Tool and Guideline # 7

Practical Tools on Irrigated Agriculture on Non-Protected Wetlands

Rwanda Environment Management Authority
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PREFACE

In 2010, REMA prepared 11 practical technical tools intended to strengthen environmental management capacities of districts, sectors and towns. Although not intended to provide an exhaustive account of approaches and situations, these tools are part of REMA's objective to address capacity-building needs of officers by providing practical guidelines and tools for an array of investments initiatives.

Tools and Guidelines in this series are as follows:

#	*TOOLS AND GUIDELINES*
1	Practical Tools for Sectoral Environmental Planning : A - Building Constructions B - Rural Roads C - Water Supply D - Sanitation Systems E - Forestry F - Crop Production G - Animal Husbandry H - Irrigation I - Fish Farming J - Solid Waste Management
2	Practical Tools on Land Management - GPS, Mapping and GIS
3	Practical Tools on Restoration and Conservation of Protected Wetlands
4	Practical Tools on Sustainable Agriculture
5	Practical Tools on Soil and Water Conservation Measures
6	Practical Tools on Agroforestry
7	Practical Tools of Irrigated Agriculture on Non-Protected Wetlands
8	Practical Tools on Soil Productivity and Crop Production
9	Practical Technical Information on Low-cost Technologies: Composting Latrines & Rainwater Harvesting Infrastructure
10	Practical Tools on Water Monitoring Methods and Instrumentation
11	11.1 Practical Tools on Solid Waste Management of Imidugudu, Small Towns and Cities : Landfill and Composting Facilities
	11.2 Practical Tools on Small-scale Incinerators for Biomedical Waste Management

These tools are based on the compilation of relevant subject literature, observations, experience, and advice of colleagues in REMA and other institutions. Mainstreaming gender and social issues has been addressed as cross-cutting issues under the relevant themes during the development of these tools.

The Tool and Guideline # 7 provides practical methods for irrigated agriculture on non-protected wetlands.

These tools could not have been produced without the dedication and cooperation of the REMA editorial staff. Their work is gratefully acknowledged.

Dr. Rose Mukankomeje
Director General, Rwanda Environment Management Authority

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1. INTRODUCTION

1.1 Overview

The present Government Policy is to increase crop production and raise productivity in the coming years. The opportunity is the increasing focus on land consolidation, crop processing industries, and introduction of new crops of the high market value crops. The opportunities to increase crop production will vary from one area to another. Local development plans will address specific needs to achieve goals.

The government views agriculture as a major driver of national economic growth. Vision 2020 sets out key targets to be achieved by the agricultural sector, which includes:

- Increase the proportion of the country farmed under modern agricultural methods from 3 to 50 percent;
- Increase in fertiliser use from an average of 0.5 to 15 kg ha-1 yr-1;
- expansion of soil protection from 20 to 90 percent of the country;
- Increase in agricultural production from 1612 to 2200 kcal day-1 person-1 (minimum daily needs are typically 2100 kcal); and
- Major increases in export earnings from crops such as tea and coffee.

Lakes and wetlands (including marshlands and swamps) sustain Rwanda's extensive hydrological network. A recent inventory recorded 101 lakes and 860 wetlands, covering a total surface area of 1,495 km² and 2,785 km², respectively. This is equivalent to 16 percent of the country's land area. Wetlands are amongst the most productive ecosystems in Rwanda in terms of plant matter, fisheries and supporting freshwater biodiversity. They provide critical services. They feed lakes and rivers, trap and filter sediments and nutrients, absorb floodwaters, buffer croplands and settlements from strong run-off, and replenish rivers and streams during the dry season.

Drivers for wetlands resource degradation include population growth, agricultural transformation and urbanization. Wetlands in Rwanda face enormous pressures due to conversion for various land uses. For instance wetlands in rural areas are used for paddy rice and sugar production. In urban areas, wetlands are most likely to be used as dumping sites for wastes. Wetlands may be converted to other forms of land-use, such as residential and industrial development, road construction, or aquaculture.

Human agricultural activities on wetlands and mismanagement the latter can degrade and destroy the wetlands. Ecosystem integrity has been compromised, riverbanks have been eroded and siltation has caused nutrient loading in water bodies including rivers and associated wetlands. Mismanagement of marshland development is leading to a number of them drying and unsuitable for sustainable agricultural development. Rwanda has new wetlands management laws such as the Environmental Organic Law and the Lands Law that relate to the development of marshlands and their surroundings are from. These are relatively recent but are being implemented to restore wetlands which would otherwise be lost. The baseline data on wetlands in Rwanda is very limited at the moment but there are on-going initiatives to characterized wetlands and establish baselines. REMA has undertaken a wetland inventory which categories wetlands for conservation and other developments.

The following are key environmental issues associated with the irrigated agricultural sector:

- *Increased agriculture production*: Cultivated area under irrigation is expected to expand significantly with the current programme of agricultural intensification. MINAGRI has planned a program to implement increased agriculture productivity in watersheds covering 30,250 ha of land. Some of these investments may require the construction of dams. Irrigation development may affect the hydrology of catchments that drain into waterways. These types of investments may lead to increased use of inputs (fertilizer, agro-chemicals).

- *Water resources*: Of the wetlands inventoried, 41 percent are in natural condition and 59 percent are farmed. While there has been growing awareness and protection of wetlands particularly following the 2002-2005 droughts, uncontrolled farming, mostly for subsistence, is widespread. Of potential concern is the impact of irrigation schemes on downstream wetlands and marshlands. Marshlands in Rwanda are being rapidly converted to agricultural uses. Based on official statistics, 94,000 ha of the total 168,000 ha of marshlands have been converted. Adverse impacts on downstream marshlands need to be considered when screening and selecting proposed sites for further development. Expansion of irrigation schemes will increase water demand and use. Agriculture is therefore a logical target for water savings and demand management, including improving yields of subsistence rain-fed agriculture, use of more efficient techniques such as drip irrigation and treadle pumps, and cultivation of less water-demanding and drought resistant crops.

- *Crop protection and soil fertility*: The use of fertilizers and agricultural chemicals can pollute water, springs and wetlands. The intensive agricultural policy is geared to increased use of mineral and organic fertilizers, pesticides and selected seeds. Misuse of agro-chemical products has harmful consequences on natural and artificial biocenosis and on man’s health. The effects of these products may also become apparent through deep changes in biological balance. The policy has to be accompanied with training on the control and manage the negative impact of agrochemicals.

