# IWMI-IPTRID Partnership

# Completion Report
# LOA 1
# (October 2001 – December 2002)

**(LOA PR No. 21400)**

## International Water Management Institute
## Colombo

## January 2003

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**IWMI-IPTRID Partnership**
**Final Report**
(LOA PR No. 21400)

# Part I – Introduction and Background

## 1 Introduction

The IPTRID Consultative Group, during the June 1998 meeting, defined the goals of the program as being to enhance the standard of irrigation and drainage research and development in and by developing countries. The objective is to improve technology and management in order to increase the production of food and agricultural commodities, enhance food security and assist in eliminating poverty, whilst giving due regard to the needs of the environment.

In year 2000, IWMI specified the Institute's goal as being to contribute to the CGIAR mission of poverty eradication, food security and environmental conservation in developing countries by Improved management of water and land resources for food livelihoods and nature, IWMI Strategic Plan 2000-2005.

During 2000 IPTRID and IWMI signed a Memorandum of Understanding to formalize IWMI as a member of the IPTRID core partners. In 2001 IPTRID/FAO and IWMI agreed that IWMI would provide support to the IPTRID program for the period 1st July 2001 to 30th June 2004. This agreement is to be implemented under four letters of agreement (LOA) between IPTRID/FAO and IWMI, funded under an agreement between the Netherlands Government and IPTRID/FAO. The first LOA (LOA PR No. 21400) was signed in December 2001 for the period 1st December 2001 to March 31st 2002.

This report is the Completion Report covering the 1st LOA from October 2001 to December 2002, including all activities since July 2001.

## 2 Project Components

Under the framework of The Netherlands Trust Fund for IPTRID-IWMI Collaborative Research in Irrigation and Drainage, research and technology transfer activities under the following themes will be covered:

Program Development. IWMI will contribute to joint research in developing strategies and options for smallholder water management systems in Asia and sub-Saharan Africa. The work will include providing strategic input to national programmes on investment, performance evaluation and capacity and institution building in the area of smallholder water management. This includes work in water harvesting, low-cost drip irrigation, treadle pumps, and other innovative approaches that show promise for alleviating poverty among smallholder farmers.

Provision of Content. IWMI will contribute substantially to the IPTRID program on benchmarking irrigation performance. IWMI will assist in program design, helping national partners with the benchmarking program, and the maintenance of an electronic database on

performance of irrigation systems. Web access to this information will be provided. IWMI will also provide content in the area of "Institutional Aspects" with special reference to Water User Associations, Turnover and Participatory Irrigation Management to IPTRID operated WCA-infoNet.

Research and Analytical tools. IWMI will provide support to IPTRID to promote the use of PODIUM and other models in at least 6 countries in Asia and sub-Saharan Africa. The activities will contribute to the knowledge to facilitate the dialogue on food on food and environmental security, a follow-up activity of the 2nd World Water Forum in preparation for the 3rd World Water Forum. Specifically, IWMI will assist host countries in selecting and integrating data sets needed to undertake useful and meaningful projections, simulations and scenario development for policy formulation. IWMI will train developing country scientists to adapt and use PODIUM to their area, state or national conditions.

Networking. IWMI will facilitate the IPTRID – IWMI partnership. This will include IWMI participation of IWMI staff in IPTRID fieldwork. In IWMI will support communication, including participation in meetings and seminars, between IWMI and IPTRID Secretariat, between IWMI and other partner institutions of IPTRID, between IWMI and IPTRID Country/Regional networks. This component will support participation by IWMI in IPTRID network activities and those of its partner institutions.

## *2.1 Components under the 1st LOA (15 October 2001 to 31 December 2002)*

The purpose of the Letter of Agreement no 1 is to enable the Recipient Organization to undertake activities in collaboration with IPTRID in the following areas (see also Inception report):

- **Smallholder irrigation**
- **Benchmarking irrigation performance**
- **Research and analytical tools in water, food and environment**
- **WCA-infoNET**
- **Networking**

## *2.2 Funding Arrangement of the Government of the Netherlands for IPTRID-IWMI Collaborative Research in Irrigation and Drainage.*

The Trust Fund under the IPTRID-IWMI Collaborative Research in Irrigation and Drainage provides for a total amount of USD 900,000 (with a maximum countervalue of NLG 2,340,000/EUR 1,061,846) for the period 1 July 2001 until 1 July 2004 (WW138710). This fund will be administered by FAO on behalf of IPTRID following Trust Fund management procedures.

