account.
	Loss of soil from marginal areas	Water- and wind-induced soil erosion combined with inappropriate land use <i>Can be exacerbated by increase in extreme events associated with climate change such as more frequent and/or severe floods and droughts</i>	Encourage re-vegetation of degraded and marginal areas to reduce runoff Reduce pressure on marginal areas through alternative income sources and/or changed land uses Consider and plan for climate impacts Encourage stakeholder (men and women)-led land use planning and agricultural practices to take climate variability and change into account.
	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)

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
	Overgrazing leading to erosion, vegetation loss and gully formation	Noneconomic reasons for large herds (e.g., prestige, marriage dowry) Lack of alternative fodder sources Climate impacts that reduce the productivity of the land and the number of animals it can support	Increase average animal productivity through health and nutrition Improve market options for culls Improve grazing management systems Improve communal land management Consider and plan for climate impacts Encourage stakeholder (men and women)-led land use planning and agricultural practices to take climate variability and change into account.
	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, cultivation of drought-resistant crops, and livestock improvement programs, to reduce crop 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 <i>Can be exacerbated by increase in extreme events and more variable precipitation patterns associated with climate change</i>	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 Use fertilizers appropriately and avoid overuse Consider and plan for climate impacts
	Increased incidence of waterborne disease	Pollution of exposed wells and springs <i>Can be exacerbated by increase in extreme events and more variable precipitation patterns associated with climate change</i>	Implement minimum setback limits for grazing and agriculture around water sources Ensure that wellheads and springs are properly constructed and protected Consider and plan for climate impacts



CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
	Contamination of environment, especially soil and water	Subsidies for farm inputs Inappropriate agrochemical input packages <i>Can be exacerbated by increase in extreme events and more variable precipitation patterns associated with climate change</i>	Improve training of farmers, including men and women, in input use, especially chemicals Train providers and venders of agricultural inputs Educate farmers, providers and venders, including men and women, on climate impacts and ensure they have access to weather forecasts and seasonal forecasts so they can time application appropriately
Siltation	Flooding and decreased navigability of rivers and waterways	Deposition of silt in rivers and water bodies from erosion <i>Can be exacerbated by increase in extreme events associated with climate change</i>	Revegetate critical watershed areas and apply soil and water conservation measures to the upstream areas for better erosion control Consider and plan for climate impacts Encourage stakeholder (men and women)-led land use planning and agricultural practices to take climate variability and change into account.
	Flooding and soil erosion after rainstorms	Watershed destabilized due to deforestation and reduced area or capacity of wetland <i>Can be exacerbated by increase in extreme events associated with climate change</i>	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 <i>Can be exacerbated by increase in extreme events, more variable precipitation patterns and sea level rise associated with climate change</i>	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 Climate impacts that make agricultural lands unproductive,	Institute community-based natural resource management (CBNRM) to manage park lands Encourage stakeholder-led land use planning and agricultural practices to take climate variability and change into account.

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
		driving users to protected areas	Adopt agricultural practices such as conservation agriculture and sustainable intensification that enhance resilience
Biodiversity loss	Decrease in wild and traditional plant and animal species	<p>Biodiversity loss due to habitat destruction and competition from foreign species</p> <p>Climate change resulting in conditions that no longer support certain species</p> <p>Over reliance on certain strains of crops or animals</p> <p><i>Competition from foreign species can be exacerbated by climate change if new conditions favor foreign species</i></p> <p><i>Over reliance on certain strains can be exacerbated by climate change if people switch to one or two crops in an effort to adapt to climate change</i></p>	<p>Use ecoagricultural techniques</p> <p>Create corridors connecting protected habitats</p> <p>Revegetate areas in and around fields to create habitat</p> <p>Use appropriate native plant and tree species</p> <p>Obey plant and animal quarantine rules</p> <p>Encourage stakeholder-led land use planning and agricultural practices to take climate variability and change into account.</p> <p>Educate farmers so that they value wild and traditional plant and animal species</p>
	Increased GHG emissions/decreasing carbon sinks	<p>Conversion of forest and other carbon-rich ecosystems (peat lands, wetlands, mangroves) to agriculture or aquaculture</p> <p>Inappropriate/excessive fertilizer application</p> <p>Soil carbon loss through over-tillage</p> <p>Methane from paddy rice fields and ruminants</p> <p>Improper waste management</p> <p>Draining of peat lands and swamps for agriculture</p> <p>Transport of food</p> <p>Waste of food</p>	<p>No-till farming, perennial crops</p> <p>Soil carbon, nitrogen and moisture sequestration into soils through Conservation Agriculture (low till, rotations, tree and shrub crops)</p> <p>Introduction of nitrogen-fixing crops and trees</p> <p>Clean energy generation from biodigesters of agricultural by-products including manure and residues</p> <p>Feed management to reduce methane emissions from livestock</p> <p>Regeneration of mangroves</p> <p>Efficient use of fertilizer; organic practices</p> <p>Sustainable Rice Intensification</p> <p>Land use planning by men and women to prevent conversion of carbon-rich landscapes to agriculture, to identify areas suitable to agriculture, and to determine which types of agriculture will</p>

