1.2 Irrigation

Brief Description of Sector

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

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

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

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

Types of Irrigation Systems

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

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

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

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

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

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

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

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

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

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

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

Potential Environmental Impacts

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

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

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

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

Potential Environmental Impacts of Irrigation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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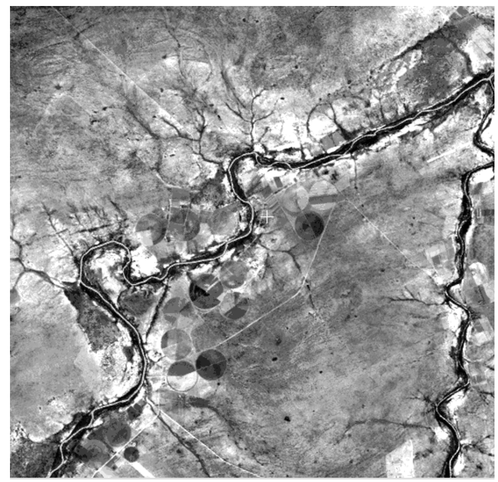
[6]For a discussion of pesticides' effects on water quality, see the sections on IPM and safer pesticides in these *Guidelines.*

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

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

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



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

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

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

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

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

Traditional Irrigation in Africa

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

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

Source: McNeely and Scherr, 2001.

Sector Program Design—Some Specific Guidance

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

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

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

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

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

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

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

Irrigation Sector Program Design Principles

Incorporate community involvement in planning and operation

Design for local soil conditions

Account for water availability

Design for local crop conditions and varieties

Plan for operation, maintenance and management of the project

Ensure that the design accounts for health risks

Follow environmentally sound construction practices

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Environmental Mitigation and Monitoring Issues

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

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

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

Table 4: Mitigation and Monitoring Table for Irrigation Impacts

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

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

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

Irrigation-Related References

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

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

Introductory Note

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

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

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

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

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

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

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

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

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

Environmental Planning for Small-Scale Irrigation: A Checklist

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

Date project planning began: ____

Expected completion date:__________ Present status:____

Site/community name: ____

Location (region, district, village):____

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

Project Design by:____

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

____

Community concurrence:__________ How reached:____

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

How established:____ Date:______________

Number of beneficiary participants in WUA:_________________________

Number of males:____________________ Number of females:_______________________

Percentage of total community to be included in scheme:____________________________

Area to be irrigated:_________________(hectares)

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

Average size of household irrigated plot:______________ (hectares)

Previous use of irrigated area:____

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

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

Average household holdings outside the scheme:____

Other major infrastructure or investments linked to SSI: ____

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

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

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

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

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

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

2. Analyzing the Basic Parameters

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

Water Resources Availability

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

Other Uses and End Users

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

Catchment Status

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

3. Estimating Crop Water Requirements

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

- What crops will be planted and in which season?

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

4. Farm/Scheme Land and Water Management and Conservation

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

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

5. Postconstruction Follow-Up and Technical Assistance

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

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

6. Water-Related Disease Hazards

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

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

7. Displacement and Land-Use Changes

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

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

8. Monitoring Plans

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

9. Mitigative Measures Planning

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