The fund will be transferred to IWMI by means of four Letter of Agreements as shown in Table 1:

## Table 1 Revised Disbursement Schedule, Dec 2002

| LOA | Period of the LOA | | Amount in US Dollars | |
|---|---|---|---|---|
| | **Original Period** | **Revised Period** | **Original Budget** | **Revised Budget** |
| 1st | 15 Oct, 01 -- 31 Mar 02 | 15 Oct 01 -- 31 Dec 02 | 145 000 | 145 000 |
| 2nd | 1 Apr 02 -- 31 Dec 02 | 1 Jan 03 -- 30 Apr 03 | 280 000 | 160 000 |
| 3rd | 1 Jan 03 -- 31 Dec 03 | 1 May 03 – 31 Dec 03 | 280 000 | 280 000 |
| 4th | 1 Jan 04 -- 31 June 04 | 1 Jan 04 -- 30 June 04 | 144 057 | 264 000 |
| | 6% Support cost charged by FAO | | 50 943 | 51 000 |
| Total | | | 900 000 | 900 000 |

Annex 1 to the 1st letter of agreement states that activities undertaken in the areas described in outline on the Project Components (section 2.1) from 1 July 2001 can be included in this Letter of Agreement. IWMI commenced work on the Benchmarking and Smallholder Irrigation tasks during July 2001, making substantial progress by the scheduled completion date in March 2002.

The first Inception Report and Work Plan, this document, was submitted in March 2002 following confirmation of the first LOA in December 2001. Some revisions to the Inception Report and proposed work plan were made in response to comments received on the draft report. However due in part to management changes at the IPTRID secretariat the work plan and inception report were not finalized until late in 2002. However IWMI continued to operate the project as agreed with the task managers at the IPTRID secretariat until December 2002. The first LOA was not concluded until December 2002 with the submission of the revised inception report, work plan and progress report. Following discussions with the IPTRID Secretariat staff the resource allocations between the components have been modified to give a larger focus on the Smallholder Irrigation Component and to WCA-infoNET. Table 1 presents the revised disbursement schedule under this agreement for the remaining three LOA.

Tables 2 and 3 summarize total resource allocations by components and by scheduled agreements.

## Table 2 Budget allocations by project component

| Project Components | | US$ |
|---|---|---|
| a | Smallholder Irrigation | 340000 |
| b | Benchmarking | 180000 |
| c | Research/Policy-Water/Food/Env. | 130000 |
| d | WCA-infoNET | 100000 |
| e | Networking | 99000 |
| | Total budget | 849000 |

**Table 3 Cost breakdown per component per LOA**

| Table 3: Cost breakdown per component per LOA | | | | | |
|---|---|---|---|---|---|
| Project Component | LOA 1 | LOA 2 | LOA 3 | LOA 4 | Total |
| Smallholder Irrigation | 50 | 75 | 120 | 85 | 330 |
| Benchmarking | 40 | 40 | 60 | 60 | 200 |
| Research/Policy-Water/Food/Env. | 25 | 20 | 30 | 30 | 105 |
| WCA-infoNET | 10 | 10 | 35 | 50 | 105 |
| Networking | 20 | 15 | 35 | 39 | 109 |
| Total budget per LOA | 145 | 160 | 280 | 264 | 849 |

## *2.3 Operation of IPTRID/IWMI Partnership:*

FAO procedures stipulate that FAO can have only one LOA operational with any single organization at any given time. The procedures also require the each LOA to be completed, formally evaluated by the task manager and closed before a subsequent LOA can be issued for any follow-on activities. These regulations present a number of potential difficulties in the execution of the partnership, which are outlined here.

IWMI will continue to progress the project components after the scheduled completion of each LOA under the assumption that the subsequent, LOAs would be issued in good time. This will be done to ensure continuity of activities with the external partnerships established during the 1st LOA activities.

### 2.3.1 Scheduling of Activities under a single LOA

Each LOA between FAO and IWMI for the IPTRID Partnership includes multiple activities to be carried out in different locations by separate teams of researchers, in some cases under contract to IWMI for specific IPTRID related activities. While IWMI undertakes to ensure the quality and quantity of work will fully fulfill the standards expected from this partnership, it is inevitable that delays and other problems will occur during the execution of the partnership.

IWMI fully expects that the overall progress of the program of work will be maintained however, there will be delays and other difficulties due to no-fault on the part of any organization or individual. Such delays simply reflect the difficulties of research and development work in the uncontrolled conditions of farmers' fields and the impacts of the vagaries of the weather.

If IWMI have to complete all tasks under each LOA before a subsequent LOA can be issued, there is a danger that one delayed component will delay the approval of the next program of work for the other component tasks. IWMI strive to ensure sufficient progress is demonstrated against the overall work plan during each LOA period even if some scheduled intermediate outputs are delayed.