1.2 Purpose

The objective of this guide is to provide practical technical methods and sustainable principles of irrigated agriculture on non-protected wetlands. It is intended to be a tool for integrating environmental considerations in planning initiatives. The tool can be adapted and used for the identification of environmental effects, appropriate mitigation measures, and guidelines for irrigation investments.

Although not intended to provide an exhaustive account of approaches and situations, this tool is intended to address capacity-building needs of officers by providing information on low-cost water and sanitation technologies. This tool can be used as field guides or as checklists of elements for discussion during training and during implementation of irrigation investments.

This document was produced to address REMA’s proposed policy action to strengthen the resource capacity of environmental and related institutions at national and district level for environmental assessment, policy analysis, monitoring, and enforcement.

2. IRRIGATED AGRICULTURE ON NON-PROTECTED WETLANDS

2.1 Effects of Irrigated Agriculture on Wetland Ecosystems

The relationship between irrigated agriculture and its effects on wetland ecosystems has often been portrayed as one of a direct trade off between the human need for food versus nature. In reality, this is much more complex, as both systems human and nature may be adaptive. Where nature might adapt automatically, such as a waterfowl adapting to paddy rice as a replacement for natural wetland habitat, humans too adapt consciously. For example, as humans have learned about the valuable services wetlands provide, the response has been to find ways to preserve and restore wetlands.

Agriculture and irrigated agriculture in particular, will be critical to supplying the food needs of an ever increasing Rwanda population. The road ahead must include ways of farming that recognize the value of wetlands. The functional value of wetlands depends on their size and placement within the landscape, as well as their relationship to adjacent water areas. There is general agreement that the existence of wetlands is due to specific hydrology, soil type, and vegetation and animal communities, and that their functions depend on the context of their relative placement within the ecosystem. Some of the services wetlands provide include:

- Habitat for aquatic birds, other animals and plants, fish and shell fish production;
- Biodiversity;
- Food production;
- Water storage, including mitigating the effects of floods and droughts;
- Groundwater recharge;
- Water purification;
- Nutrient cycling;
- Sediment retention and export;
- Recreation and tourism;
- Climate change mitigation;
- Timber production;
- Education and research; and
- Aesthetic and cultural value.

Irrigation allows for increased productivity through more optimal timing of water application. Irrigated agriculture in combination with improved crop varieties and chemical inputs can lead to increased agriculture production and food security. In addition to increase food security, there is a net increase in economic gains to farmers. Some of the established effects of agriculture on wetlands can include:

- Direct loss of wetlands due to draining and conversion to agricultural land;

- Indirect loss of wetlands area due to water withdrawal from rivers and streams for irrigation;

- Loss of wetland area and function due to damming for water storage;

- Loss of seasonal wetlands due to changed hydrologic cycle from water storage;

- Loss of wetland function due to salinization, sediment deposition, erosion, eutrophication; and

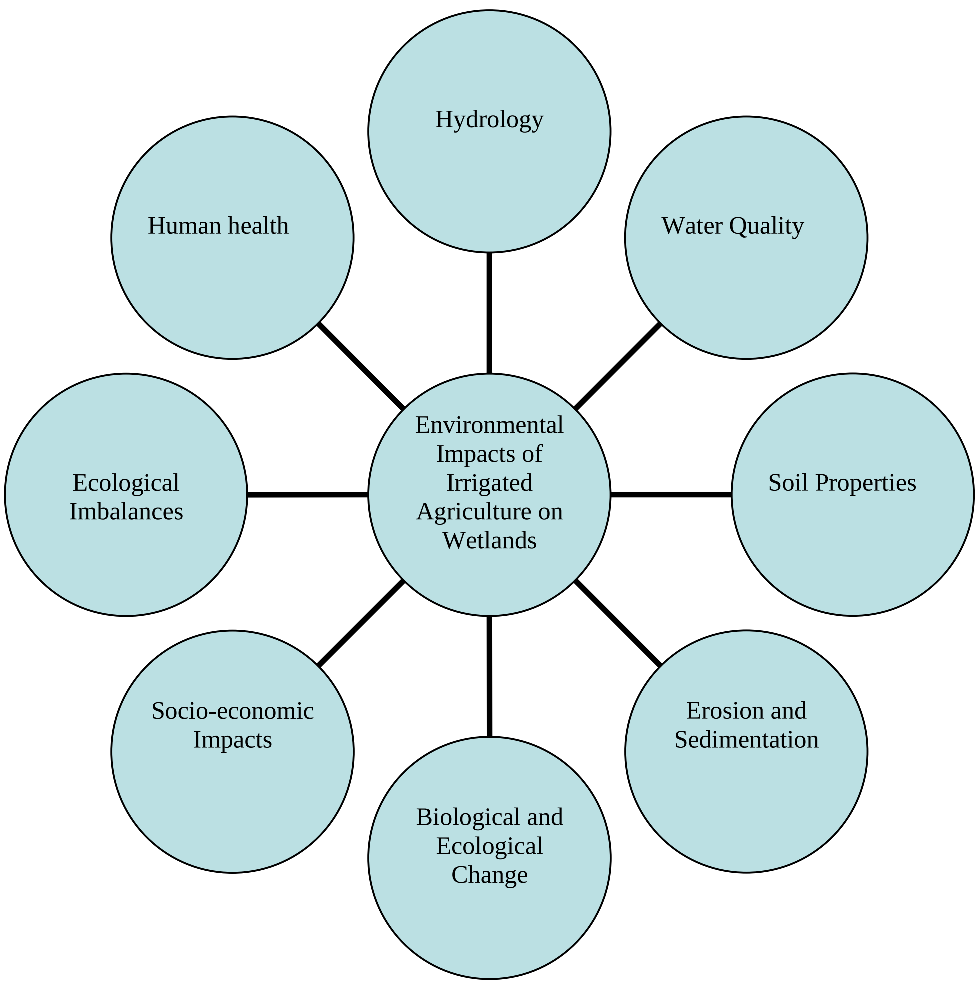
- Pollution from use of pesticides and other chemicals.

While environmental impacts have been recognized as important in assessing agricultural projects, active monitoring against baseline pre-project conditions is important. Some aspects often regarded as important in monitoring are hydrology, water and air quality, soil properties, erosion and sedimentation, biological and ecological change, socio-economic impacts, ecological imbalances and human health.