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
			perform best Alignment of land use planning with national REDD+ and Low Emission Development strategies

# 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 is likely to gain importance as a climate change adaptation technique. Farmers may adopt irrigation as a response to temperature increases, more variable precipitation patterns, and more extreme events, such as droughts, associated with climate change.

**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.**

Irrigation systems contribute to 40% of the world's food production and are used on 227 million hectares worldwide, and 20% of cropland, although the number of irrigated areas varies widely among developing countries. According to FAO's Global Map of Irrigated Areas and Aquastat database, Egypt, Sudan, India, Pakistan, Thailand, parts of China, and Iraq have the highest percentage of irrigated land. Where rainfall is less scarce, as in many in equatorial 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.

There are many obstacles to increased irrigation in developing countries, such as in circumstances of limited and diminishing freshwater resources. In a number of areas where water is scarce, 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 typically irrigate 100 hectares or less. Surface and gravity-flow irrigation are the most widely used techniques, although sprinkler systems are used on larger commercial farms in Zimbabwe, South Africa, Kenya, Zambia, various countries in North Africa, China, India, and Mongolia. 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.



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.

- **Spate systems.** Similar, but less sophisticated than diversion systems, 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).
- **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. Fertilizers may be added to the water to increase yield.
- **Plastic mulch.** Plastic mulch can be a very effective method for controlling weeds in drip irrigation systems. It also helps retain soil moisture and help control soil temperature (depending on the color of the mulch). However, some advanced technology and technical expertise is needed to put down the plastic and make harvesting effective.

## 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. Irrigated water is taken up by plants or evaporates into the atmosphere, but salts accumulate in the soil. 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 cause salt to accumulate at an increased rate.
- Artificial and natural fertilizers may not be fully absorbed by plants, leaving salts to build up 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.

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.

### 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
- Depletion of groundwater resources
- Cumulative and area-wide effects on environmental quality

## 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, 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

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. However, irrigation may also support 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. This may become more of a concern, particularly for areas that are currently less affected by vector-borne diseases, but may become more so due to the projected expansion of vector borne illnesses due to climate change.

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).<sup>7</sup> 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 among other changes to ecosystem composition.

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 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 guideline, wetlands are often deliberately