# Part II. Activities, Output and Incurred Expenditure per component

**(LOA 1, as related to the final expense claim (Annex 1)**

**Progress between October 2001 – December 2002**

## 3 LOA 1 Completion Reports

## *3.1 Smallholder irrigation*

### 3.1.1 Objectives

The main objective of this component is to further develop and evaluate the performance, application and accessories required to operate three treadle pump models kits to final production stage. Research into complimentary products such as cheaper hose pipes is being carried out. The development of water sources will be looked into. This evaluation considers sound engineering and commercial practices, and will use participatory approaches. Development of strategies and options to upscale the adoption of low cost irrigation and water harvesting technologies in Kenya, Tanzania, R. S. A. is an integral part of this component. An expansion of this component to include activities in West Africa (Senegal) and Asia (Mekong Basin) will be considered during LOA 2.

### 3.1.2 IWMI Point of Contact

Dr Marna de Lange, Regional Director (Africa). (Email: m.delange@cgiar.org) is the leader for this component of the project.

### 3.1.3 Activities

(i) Work in South Africa has been completed in accordance with the workplan and outputs produced as envisaged. This involves 75% of the envisaged contract research for this period.

(ii) Less IWMI staff time than envisaged was used for background research for the IPTRID paper. However, a quality output was produced.

(iii) Contract research by KARI did not commence as planned, and is presently being replaced by developing collaboration with Sokoine University, Tanzania. This involves 25% of the envisaged contract research and a total of 10% of the overall budget for this period.

The IWMI paper for IPTRID Day was completed on time and presented at the ICID Congress in Montreal, Canada, July 2002. The paper was very well received and contributed to more wide-scale acceptance of the relevance and importance of small-scale irrigation technologies to enable widespread small-farm development in Sub-Saharan Africa. The paper highlighted the challenges to improve the enabling environment for the distribution and utilization of small-scale water technologies by individual smallholders.

Contract research by ARC-ILI has been completed in December 2002 in accordance with the contract.

- Prototype kit treadle pumps are ready for production and dissemination. Caryn Seago's double cylinder kit treadle pump won the World Bank prize for innovation in 2002.

- A report is available on the engineering aspects of the prototype development, laboratory and field testing and the outcomes of a training workshop for rural manufacturers.

- A draft report is available on the South African context for introduction of treadle pumps and low-cost water technologies for smallholder irrigation.

- Follow-up planning is underway for a program of introduction of small-scale technologies into rural South Africa from 2003. A draft proposal and business plan has been prepared under the SIMI banner, in collaboration between IWMI, IDE, ApproTEC and two local South African partners, viz. ARC-ILI and an NGO, the Water for Food Movement.

Despite repeated efforts, the contract research by KARI did not commence.

- An alternative agreement is being developed with Sokoine University in Tanzania, where adoption of these small individual water technologies is on the increase. A draft proposal is expected from Sokoine in December 2002.

### 3.1.4 Outputs

- The IWMI paper for IPTRID Day was completed and presented at Montreal 2002. Conversion of this paper to become an IWMI-IPTRID Report will be considered during LOA 2.
- Contract research by ARC-ILI for 2002 completed according to contract.
- Prototype kit treadle pumps ready for production and dissemination. Caryn Seago's double cylinder kit treadle pump won the World Bank prize for innovation in 2002. A report is available on the engineering aspects of the prototype development, laboratory and field-testing and the outcomes of a training workshop for rural manufacturers.
- A draft report is available on the South African context for introduction of treadle pumps and low-cost water technologies for small holder irrigation.
- Follow-up planning is underway for a program of introduction of small-scale technologies into rural South Africa from 2003. A draft proposal and business plan has been prepared under the SIMI banner, in collaboration between IWMI, IDE, ApproTEC and two local South African partners, viz. ARC-ILI and an NGO, the Water for Food Movement.
- A draft proposal is expected in December 2002 from Sokoine University in Tanzania, where adoption of these small individual water technologies is on the increase.