2.2 Environmental Impacts of Irrigated Agriculture on Wetlands

The intensification of irrigated agriculture land can lead to groundwater pollution related to the increased use of pesticides and fertilizers. Improved efficiency may significantly reduce water flows which are often utilized downstream by other irrigation schemes or wildlife habitats. Similarly, upstream developments are likely to impact on an irrigation scheme either in the form of reduced water availability (surface or groundwater) or reduced water quality.

Different types of irrigation schemes will have different impacts. Impacts will also vary according to the stage of implementation. For example, during the construction period there may be specific health and other social risks due to an influx of migrant workers living in temporary and unsanitary accommodation. Later, once the irrigation scheme has been operating for several years, cumulative impacts may begin to present environmental constraints to project sustainability. Such issues must be predicted and mitigation measures prepared.



The sections below these describe the most common environmental impacts associated with irrigation schemes. Positive and negative impacts are briefly described and the most usual mitigating measures outlined. The opportunity to identify positive impacts and to propose measures to enhance such impacts should not be neglected.

2.2.1 Hydrology

Impacts can results from a change in the flow regime of rivers, or a change in the movement of the water table, through the seasons. The consumptive nature of irrigation means that some change to the local hydrological regime will occur when new schemes are constructed. To a lesser extent, the local hydrological regime will change when old schemes are rehabilitated. The ecology and uses of a river will have developed as a consequence of the existing regime and may not be able to adapt easily to major changes. It is also important to recognize the interrelationship between river flows and the water table. During high flow periods, recharge tends to occur through the river bed whereas groundwater often contributes to low flows.

2.2.2 Water Quality

In general the purer the water, the more valuable and useful it is for riverside ecology and for abstractions to meet human demands such as irrigation, drinking and industry. Conversely, the more polluted the water, the more expensive it is to treat to satisfactory levels. As soil salinity levels rise above plant tolerance levels, both crops and natural vegetation are affected. This leads to disruption of natural food chains and the loss of agricultural production.

2.2.3 Soil Properties

On-going comprehensive soil studies are essential to the successful management of irrigated areas. A wide range of activities associated with an increased intensity of production can contribute to reduced soil fertility. Soil salinity is probably the most important issue although mono-cropping, without a fallow period, rapidly depletes the soil fertility. A reduction in organic content will contribute to a soil's erodability. The increased use of agro-chemicals, needed to retain productivity under intensification, can introduce toxic elements that occur in fertilizers and pesticides. On irrigated lands salinization is the major cause of land being lost to production and is one of the most prolific adverse environmental impacts associated with irrigation. Saline conditions severely limit the choice of crop, adversely affect crop germination and yields, and can make soils difficult to work. Careful management can reduce the rate of salinity build up and minimize the effects on crops. Management strategies include: leaching; altering irrigation methods and schedules; installing sub-surface drainage; changing tillage techniques; adjusting crop patterns; and, incorporating soil ameliorates. All such actions, which may be very costly, would require careful study to determine their local suitability.

2.2.3 Erosion and Sedimentation

Upstream erosion may result in the delivery of fertile sediments to delta areas. However, this gain is a measure of the loss of fertility of upstream eroded lands. A major negative impact of erosion and the associated transport of soil particles is the sedimentation of reservoirs and abstraction points downstream, such as irrigation intakes and pumping stations. Desilting intakes and irrigation canals is often the major annual maintenance cost on irrigation schemes. The increased sediment load is likely to change the river morphology which, together with the increased turbidity, will affect the downstream ecology.

2.2.4 Biological and Ecological Change

The most obvious biological and ecological change are a consequence of the change of land use and water use in the project area but effects on the land around the project and on aquatic ecosystems that share the catchment are likely. Biological diversity, areas of special scientific interest, animal migration and natural industry are important study areas. The overall habitat as well as individual groups (mammals, birds, fish, reptiles, insects etc.) and species need to be considered. Rare and endangered species are often highly adapted to habitats with very narrow ranges of environmental gradients. Such habitats may not be of obvious economic value to man, e.g. arid areas, and therefore current knowledge of the biota may be poor and a special study may be required. Local knowledge is particularly important as the range of species may be very local.

2.2.5 Socio-economic Impacts

The major purpose of irrigated agriculture is to increase agricultural production and consequently improve the economic and social well-being of the area of the project. Changing land-use patterns are a common cause of problems. Small plots, communal land-use rights, and conflicting traditional and legal land rights all create difficulties when land is converted to agriculture. Land tenure/ownership patterns are almost certain to be disrupted by major rehabilitation work as well as a new irrigation project. Access improvements and changes to the infrastructure are likely to require some field layout changes and a loss of some cultivated land. The 'losers' will need tailored compensation best designed with local participation. Similar problems arise as a result of changes to rights to water. User participation at the planning and design stages of both new schemes and the rehabilitation of existing schemes, as well as the provision of extension, marketing and credit services, can minimize negative impacts and maximize positive ones. Consultations can be particularly helpful in minimizing adverse socio-economic impacts.

2.2.6 Ecological Imbalances

Without appropriate management measures, irrigated agriculture has the potential to create serious ecological imbalances both at the project site and in adjacent areas. Excessive clearance of natural vegetation cover in the command area, for example, can affect the microclimate and expose the soil to erosion, leading to a loss of top soil and nutrient leaching. The removal of roots and vegetation disrupts the water cycle, increasing the rate at which water enters rivers and streams, thereby changing flow regimes and increasing siltation in the downstream zone. This is often to the detriment of fisheries and aquaculture activities. The destruction of natural habitats in this manner and the creation of agricultural monocultures also impacts on the local flora and fauna reducing biodiversity.