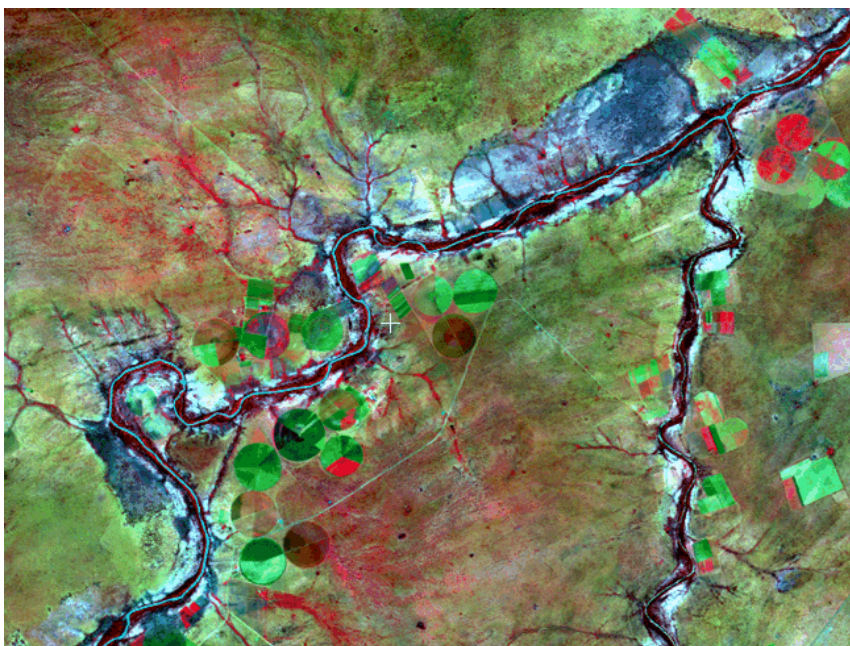
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<sup>7</sup> For a discussion of pesticides' effects on water quality, see the sections on IPM and safer pesticides in these *Guidelines*.

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 image 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, if growth is unplanned, the community may be 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 or donor projects in the watershed. Although a single project may only divert one 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 can breed and spread disease. Also, excessive diversion of water may have unforeseen impacts on biodiversity by exacerbating conditions that already threaten local populations of endemic species.

## SECTOR PROGRAM DESIGN – SOME SPECIFIC GUIDANCE

Designing an irrigation system from the ground up, or rehabilitating an existing one, demands attention to numerous social, economic, and technical factors. 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 (e.g., tools, seeds, machinery);
- Output markets for increased production;
- Role of the community in managing the system;
- Farmers' experience with irrigation farming techniques; and
- Whether immigration into the area is likely and may impact local health and increase demand for housing, health, education and other services.

### Irrigation sector program design principles

- Incorporate community involvement including men and women in planning and operation
- Design for local soil conditions
- Account for water availability, including considering climate variability and future change
- 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

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 hand-dug canals, or *dambos*, *marais* and *bas-fonds* can cause major problems.

## COMMUNITY INVOLVEMENT

Community and farmer participation in planning and designing 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. It is important to make sure women and other potentially marginalized groups are considered in these discussions as they may be differently impacted by irrigation projects.

### 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.

### Traditional irrigation in Southeast Asia

The lengthy and voluminous Mekong River runs through China, Myanmar, Laos, Thailand, Cambodia, and Vietnam in Southeast Asia and provides a reliable source for irrigation. Agriculture is a primary sector of employment in the region and along with fishing sustains seventy-five percent of the communities residing in the Mekong River Basin. Types of irrigation systems in this region vary with the landscape and irrigation continues to develop. In areas around swamps and lakes, a combination of canals, dikes, reservoirs, and/or small pumps are employed. In other areas, use of surface water ponds is prevalent. Current and future development of reservoirs and dams for irrigation in the Mekong River Basin has the potential to cause changes in water quality, flow patterns, salinity, and wildlife habitat.

Sources: Mekong River Commission; Ministry of Water Resources and Meteorology in association with Cambodia National Mekong Committee, 2003.

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? Will benefits from production be equitably shared?
- 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 there be adequate supply of inputs?
- 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?
- How have fluctuations in rainfall and temperature affected water availability in the past and how this been managed? How might these be managed in the future under climate change scenarios, as higher temperature and more variable precipitation?
- 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 or bilharzia?
- Is there potential for introduction of non-traditional 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)?
- 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 clay-rich 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 cover crop or catch crop<sup>8</sup> of a salt-tolerant plant such as a native pea plant. 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 this *Guideline*.) Cover crops used to prevent soil erosion may also have secondary benefits in retaining soil carbon and nitrogen and build – or at least slow the decline of – soil

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<sup>8</sup> 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.)

organic matter. For these reasons, many farmers view cover crops as an essential tool in managing farmland for long-term sustainability.