### 3.1.5 Expenditure incurred

| LOA | LOA 1 | LOA 2 | LOA 3 | LOA 4 |
|---|---|---|---|---|
| Year | 2001-2002 | 2003 | | 2004 |
| Period | (whole period) | Jan-Mar | Apr-Dec | Jan-Jun |
| Activity | Actual Expenditure | Proposed | Proposed | Proposed |
| Research staff | 24 | 35 | 40 | 21 |
| Consultants | 13 | 15 | 15 | 10 |
| National Staff | 3 | 5 | 15 | 15 |
| Office & research Supplies | | 1 | 3 | 2 |
| International travel | | 5 | 4 | 5 |
| Workshops | | 3 | | 10 |
| Fellowships | | | | |
| Publications, dissemination | | | | |
| Contract research | | | 25 | 5 |
| Contingency | | | | |
| Vehicles, equipment | | | | |
| Overhead @ 18% | 8 | 11 | 18 | 12 |
| Total per LOA | 50 | 75 | 120 | 85 |

**Table 4 Budget breakdown per LOA: Smallholder Irrigation**

## 3.2 Benchmarking Irrigation Performance

### 3.2.1 Objectives

Benchmarking is described as a "A systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards", benchmarking aims to improve the performance of an organisation as to achieve its mission and objectives. The process implies comparison – either internally with previous performance and desired future targets, or externally against similar organisations, or organisations performing similar functions. The World Bank program for Institutional Reform in Irrigation and Drainage has identified benchmarking in the Irrigation and Drainage sector as a key element in the search for improvement in irrigation and drainage performance.

Until recently the mechanisms that enable effective implementation of a routine benchmarking system in the irrigation & drainage sector have not been available. IWMI is providing support to the Benchmarking initiative through the development and maintenance of a central data management and analysis unit (CDPU), based on an Online data entry and analysis system (OIBS).

### 3.2.2 IWMI Point of Contact

Mr Ian Makin (email: i.makin@cgiar.org) is the team leader for this activity.

### 3.2.3 Activities

During late 2001 IWMI designed, implemented and tested version one of the On-line Irrigation Benchmarking Service (OIBS). This required development of a relational data model from the IPTRID Guidelines for Benchmarking (Malano and Burton, 2001). The prototype web interface

was developed in parallel to conversion of the conceptual data model to a full implementation in Microsoft SQL Server, hosted on the IWMI web server in Colombo. OIBS version 1 went on-line from 1st January 2002. Version 2 of the interface and the underlying database were put on-line in June 2002.

IWMI participated at Benchmarking workshops at the World Bank in May 2002 and in Montreal at the ICID Congress in July 2002. Following the Montreal workshop, IWMI took the lead in proposing and organizing a special edition of the ICID journal, Irrigation and Drainage to be published in September 2003. This will coincide with the next ICID Benchmarking workshop in Montpelier, France.

The Department of Irrigation and Drainage (DID) Malaysia adopted Benchmarking as an integral part of the department's strategy to improve service provision in the eight granary areas. A workshop for 90 members of DID operations and management staff was organized during November 2002. Ian Makin participated as keynote speaker and also trainer in the OIBS web service.

IWMI supported benchmarking activities in P.R. China and Sri Lanka during the period of the first LOA.

Initial development and testing of an off-line version of the data entry system for use by system operators without reliable access to the Internet was started during 2002.

### 3.2.4 Outputs

The initial OIBS web service was initiated on schedule on 1st January 2002, with links being established from the IWMI, IPTRID and ICID web sites. Based on user feedback an updated version of the interface was developed between January and June 2002 and was put on-line during June 2002. OIBS Version 2 introduced a number of refinements to the user interface and provided an On-line administration toolkit for remote maintenance of the web site.

Further developments to the web interface and database were designed during October and November following up-loading of data sets from Mexico and Australia which highlighted some constraints inherent in the original design, based on the IPTRID Guidelines.

Tables 5, 6 and 7 summarize the current level of use of the OIBS web site. Additional effort will be directed towards encouraging practicing irrigation and drainage scheme operators to register with the site and to benchmark the performance of their schemes during 2003.

| Region | User Registrations |
|---|---|
| Africa | 16 |
| Asia | 69 |
| Australasia | 6 |
| C Asia | 0 |
| Europe | 64 |
| N America | 24 |
| S America | 5 |
| WANA | 12 |
| **Grand Total** | 196 |

**Table 5 Summary of registered OIBS users (December 2002)**

| | Size of Schemes in (ha) | | | |
|---|---|---|---|---|
| **Region** | **Less than 2,500 (Small)** | **2,500> ha <10,000 (Medium)** | **Greater than 10,000 (Large)** | **Total** |
| Africa | 76 | 2,900 | - | 2,976 |
| Asia | 3,988 | 64,624 | 722,098 | 790,710 |
| Australasia | - | 5,402 | 1,681,522 | 1,686,924 |
| C Asia | - | - | 13,000 | 13,000 |
| Europe | 2,223 | 8,937 | 15,068 | 26,228 |
| N America | - | 32,602 | 252,891 | 285,493 |
| S America | 103 | - | - | 103 |
| WANA | - | - | - | - |
| **Grand Total** | 6,390 | 114,465 | 2,684,579 | 2,805,434 |