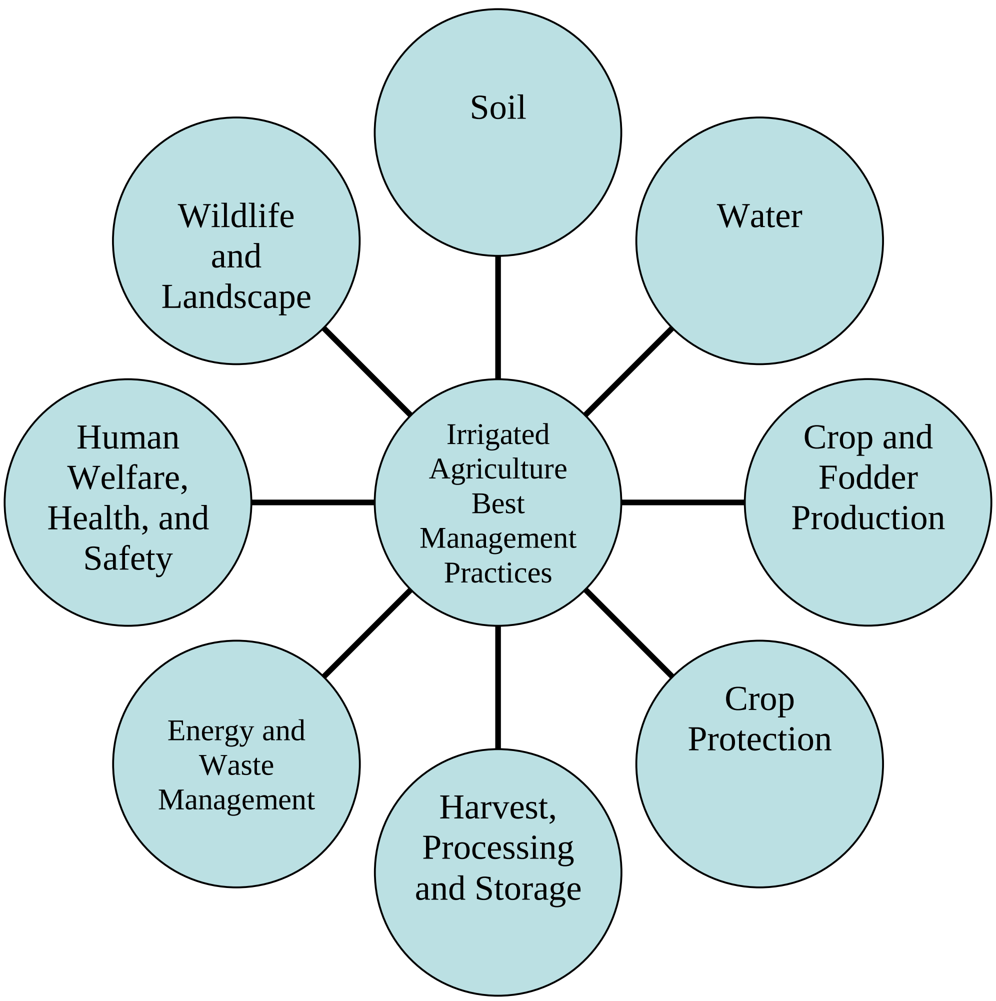
The introduction of exotic species of plant or animal may oust indigenous species or introduce disease agents who may affect plants, animals and/or man. Fertilizers and pesticides are widely applied to correct imbalances. These can percolate through the soil and/or be carried away in the drainage water polluting both groundwater and surface waters especially in the downstream zone. The nutrients in fertilizers may give rise to eutrophication of surface water bodies and promote the growth of aquatic weeds. Pesticide residues are hazardous to the health of both man and animals. The above examples serve to illustrate, together with the range of biological and ecological changes described in the section Biological and ecological change, the wide variety of potential impacts which may arise. Many may be of relatively minor significance in their own right but they often interact to produce a cumulative effect over a prolonged period of time which can result in very significant long term changes to the local ecology. This cumulative effect may impair the long-term viability of both the project and economic activities in the surrounding area.

2.2.7 Human health

Human health issues associated with irrigation and drainage can include health and safety in their broadest sense, including for example human settlements and shelter, and nutrition.

2.3 Irrigated Agriculture Best Management Practices

The concept of Good Agricultural Practices is the application of available knowledge to the utilization of the natural resource base in a sustainable way for the production of safe, healthy food and non-food agricultural products, in a humane manner, while achieving economic viability and social stability. The underlying theme is one of knowing, understanding, planning, measuring, recording, and managing to achieve identified social, environmental and production goals. This requires a sound and comprehensive management strategy and the capability for responsive tactical adjustments as circumstances change. Success depends upon developing the skill and knowledge bases, on continuous recording and analysis of performance, and the use of expert advice as required.



The framework portrays the guiding principles of good agriculture within 8 elements of resource concerns, disciplines and practices in irrigated land. Using the framework, detailed management guidelines can be prepared for individual production systems within specific agro-ecosystems.

2.3.1 Soil

Efficient irrigation is very difficult without good information about the capacity of the soil that is being irrigated to retain water and make it available to the roots of the crop, and in what layers of the soil profile the roots of the crop are growing. Irrigation management can be greatly improved by an understanding of the soils. The physical and chemical structure, and biological activity, of soil are fundamental to sustaining agricultural productivity and determine, in their complexity, soil fertility. Soil management will maintain and improve soil fertility by minimizing losses of soil, nutrients, and agrochemicals through erosion, runoff and leaching into surface or ground water. Such losses represent inefficient and unsustainable management of these resources, in addition to their potential deleterious off-site effects. Management also seeks to enhance the biological activity of the soil and protect surrounding natural vegetation and wildlife. These good agricultural practices are suggested for proper soil management:

- Manage farms in accordance with the properties, distribution, and potential uses of the soils, maintaining a record of the inputs and outputs of each land management unit.
- Maintain or improve soil organic matter through the use of soil-building crop rotations and appropriate mechanical and conservation tillage practices.
- Maintain soil cover to minimize erosion loss by wind and/or water.
- Apply agrochemicals and organic and inorganic fertilizers in amounts and timing and by methods appropriate to agronomic and environmental requirements.

2.3.2 Water

Agriculture carries a high responsibility for the management of water resources in quantitative and qualitative terms. Careful management of water resources and efficient use of water for irrigation is criteria for good agricultural practice. They include maximizing the infiltration of water on irrigated land. The maintenance of adequate soil structure, including continuous macro-pores and soil organic matter, are important factors to achieve this. Efficient irrigation methods and technologies will minimize losses during the supply and distribution of irrigation water by adapting the quantity and timing to agronomic requirements to avoid excessive leaching and salinization. Water tables should be managed to prevent excessive rise or fall. These good agricultural practices are suggested for water management:

- Maximize water infiltration and minimise unproductive efflux of surface waters from watersheds.
- Manage ground and soil water by proper use, or avoidance of drainage where required, and by build-up of soil structure and soil organic matter.
- Apply production inputs, including waste or recycled products of organic, inorganic and synthetic nature by practices that avoid contamination of water resources.
- Adopt techniques to monitor crop and soil water status, accurately schedule irrigation, and prevent soil salinization by adopting water-saving measures and re-cycling where possible.
- Manage water tables to prevent excessive extraction or accumulation.
- Provide adequate, safe, clean watering points for livestock.