## DESIGN FOR WATER AVAILABILITY

It is very important to install water-level gauges to collect data on regular and lean conditions. This information will assist with the planning of irrigated fields and new crops, and the need for maintenance or new infrastructure. This information is also needed to develop and establish legal agreements between farmers and communities over water use and distribution. 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 I, 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 due to increased water availability and productivity will, over time, create competing uses for surface water and groundwater. To protect the source, while designing new irrigation systems or rehabilitating old systems communities should be encouraged to conserve natural areas surrounding the upstream watershed. This conservation zone or source water protection area will ensure supplies of quality water in the future via increased filtration and pollution control. This type of protection maximizes the fresh water provisioning service of the ecosystem, water regulation, and waste purification ecosystem services. If this conservation area is effectively protected, secondary ecosystem services—including local climate regulation, food and fiber provisioning services—may also be secured.

Gravity-flow irrigation uses gates, siphons and checks to evenly distribute water in a field. Other systems, such as overhead, drip or trickle, and solar-powered pumps<sup>9</sup> grow more crops per unit of water but 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.

Long term availability of water can be impacted by temperature increases, more variable precipitation patterns, and more extreme events, such as floods and droughts, associated with climate change. Historical patterns of climatic conditions, such as temperature and rainfall, as well as future projections should inform discussions of water availability. If such information is not available, project designers should consider making the investments necessary to obtain it.

## 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, oils, and trash, 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.

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<sup>9</sup> FAO. 4.8 Solar Power. <http://www.fao.org/docrep/010/ah810e/ah810e11.htm>

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 guidelines on small-scale construction, roads, and water and sanitation in this sector-specific ESDM series).

## 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.

The following table provides specific guidance for mitigating and monitoring adverse environmental impacts for irrigation activities.



## MITIGATION AND MONITORING TABLE FOR IRRIGATION IMPACTS

Note: Many of the problems listed in the table below may be affected by climate change, or may impact climate. The associated mitigation measures may be particularly helpful for increasing adaptive capacity, or for decreasing sensitivity or exposure to potential climate changes.

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
Soil problems	Waterlogged soil	Overwatering; inadequate drainage <i>Can be exacerbated by increased precipitation and increase in extreme events associated with climate change</i>	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 male and female farmers to value water resources by establishing a system of water user fees tied to consumption. Encourage stakeholder-led land use planning and agricultural practices to take climate change into account.
	Salt buildup on irrigated land	Irrigation system does not adequately leach salts from soils	Design system to allow 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 a native pea.
	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.

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
Water problems	Crops not growing over entire irrigated field	Intrafield distribution system is malfunctioning	Maintain irrigation canals. Clear weeds. Line canals against leaks. Encourage male and female 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 <i>Can be exacerbated by decreased precipitation and increased temperatures associated with climate change</i>	Reduce off-take or pumping to allow natural aquifer recharge. Encourage male and female farmers to value water resources by establishing a system of water user fees tied to consumption. Encourage stakeholder (men and women)-led land use planning and agricultural practices to take climate change into account.
	Salt water in wells for drinking water and irrigation	Saline intrusion in coastal aquifer due to excessive groundwater pumping <i>Can be exacerbated by sea level rise and decreases in precipitation associated with climate change</i>	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 <i>Can be exacerbated by decreases in precipitation and increased temperatures associated with climate change</i>	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. Encourage stakeholder (men and women)-led land use planning and agricultural practices to take climate change into account.

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
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 and men in health issues.
Social problems	Increased inequity*	Inequitable access to irrigation waters or crops <i>Can be exacerbated by increased demand for water resources due to climate change</i>	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. Encourage stakeholder (men and women)-led planning that takes climate change into account
	Hinterland effect	Increased migration into area due to successful project <i>Can be exacerbated by increased demand for water resources due to climate change</i>	Ensure adequate social and other infrastructure to meet needs of immigrants. Encourage stakeholder (men and women)-led planning that takes climate change into account
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	Use dam operations to maintain minimum flow conditions to dilute pollutants.