**Table 6 Summary of Irrigated Command Area registered with OIBS, December 2002**

| | Number of Schemes | | | |
|---|---|---|---|---|
| **Region** | **Less than 2,500 (Small)** | **2,500> ha <10,000 (Medium)** | **Greater than 10,000 (Large)** | **Total** |
| Africa | 1 | 1 | 0 | 2 |
| Asia | 6 | 11 | 8 | 25 |
| Australasia | 13 | 2 | 14 | 29 |
| C Asia | 0 | 0 | 1 | 1 |
| Europe | 3 | 1 | 1 | 5 |
| N America | 0 | 4 | 2 | 6 |
| S America | 1 | 0 | 0 | 1 |
| WANA | 8 | 0 | 0 | 8 |
| **Grand Total** | 32 | 19 | 26 | 77 |

**Table 7 Summary of locations of schemes registered with OIBS, December 2003**

In the second half of the year development of the Off-line data entry system was completed and initial testing undertaken. The Off-line data entry system (OIBS-Offline) was not released for general use changes proposed to the underlying data base structure must be incorporated in the OIBS-Offline interface. These upgrades are planned for 2003.

The authors, contents and review panel for the Special Edition of the ICID Journal (Irrigation and Drainage) to be published in 2003 were agreed with Dr Hoffwegen, Chief Editor of the Journal.

### 3.2.5 Expenditure incurred

| LOA | LOA 1 | LOA 2 | LOA 3 | LOA 4 |
|---|---|---|---|---|
| Year | 2001-2002 | 2003 | | 2004 |
| Period | (whole period) | Jan-Mar | Apr-Dec | Jan-Jun |
| Activity | Actual | Proposed | Proposed | Proposed |
| Research staff | 27 | 27 | 35 | 30 |
| Consultants | | | | |
| National Staff | 4 | 4 | 1 | 6 |
| Office & research Supplies | | 2 | | |
| International travel | 3 | | 3 | 3 |
| Workshops | | | 4 | 7 |
| Fellowships | | | | |
| Publications, dissemination | 6 | 4 | 5 | 2 |
| Contract research | | | | |
| Contingency | | | | |
| Vehicles, equipment | | | | |
| Overhead (20%) | 6 | 6 | 9 | 9 |
| Total per LOA | 40 | 40 | 60 | 60 |

**Table 8 Budget breakdown per LOA: Benchmarking**

## 3.3 Research and analytical tools in water, food and environment policy

### 3.3.1 Objective

The main objective of this component is to contribute knowledge to facilitate dialogue on food and environmental security in countries in Asia and sub-Saharan Africa. The specific objective is to use the improved version of PODIUM model as a scenario development tool for policy formulation in three countries in Asia: India, Pakistan and P.R. China, and four countries in Africa: R.S.A., Ethiopia and Tanzania and Senegal in the sub-Saharan Africa.
IWMI Point of Contact:

Dr Upali Amarasinghe (email: u.amerasinghe@cgiar.org) is the team leader for this activity.

### 3.3.2 Activities

The PODIUM model has been adapted and tested to enable scenario analysis at sub-national level, generally using river basins as the unit of analysis.

A training program was held in Colombo during 2001 for researchers from three Asian countries (India, Pakistan and China) involved in calibration of the revised PODIUM model for their country conditions. PODIUM models were completed for these three Asian countries.

A training program was held in Pretoria during 2002 for researchers from three SSA countries (Republic of South Africa, Tanzania and Ethiopia) involved in calibration of PODIUM to conditions in these countries.

### 3.3.3 Outputs

The major output during the first LAO was the two training programs for the partners and researchers involved in the study for the six countries. The researchers in the three Asian countries started data collection for the basins in the analysis.

The data collection for Indian basins was completed and the data collection for the Pakistan Canal command areas is almost complete. The collection for Chinese basins is in progress.

The PODIUM model is revised to handle the issues at river basin level, and the data collected for Indian Basins and some canal command areas of Pakistan are integrated into the revised model.

A brochure for the revised PODIUM is in preparation.