2.3.3 Crop and Fodder Production

Individual annual and perennial crops, their cultivars and varieties, are chosen to meet local consumer and market needs according to their suitability to the site and their role within the crop rotation for the management of soil fertility, pests and diseases, and their response to available inputs. Perennial crops are used to provide long-term production options and opportunities for intercropping. Annual crops are grown in sequences, including those with pasture, to maximize the biological benefits of interactions between species and to maintain productivity. These good agricultural practice are suggested for crop and fodder production:

- Select cultivars and varieties on an understanding of their characteristics, including response to sowing or planting time, productivity, quality, market acceptability, disease and stress resistance, climatic adaptability, and response to fertilizers and agrochemicals.
- Devise crop sequences to optimize use of labour and equipment and maximize the biological benefits of weed control by competition, mechanical, biological and herbicide options, provision of non-host crops to minimize disease and, where appropriate, inclusion of legumes to provide a biological source of nitrogen.
- Apply fertilizers, organic and inorganic, in a balanced fashion, with appropriate methods and equipment and at adequate intervals to replace nutrients extracted by harvest or lost during production.
- Maximize the benefits to soil and nutrient stability by re-cycling crop and other organic residues.

2.3.4 Crop Protection

Maintenance of crop health is essential for successful farming for both yield and quality of produce. This requires long-term strategies to manage risks by the use of disease- and pest-resistant crops, crop and pasture rotations, disease breaks for susceptible crops, and the minimal use of agrochemicals to control weeds, pests, and diseases following the principles of Integrated Pest Management. Any measure for crop protection, but particularly those involving substances that are harmful for humans or the environment, must only be carried out with full knowledge and appropriate equipment. These good agricultural practices are suggested for crop protection:

- Use resistant cultivars and varieties, crop sequences, associations, and cultural practices that maximize biological prevention of pests and diseases.
- Maintain regular and quantitative assessment of the balance status between pests and diseases and beneficial organisms of all crops.
- Adopt organic control practices where and when applicable.
- Apply pest and disease forecasting techniques where available.
- Decide on interventions following consideration of all possible methods and their short- and long-term effects on farm productivity and environmental implications in order to minimize the use of agrochemicals, in particular to promote integrated pest management.
- Store and use agrochemicals according to legal requirements of registration for individual crops, rates, timings, and pre-harvest intervals.
- Ensure that agrochemicals are only applied by specially trained and knowledgeable persons.
- Ensure that equipment used for the handling and application of agrochemicals complies with established safety and maintenance standards.
- Maintain accurate records of agrochemical use

2.3.5 Harvest, Processing and Storage

Product quality also depends upon implementation of acceptable protocols for harvesting, storage, and where appropriate, processing of farm products. Harvesting must conform to regulations relating to pre-harvest intervals for agrochemicals and withholding periods for veterinary medicines. Food produce should be stored under appropriate conditions of temperature and humidity in space designed and reserved for that purpose. Operations involving animals, such as shearing and slaughter, must adhere to animal health and welfare standards. These good agricultural practices are suggested for harvest, processing and storage:

- Harvest food products following relevant pre-harvest intervals and withholding periods.
- Provide for clean and safe handling for on-farm processing of products. For washing, use recommended detergents and clean water.
- Store food products under hygienic and appropriate environmental conditions.
- Pack food produce for transport from the farm in clean and appropriate containers.
- Use methods of pre-slaughter handling and slaughter that are humane and appropriate for each species, with attention to supervision, training of staff and proper maintenance of equipment.
- Maintain accurate records regarding harvest, storage and processing.

2.3.6 Energy and Waste Management

Farms require fuel to drive machinery for cultural operations, for processing, and for transport. The objective is to perform operations in a timely fashion, reduce the drudgery of human labour, improve efficiency, diversify energy sources, and reduce energy use. Farming produces by-products, some of which are potential pollutants of soil, water, or air. The production of these by-products should be minimized while others are resources that can be recycled. These good agricultural practices are suggested for energy and waste management:

- Establish input-output plans for farm energy, nutrients, and agrochemicals to ensure efficient use and safe disposal.
- Adopt energy saving practices in building design, machinery size, maintenance, and use.
- Investigate alternative energy sources to fossil fuels (wind, solar, biofuels) and adopt them where feasible.
- Recycle organic wastes and inorganic materials, where possible.
- Minimize non-usable wastes and dispose of them responsibly.
- Store fertilizers and agrochemicals securely and in accordance with legislation.
- Establish emergency action procedures to minimize the risk of pollution from accidents.
- Maintain accurate records of energy use, storage, and disposal.

2.3.7 Human Welfare, Health, and Safety

Farming must be economically viable to be sustainable. The social and economic welfare of farmers, farm workers, and their local communities depends upon it. Health and safety are also important concerns for those involved in farming operations. Due care and diligence is required at all times. Good agricultural practices in human welfare, health and safety include:

- Direct all farming practices to achieve an optimum balance between economic, environmental, and social goals.
- Provide adequate household income and food security
- Adhere to safe work procedures with acceptable working hours and allowance for rest periods.
- Instruct workers in the safe and efficient use of tools and machinery.
- Pay reasonable wages and not exploit workers, especially women and children.
- Purchase inputs and other services from local merchants if possible.

2.4.8 Wildlife and Landscape

Agricultural land accommodates a diverse range of animals, birds, insects, and plants. Much public concern about modern farming is directed at the loss of some of these species from the countryside because their habitats have been destroyed. The challenge is to manage and enhance wildlife habitats while keeping the farm business economically viable. Good agricultural practice to conserve wildlife and landscape include:

- Identify and conserve wildlife habitats and landscape features, such as isolated trees, on the farm.
- Create, as far as possible, a diverse cropping pattern on the farm.
- Minimize the impact of operations such as tillage and agrochemical use on wildlife.
- Manage field margins to reduce noxious weeds and to encourage a diverse flora and fauna with beneficial species.
- Manage water courses and wetlands to encourage wildlife and to prevent pollution.
- Monitor those species of plants and animals whose presence on the farm is evidence of good environmental practice.

3. RESTORATION OF NON-PROTECTED WETLANDS FOR IRRIGATION

These are typical technical approaches that can be used in wetland restoration:

3.1 General Approach

The most common problems and threats to, irrigation schemes are listed in Table 1, together with potential mitigation measures. Irrigation is defined as much, if not more, by farmers and managers as by the physical infrastructure; the 'hardware'. Its sustainable operation is just as dependent on the 'soft' environment: education, institutional building, legal structures and external support services. These are all powerful tools to ensure sustainability in conjunction with well-designed and well-managed hardware and Table 1 indicates that many of the mitigation measures are 'soft'.