CATEGORY	PROBLEM	ROOT CAUSE	MITIGATION MEASURE
		behind the dam	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 <i>Can be exacerbated by increased stress on ecosystems due to climate change</i>	Use dam operations to mitigate changes in flow regimes of rivers and prevent weeds and diseases. Encourage stakeholder (men and women)-led planning that takes climate change into account
	Increased GHG emissions/decreasing carbon sinks	Conversion of forest and other carbon-rich ecosystems (peatlands, wetlands, mangroves) to agriculture or aquaculture Inappropriate/excessive fertilizer application Soil carbon loss through over-tillage Methane from paddy rice fields and ruminants Improper waste management Draining of peatlands and swamps for agriculture Transport of food Waste of food	No-till farming, perennial crops Soil carbon, nitrogen and moisture sequestration into soils through Conservation Agriculture (low till, rotations, tree and shrub crops) Introduction of nitrogen-fixing crops and trees Clean energy generation from biodigesters of agricultural by-products including manure and residues Regeneration of mangroves Efficient use of fertilizer; organic practices Sustainable Rice Intensification Land use planning by women and men to prevent conversion of carbon-rich landscapes to agriculture, to identify areas suitable to agriculture, and to determine which types of agriculture will perform best Alignment of landuse planning with national REDD+ and LED strategies.

# RESOURCES AND REFERENCES

## INTERNET SITES PERTINENT TO ENVIRONMENTAL REVIEW OF THE AGRICULTURE SECTOR

- The 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 website: <http://www.fao.org/nr/water/aquastat/main/index.stm>
- Conservation Agriculture in Europe: <http://www.ecaf.org/> (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](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 2010-2011: <http://www.fao.org/docrep/013/i2050e/i2050e.pdf>

- 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/Pages/default.aspx>
- Swedish International Development Cooperation Agency (Sida). A major international donor supporting soil and water conservation development programs in many countries: <http://www.sida.se/English/>
- Revised Universal Soil Loss Equation project version 2: [http://www.ars.usda.gov/research/publications/Publications.htm?seq\\_no\\_115=175643](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 U.S. EXPERTISE 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\\_IOB?navtype=MA&navid=AGENCIES\\_OFFICE\\_S](http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_IOB?navtype=MA&navid=AGENCIES_OFFICE_S)
- 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 [listserv@sare.org](mailto:listserv@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](http://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](http://www.attra.org)
- The Cornell University-managed Agricultural Network Information Center, or AgNic ([www.agnic.org](http://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://conservationagriculture.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 (CIESIN), and other partners (<http://srdis.ciesin.org/>), is another specialized online library of Internet-based resources.

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## IRRIGATION-RELATED REFERENCES

DISCLAIMER: It is beyond the scope of these guidelines to cover the diversity of small-scale irrigation systems found in developing countries, which occur across a variety of ecological, social and geographic settings. Extensive literature collections on these specialized topics can be found 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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## GENERAL CLIMATE CHANGE

*Note: USAID's Global Climate Change (GCC) Office can provide support on the climate change aspects of this Guideline. To contact the GCC office, please email: [climatechange@usaid.gov](mailto:climatechange@usaid.gov)*

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The guidances provide information to assist planners and stakeholders as they cope with a changing climate throughout the project cycle.
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Provides publications, resources, case studies, and other information on climate change, and climate-smart agriculture, including:
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  - These country-specific reports provide information and research on a country's sensitivities to climate change by sector, including agriculture.
- National Adaptation Programs of Action. These country-specific reports produced by Least Developed Countries include information a country's sectoral or location-specific sensitivities, including agriculture, to climate change and outline adaptation priorities. [http://unfccc.int/adaptation/workstreams/national\\_adaptation\\_programmes\\_of\\_action/items/4585.php](http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4585.php)
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# 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

## I. 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: \_\_\_\_\_

How have women and any other marginalized social groups been consulted?

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).
- How have fluctuations in rainfall and temperature affected water availability in the past and how has this been managed?
- How might these be managed in the future under climate change scenarios, as higher temperature and more variable precipitation?
- 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 mitigation 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. Mitigation 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?