### 3.3.4. Expenditure incurred

| LOA | LOA 1 | LOA 2 | LOA 3 | LOA 4 |
|---|---|---|---|---|
| Year | 2001-2002 | 2003 | | 2004 |
| Period | (whole period) | Jan-Mar | Apr-Dec | Jan-Jun |
| Activity | Actual | Proposed | Proposed | Proposed |
| Research staff | 9 | 4 | 18 | 10 |
| Consultants | 5 | 5 | 5 | |
| National Staff | | | | 5 |
| Office & research Supplies | | | | |
| International travel | | 6 | 2 | |
| Workshops | 7 | 2 | | 10 |
| Fellowships | | | | |
| Publications, dissemination | | | | |
| Contract research | | | | |
| Contingency | | | | |
| Vehicles, equipment | | | | |
| Overhead (18%) | 4 | 3 | 5 | 5 |
| Total per LOA | 25 | 20 | 30 | 30 |

**Table 9 Budget breakdown per LOA: PODIUM**

## *3.4 WCA–infoNET*

### 3.4.1 Objectives

The Institutional Aspects section of WCA infoNET is intended to provide an effective resource for practitioners and researchers looking for information and documented experience with alternate forms of Water User Associations and PIM. IWMI will be the editor responsible for quality control of material submitted for inclusion in the WCA infoNet database.

### 3.4.2 IWMI Point of Contact

Dr M Samad (email: m.samad@cgiar.org ) is the team leader for this activity.

### 3.4.3 Activities

During 2002 IWMI conducted a critical review of the existing structure of the WCA infoNET subject tree on Institutional Aspects of Integrated Water Management for Agriculture. Following an exchange of emails with the WCA infoNET task manager at the IPTRID Secretariat and subsequent discussions with Harry Denecke during Decmber 2002, IWMI was asked to consider providing a chief editor for the WCA infoNET service. This proposal will be further considered under LOA 2.

### 3.4.4 Outputs

No formal output was produced by this activity under LOA 1. However, IWMI researchers have contributed to the further development of the WCA infoNET site and have created the base for further progress during 2003 and 2004.

### 3.4.5 Expenditure incurred

| LOA | LOA 1 | LOA 2 | LOA 3 | LOA 4 |
|---|---|---|---|---|
| Year | 2001-2002 | 2003 | | 2004 |
| Period | (whole period) | Jan-Mar | Apr-Dec | Jan-Jun |
| Activity | Actual | Proposed | Proposed | Proposed |
| Research staff | 6 | 6 | 10 | 20 |
| Consultants | | | | |
| National Staff | 3 | 3 | 15 | 17 |
| Office & research Supplies | | | | |
| International travel | | | | |
| Workshops | | | | |
| Fellowships | | | | |
| Publications, dissemination | | | 5 | 5 |
| Contract research | | | | |
| Contingency | | | | |
| Vehicles, equipment | | | | |
| Overhead (18%) | 1 | 1 | 5 | 8 |
| Total per LOA | 10 | 10 | 35 | 50 |

**Table 10 Budget breakdown per LOA: WCA-infoNET**

## *3.5 Networking*

### 3.5.1 Objectives

The objective of this component is to enable participation by IWMI staff in IPTRID fieldwork, missions and as part of the IPTRID management committee. IWMI will support the IPTRID communication strategy, including participation in meetings and seminars between IWMI and IPTRID Secretariat, between IWMI and other partner institutions of IPTRID, between IWMI and

IPTRID Country/Regional networks. IWMI will participate in IPTRID network activities and those of its partner institutions.

### 3.5.2 IWMI Point of Contact

Mr Ian Makin (email: i.makin@cgiar.org) is the coordinator for these activities.

### 3.5.3 Activities

During the period of LOA 1, IWMI has been an active participant in the IPTRID Management committee, participating in physical and electronic meetings. IWMI participated at Management Team meetings at ICID meetings in Seoul (2001) and Montreal (2002).

IWMI researchers participated in field missions to Turkey, November 2001; and Egypt, January 2002. Participation in a follow up mission to Egypt could not be materialized due to conflicting schedules of the appropriate IWMI and IPTRID staff. The IPTRID Secretariat did not request IWMI participation in a mission to a third country during 2002.

A background paper and presentation at the IPTRID sessions at ICID Montreal were completed. The paper may be converted to an IWMI-IPTRID report during 2003.

IWMI commissioned a case study of Tao-Yuan Irrigation Association, Taiwan on behalf of the IPTRID Secretariat as part of the study on Modernization of Irrigation Systems. The report was submitted to the Secretariat during the third quarter of 2002.

IWMI provided feedback and comments on the new IPTRID mission and future strategic plan.