Table 1 : Problems and Appropriate Mitigation Measures

Problem	*Mitigation Measures*
Degradation of irrigated land:	
Salinization	- Provide drainage including disposal of water to evaporation ponds if quality of river flow adversely affected by drainage water.
Alkalization	- Maintain channels to prevent seepage, and reduce inefficiencies resulting from siltation and weeds. Allow for access to channels for maintenance in design.
Water logging	- Provide water for leaching as a specific operation.
Soil acidification	- Set-up or adjust irrigation management infrastructure to ensure sufficient income to maintain both the irrigation and drainage systems.
	- Analyse soils and monitor changes so that potential problems can be managed.
Reduced socio-economic conditions:	
Increased incidence of water related disease	- Educate about causes of disease.
Increased inequity	- Improve health facilities.
Weaker community infrastructure	- Allow sufficient time and money for extensive public participation to ensure that plans are optimal, that all sections of affected society are considered and that local institutions are in place to sustain irrigated agriculture, particularly in respect of land and water rights.
	- Consider markets, financial services and agricultural extension in conjunction with proposed irrigation and drainage changes.
	- Ensure that agricultural intensification does not preclude other economic or subsistence activity, such as household vegetables, fodder or growing trees for firewood.
	- Provide short-term support and/or skills for an alternative livelihood if irrigation removes existing livelihood
Poor water quality:	
Reduction in irrigation water quality	- Define and enforce return water quality levels (including monitoring).
	- Control industrial development.
Water quality problems for downstream users caused by irrigation return flow quality	- Designate land for saline water disposal; build separate disposal channels.
	- Educate for pesticide or sewage contamination dangers.
	- Monitor irrigation water quality
Ground water depletion:	
Dry drinking & irrigation wells	- Monitor ground water levels.
Saline intrusion at coasts	- Adjust abstraction charges.
Reduced base flow/wetlands	

Problem	*Mitigation Measures*
Ecological degradation:	
Reduced big-diversity in project area	- Operate dams to suit downstream requirements and encourage wildlife around reservoirs
Damage to downstream ecosystems due to reduced water quantity and quality	- Designate land (in law and supported by protection institutions) for flood plains; wetlands; watersheds; drainage water disposal; river corridors.

3.2 Infrastructure

3.2.1 Small dams

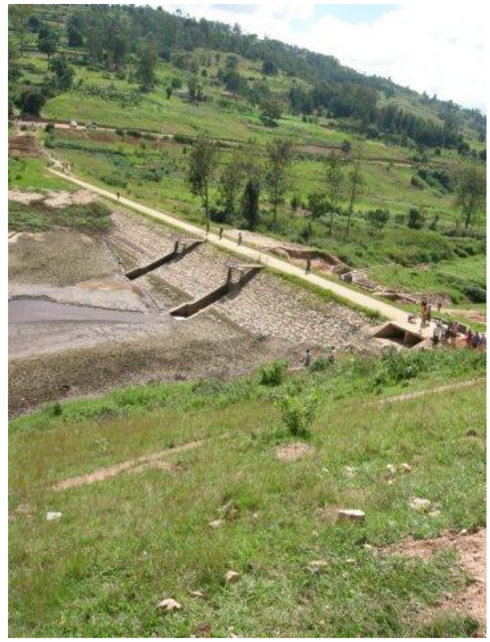
Small dams can be constructed in all wetland type, in limited circumstances. Dams have been widely and correctly condemned for their negative influence on the environment. However, small dams built specifically to restore or create wetland habitat have been used successfully in a number of circumstances. Where wetlands have been drained, drainage ditches can be plugged with small dams. Where natural drainage ways exist, dams can be installed to hold water in place and create small wetlands. Small dams can be used to re-establish or create wetland hydrology. Small earthen dams can be built at very low costs. Even dams intended for wetland restoration and creation can have negative impacts. Potential impacts to downstream areas and to areas that might be flooded should be carefully considered. Also, dams will require maintenance and in general should not be thought of as permanent structures.

3.2.2 Canals

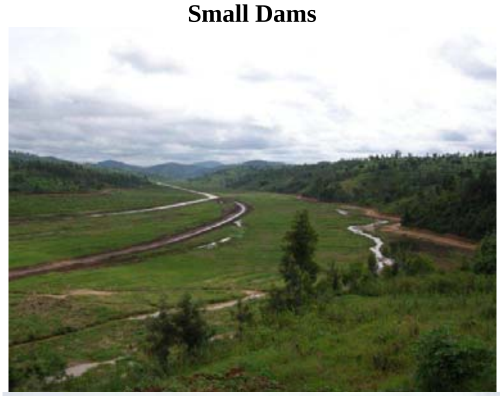
Canals are dredged through wetlands to allow proper hydrological regime. Dredged material removed from canals is usually piled along the edge of canals in spoil banks. Vegetated habitat in the canal itself is replaced by open water habitat, while vegetated habitat along the edge of the canal is buried under spoil banks. Canals can also lead to the partial restoration of wetlands.

3.2.3 Dredged Material and Excavation

Dredging is often required to construct or maintain canals or flood control channels. Dredged material can be used to create or restore wetlands on shallow, un-vegetated low areas. Upland areas can be excavated to create wetlands. Excavation lowers elevation to intercept groundwater may be used to create a receiving basin or to otherwise establish wetland



Small Dams

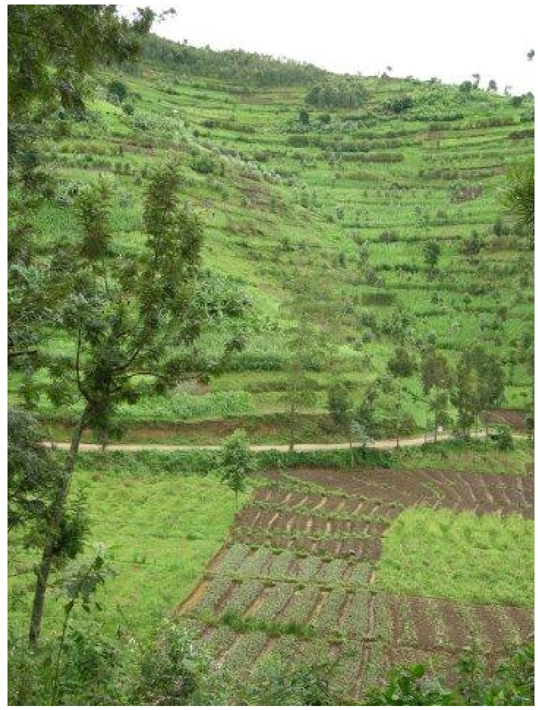


Canals

hydrology. In some cases, sediment that has been deposited in a wetland can be removed to restore the wetland. This allows the creation of wetlands at a number of locations; however, cost of excavation and removal of excavated material can be high. In some circumstances, it is also difficult to predict appropriate excavation depths. Excavation to subsoil leaves poor substrate for plant growth. Excavation to create a wetland displaces other habitat (i.e., upland habitat may be lost).