### 3.5.4 Expenditure incurred

| LOA | LOA 1 | LOA 2 | LOA 3 | LOA 4 |
|---|---|---|---|---|
| Year | 2001-2002 | 2003 | | 2004 |
| Period | (whole period) | Jan-Mar | Apr-Dec | Jan-Jun |
| Activity | | | | |
| Research staff | 8 | 7 | 20 | 20 |
| Consultants | | | | |
| National Staff | | | | |
| Office & research Supplies | | | | |
| International travel | 6 | 5 | 7 | 7 |
| Workshops | 3 | | | |
| Fellowships | | | | |
| Publications, dissemination | | | | 3 |
| Contract research | | | | |
| Contingency | | | 3 | 3 |
| Vehicles, equipment | | | | |
| Overhead (18%) | 3 | 2 | 5 | 6 |
| Total per LOA | 20 | 15 | 35 | 39 |

**Table 11 Budget breakdown per LOA: Networking**

# Part III –Proposed Activities under LOA 2

# 4 Work plan for Period January - April 2003

## *4.1 Smallholder irrigation*

### 4.1.1 Planned Activities

1. In Tanzania, initiate assessments of low cost water harvesting and micro-irrigation technologies for crop production.
2. In West Africa, initiate the assessment of the scale of, and factors influencing, the adoption of treadle pumps for independent smallholder irrigation development.
3. In South Africa, initiate the introduction of treadle pumps and SIMI: action research in support of the introduction of treadle pumps and low-cost watertechnologies into South Africa, as follow up to the development work done under this IPTRID collaboration to date.

### 4.1.2 Proposed Outputs (full year 2003)

Report on the adoption and impact of low-cost water technologies in Tanzania and several West African countries, similar to the IWMI Research Report tiled 'Pedalling out of Poverty' by Tushaar Shah on treadle pump adoption in Asian countries.

Reports on the uptake, impact and factors of adoption of low-cost water technologies in South Africa.

Report on lessons learnt on the proposed SIMI collaboration in 2003, to inform future replication in other Southern African and other Sub-Saharan countries.

Tools for the planning and implementation of on-farm and in-field rainwater harvesting for low-cost individual irrigation development.

### 4.1.3 Budget Estimate

The estimated budget for this component is shown in table 4 above. Further revisions to budget and resource allocations may be made in subsequent LOA after agreement with IPTRID Secretariat.

## *4.2 Benchmarking*

### 4.2.1 Planned Activities

Development of the On-line Irrigation Benchmarking Service – web site version 3 will be initiated with a target release date for general use by mid year 2003.

Contribution to ICID Report to Kyoto World Water Forum 3 – February 2003

Preparation of the Special Edition of ICID Journal – Irrigation & Drainage on Benchmarking will continue. Papers will be received for pre-review in January, distributed to reviewers in February. Authors will revise papers in April in time for submission to the chief editor and publishers in May 2003. The special edition is expected to be printed in time for ICID Montpelier in September 2003.

### 4.2.2 Proposed Outputs (Full Year 2003)

- On-line Irrigation Benchmarking Service – web site version 3 – March 2003
- Contribution to ICID Report to Kyoto World Water Forum 3 – February 2003
- Paper on OIBS for Special Edition of ICID Journal – February 2003
- Special Edition of ICID Journal – Irrigation & Drainage – papers submitted to reviewers Journal Published in September 2003
- Web site utilization report –December 2003

### 4.2.3 Budget Estimate

The estimated budget for this component is shown in table 8 above. Further revisions to budget and resource allocations may be made in subsequent LOA after agreement with IPTRID Secretariat.

## *4.3 Podium*

4.3.1. Planned Activities

It is expected to complete the integration of Indian and Chinese river basin data to the revised PODIUM models. The completed model will be posted in the IWMI and ICID web sites. The brochure of the revised model will be completed and posted in the IWMI web sites.

4.3.2. Proposed outputs

The completed model and the brochure will be published in the IWMI and ICID web sites during March 2003.

A draft research report on the spatial variability of water supply and demand of India will be available by April, 2003.

1.3.3. Budget Estimate

The estimated budget for this component is shown in table 9 above. Further revisions to budget and resource allocations may be made in subsequent LOA after agreement with IPTRID Secretariat.

## *4.4 WCA-infoNET*

### 4.4.1 Planned Activities

IWMI will continue to provide on-line quality controlled information on "Institutional Aspects of Irrigation Management" (including Water User Associations, Turnover and Participatory Irrigation Management) in the form of an elaborated subject tree, selected documentation on the subject and identifying and linking related Website and data bases. Specifically IWMI will act as

the editor of content in the area of "Institutional Aspects" with special reference to Water User Associations, Turnover and Participatory Irrigation Management in the IPTRID operated WCA-infoNet.

IWMI and IPTRID Secretariat will determine the modalities of IWMI becoming chief editor for WCA-infoNet, including definition of the TOR and scope of work for the chief editor. This will include definition of the respective roles of IWMI, IPTRID Secretariat and FAO Information Services.

### 4.4.2 Proposed Outputs

IWMI will review 30 knowledge objects in the Institutional Aspects domain of WCA-infoNet by end of March 2003.