3.2.4 Terracing

In subsiding deltas, marshes are converted to open bay bottom as elevations become lower, allowing prolonged inundation of vegetation and subsequently leading to plant death. If sediment deposition rates can be increased to a point at which sedimentation can outpace subsidence, marsh vegetation can become re-established. In terracing, linear mounds of dredged material are constructed, some times in a checkerboard pattern. The intent of terracing is to provide patches of quiescent water that will allow sediment deposition. If sediment deposition rates do not increase sufficiently to outpace subsidence, lower turbidity within terrace cells may still support submerged aquatic vegetation. In some circumstances, terracing may lead to recovery of vegetated emergent marsh habitat or establishment of submerged aquatic vegetation within terrace cells. Even if this does not occur, linear mounds of dredged material provide marsh "edge" habitat, believed to be more important than open bay bottom to fish and crustaceans.



Terracing

3.3 Operation and Maintenance

3.3.1 Planting

Planting can be used as part of the overall restoration methods or as the sole restoration activity. Different plant species require different methods of site preparation, planting, and care. In some situations, planting is necessary to introduce desired species to a site, but in other settings the desired plant species would probably become established on the site through natural colonization, which has prompted some restoration ecologists to suggest that planting is overused in wetland projects. Planting quickly establishes vegetation structure under some circumstances. For wetlands that are isolated, planting can introduce species that would otherwise be permanently excluded from the site. Rapid establishment of plant cover can reduce problems with erosion. However, many planting efforts fail to establish desired plant communities because of improper handling of stock, poor weather conditions after planting, planting of species that are inappropriate to environmental conditions, inability of planted stock to compete with other species, and grazing by livestock, rodents, birds, and fish. Planting cannot replace establishment of appropriate hydrology and other restoration activities.

3.3.2 Weed Control

In tropical freshwater wetlands, thousands of species of plants have been transported beyond their natural ranges, both intentionally and unintentionally. Many introduced species spread prolifically in environments where predation and competition are limited. Examples of plant species that have led to wetland degradation include Eichornia crassipes (water hyacinth) and the Salvinia molesta (salvinia, a water fern). Plants can sometimes be controlled manually or mechanically harvested, with pesticides, with biological control agents (grazers or pathogens intentionally introduced to control nuisance species), through hydrological manipulation, or by some combination of these methods. Weed control can allow re-establishment of native plant communities. Once introduced plant populations become well established, complete removal is difficult or impossible. Biological controls that are effective on dense populations become less effective as populations decrease in size and become patchy in distribution. Manual and mechanical control is prohibitively expensive. Control using pesticides is not appropriate in all circumstances, either because chemical pesticides may not be appropriate for the restoration site or because available pesticides may impact desirable native species. Hydrological manipulation is not always possible. In all cases, scattered individuals or seed-banks remaining after restoration efforts can lead to renewed infestation of sites.

3.3.3 Flooding

Flooding

Temporary floodplain wetlands may receive less effective flooding due to blockages in floodplain flow paths. Development on floodplains includes many features that create barriers to flow in floodplain flow paths. These include flood levees, road causeways, fences, and earth banks. By modifying or removing these barriers in floodplain creeks, floods can be directed more effectively across the floodplain to fill temporary wetlands and have the maximum effect similar to natural conditions. When water flows across the floodplain, natural regeneration processes are triggered by the simulated flood pulse. Rehabilitation projects can identify opportunities to remove or modify barriers to allow flows to reach the floodplain more effectively when natural flow peaks occur in the river system.

Temporary floodplain wetlands drought by reduced flood volumes and frequency are due to river regulation and upstream storages. Upstream storages and regulation of river systems with variable flows have ensured water supply for domestic, irrigation, and electricity production. The changed water regime has greatly reduced flood frequency, volume, and duration, causing a major reduction in natural flood pulses which act as cues for breeding and regeneration of aquatic and riparian species. By lowering the threshold-to-flow for floodplain creeks, smaller floods can be directed onto the floodplain to fill temporary wetlands and have the same effect as a larger flood under natural conditions. When water flows onto the floodplain, natural regeneration processes are triggered by the simulated flood pulse.

River floodplain wetlands have been degraded by the construction of upstream dams and water diversions. Floodplain wetlands can be severely degraded by changes in the magnitude, timing, duration, and frequency of flooding events resulting from the management of upstream dams and water diversions. Re-establishing the physical and biological connections between the river channel and associated floodplain wetlands is essential to the rehabilitation of river-floodplain systems. Artificial flood releases below dams is a means of wetland management and sustainable development. Prescribed flood releases may be the only way to reintroduce the natural timing, duration, magnitude, and frequency of floodwaters in flood-dependent wetland systems, using natural processes to restore wetland diversity and heterogeneity; numerous studies suggest that the economic benefits of improved flood management may outweigh the costs in terms of other potential water uses; efforts may benefit both human and ecological communities. However, this may involve an often complex political process to gain local and institutional support for flood releases from among competing demands for water among river basin stakeholders, particularly in larger river-floodplain systems; flood releases may not solve other problems associated with dams and diversions such as reduced floodplain siltation or poor water quality; some of the changes in wetlands systems caused by water regulation may not be readily reversed by mimicking former hydrological conditions, requiring other complementary restoration practices; some dams may not be designed to enable planned flood releases.

Regulation of river systems with variable flows has produced stable higher water levels to ensure water supply for domestic, irrigation and industrial use. The changed water regime has lost variability and natural flood pulses which act as cues for breeding and regeneration of aquatic and riparian species. By installing a flow control structure on a drowned wetland, water can be excluded to allow evaporative drying to the point where the bed of the wetland dries out and cracks. When the wetland is re-filled, natural regeneration processes are triggered by the simulated flood pulse. Demonstration projects indicate a powerful positive response from the first drying cycle, which continues to expand with a second cycle. Wetting and drying cycles are managed to coincide with natural flow patterns in the river system. The method uses natural processes to restore wetland biodiversity; quick local response in wetland health is visible to community and funding bodies however, the ongoing management and monitoring needs are required.

4. GENDER AND SOCIAL ISSUES

The different roles and responsibilities of women and men in water resources use and management are closely linked to environmental change and well-being. This is true both for how women and men affect the environment through their economic and household activities and how the resulting environmental changes affect people's well-being. Understanding these gender differences is an essential part of developing policies aimed at both better environmental outcomes and improved health and well-being.

Women play a critical role in the field of environment, especially in the management of plants and animals in forests, arid areas and wetlands. Rural women in particular maintain an intimate interaction with natural resources, the collection and production of food products, fuel biomass, traditional medicine and raw materials. Poor women and children especially may collect grasshoppers, larvae, eggs and birds' nests to sustain their families.

Wetlands are fundamental ecosystems for the maintenance of life in Rwanda. For centuries people have depended on wetlands for services such as food, water, natural resources and transport. For women, wetland ecosystems and the goods they yield sustain rural livelihoods. The main economic activities undertaken by woman in wetland areas are:

- *Wild resources* provide materials for utensils and construction, and contribute to improved diets and health, food security, income generation and genetic experimentation.
- *Fishing* is done throughout the year using different equipment for different seasons. The flooding of the wetland due to dams, diversions and climate change reduces fishing revenues.
- *Agriculture* includes dry-land farming, seasonally flooded rice farming, flood-retreat farming and irrigated farming. Rice is the most important crop grown in seasonally flooded areas.
- *Dry season grazing* of sheep, goats and cattle occurs when pastoralists move into the area during the dry season.
- *In the urban centres*, the women process fish products, particularly the steaming of fish and oyster breeding. Recently several women's organisations have been getting involved in urban agriculture (market gardens).

As their knowledge is transmitted through generations, girls and women often acquire a thorough understanding of their environment, and more specifically of its biodiversity. Their experience gives them valuable skills required for the management of the environment. Women have an important role to play in preserving the environment and in managing natural resources to achieve ecologically sustainable production. Despite women's assumed special relations to nature it should be stressed that all people depend on the environment and all should share the responsibility for sustainable use of water and other natural resources. These are some of the challenges in gender related issues in water and other natural resources.

- *Environment vulnerability:* The impacts of the degradation of the environment on people's everyday lives are not the same for men and women. When the environment is degraded, women's day-to-day activities, such as fuel and water collection, require more time, leaving less time for productive activities. When water becomes scarce, women and children in rural areas must walk longer distances to find water, and in urban areas are required to wait in line for long hours at communal water points. Despite their efforts, women living in arid areas tend to be categorised among the poorest of the poor, and have absolutely no means to influence real change. They are often excluded from participating in land development and conservation projects, agricultural extension activities, and policies directly affecting their subsistence. Men make most decisions related to cattle and livestock, and even in households headed by women, men still intervene in the decision-making process through members of the extended family. However, because of the important contribution of women, the fight against the degradation of arid areas requires a gender-inclusive approach.

- *Access To and Control over Resources:* Land tenure influences how different groups use natural resources. Women, the poor, and other marginalised groups are less likely to invest time and resources or adopt environmentally sustainable farming practices on land they do not own. Women's food crops are relegated to rented, steeply sloped land with eroding soils. Because tenure is not secure, women have little incentive to invest in soil conservation measures. These restrictions on women's land rights hinder their ability to access other resources and information.

- *Watershed management:* Women do sometimes participate in watershed management, for example, by maintaining forest cover to reduce soil erosion which often floods and silts reservoirs and waterways. Training programmes on the technical and scientific aspects of watershed development including soil and water conservation measures and techniques on wetland restoration must include women. Women need the necessary skills, knowledge and confidence to participate in community decision-making and to assume leadership roles in management of watershed development. Gender analysis is need for all components of most watershed development activities.

Women's status in conserving biodiversity may be enhanced through the following types of actions to integrate gender concerns into environmental planning:

- Improve data collection on women's and men's resource use, knowledge of, access to and control over resources. Collecting sex-disaggregated information is a first step toward developing gender-responsive policies and programmes.
- Train staff and management on the relevance of gender issues to water resources and environmental outcomes.
- Establish procedures for incorporating a gender perspective in planning, monitoring, and evaluating environmental projects.
- Ensure opportunities for women to participate in decisions about environmental policies and programmes at all levels, including as designers, planners, implementers, and evaluators. Women need official channels to voice their environmental concerns and contribute to policy decisions.

Irrigated agriculture will grow in Rwanda. Investments in irrigation will tended to focus on small scale projects benefiting small and marginal farmers who have been evicted, displaced, or had their land expropriated. Small-scale irrigation planning should include gender differentiated needs and priorities. For example, women should be represented in Water User Associations responsible for decision making on the distribution and management of water. Women often have to balance other household tasks along with irrigation and usually find it difficult to irrigate at night, particularly if they are single women, because of social norms defining mobility and security concerns. Female-headed households usually have to hire (male) labour to help with irrigation or depend on social networks of family and friends during the peak season. Moreover, female farmers who grow the same crops as men, and should be entitled to receive an equal amount of water, find it difficult to claim and receive their water entitlement, especially when water is scarce.

Irrigation also has an impact on female labour participation, albeit mixed, providing employment opportunities for women on their husband's plots (unpaid, extra work) or as agricultural labourers on land belonging to large farmers. At the same time, the introduction of irrigation in dry-land or rain-fed areas may reduce distress migration, particularly by women, as it enables families to grow a second or third crop. Women also use irrigation water for other purposes, such as watering cattle, washing clothes and utensils in canals or watering their kitchen plots gardens.

Despite the growing recognition of the different needs of women irrigators, their participation in community water management associations is limited or lower than men's for a variety of social and institutional reasons. Formal membership is often restricted to those who legally own irrigated land, or are household-heads, or sometimes a combination of both factors. Since these categories largely apply to men, women farmers are not considered eligible for membership although in many cases they are cultivating and managing land in the absence of men who have migrated. While it is clear that access to irrigation is a source of power and conflict, the role of participatory and gender-sensitive external facilitators in capacity building and communication processes in order to encourage the articulation of socially inclusive rights and obligations is critical. The participation of women farmers and other marginalised groups can make a difference in sustainable management of water for agriculture.

Annex 1: References and Useful Resources

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