IWMI and IPTRID Secretariat will develop TOR for the task of Chief Editor of WCA-infoNet by April 2003

### 4.4.3 Budget Estimate

The estimated budget for this component is shown in table 10 above. Further revisions to budget and resource allocations may be made in subsequent LOA after agreement with IPTRID Secretariat.

## *4.5 Networking*

### 4.5.1 Planned Activities

IWMI will continue to facilitate the IPTRID – IWMI partnership. This will include IWMI participation of IWMI staff in IPTRID fieldwork. In IWMI will support communication, including participation in meetings and seminars, between IWMI and IPTRID Secretariat, between IWMI and other partner institutions of IPTRID, between IWMI and IPTRID Country/Regional networks. Participation by IWMI in IPTRID network activities and those of its partner institutions. Specific activities will be agreed between the IPTRID Secretariat and IWMI.

### 4.5.2 Proposed Outputs (Full Year 2003)

IWMI will contribute to the discussions at IPTIRD management meetings and also during the Working Group discussions at the ICID Symposium in Montpelier in September 2003.
IWMI will provide inputs to any mission reports in which IWMI staff are members of the IPTRID mission team.

### 4.5.3 Budget Estimate

The estimated budget for this component is shown in table 11 above. Further revisions to budget and resource allocations may be made in subsequent LOA after agreement with IPTRID Secretariat.

If IWMI is not requested to undertake IPTRID missions during the period of any given LOA, the balance of this budget line will be reallocated to other components in discussion with the IPTRID Task Manager.

## Annex 1 Final Expense Claim LOA 1 – October 2001 – December 2002

| FAO-IPTRID | | | | | | |
|---|---|---|---|---|---|---|
| Letter of Agreement 1 (October 2001 - December 2002) | | | | | | |
| US$'000 | | | | | | |
| | | | | | | |
| | **Small-holder** | **Bench-marking** | **Policy Dialogue** | **Info-net** | **Net-working** | **Total** |
| | | | | | | |
| International Staff Salaries and Benefits | 24 | 27 | 9 | 6 | 8 | **74** |
| Consultants | 13 | | 5 | | | **18** |
| National Staff Salaries and Benefits | 3 | 4 | | 3 | | **10** |
| International travel | 2 | 3 | | | 6 | **11** |
| Workshops | | | 7 | | 3 | **10** |
| Overhead (18%) | 8 | 6 | 4 | 1 | 3 | **22** |
| | | | | | | |
| **Total** | **50** | **40** | **25** | **10** | **20** | **145** |
| | | | | | | |
| Funds received on 28 February 2002 | | | | | | **45** |
| | | | | | | |
| Balance receivable to IWMI | | | | | | **100** |

**Gamini Halvitige**
**Financial Controller**
**IWMI**

## Annex 2 Deliverables and date of publication

| Component | Product | Date of publication | LOA |
|---|---|---|---|
| **a. Small holder irrigation** | **1.** Paper for IPTRID Day at the ICID Congress in Montreal, Canada, July 2002 | **July, 2002** | **1 (Complete)** |
| | **2.** Literature review of issues facing irrigation and drainage in Africa | **Dec 2002** | **1 (Draft)** |
| | **3.** Report Adoption and impact of low-cost water technologies in Tanzania | **June 2003** | **3** |
| | **4.** Reports on the uptake, impact and factors of adoption of low-cost water technologies in South Africa. | | |
| | **5.** Report on lessons learnt on the proposed SIMI collaboration in 2003, to inform future replication in other Southern African and other Sub-Saharan countries. | | |
| | **6.** Tools for the planning and implementation of on-farm and in-field rainwater harvesting for low-cost individual irrigation development. | | |
| | **7.** IWMI/IPTRID Report: Strategies and options to upscale adoption of low cost irrigation and water harvesting technologies | **Dec 2003** | |
| | **8.** IWMI/IPTRID Report: Gender-sensitive and participatory socio-economic adoption/perception analyses | **Dec 2003** | **3** |
| | **9.** Synthesis Reports on Small Holder Irrigation in Kenya and South Africa | **June 2004** | **4** |
| **b. Benchmarking** | **1.** On-line Irrigation Benchmarking Service – web site version 1 | **Jan 2002** | **1 (Complete)** |
| | **2.** On-line Irrigation Benchmarking Service – web site version 2 | **July 2002** | **1 (Complete)** |
| | **3.** On-line Irrigation Benchmarking Service – web site version 3 | **March 2003** | **2** |
| | **4.** Contribution to ICID Report to Kyoto World Water Forum 3 | **Feb 2003** | **2** |
| | **5.** Paper on OIBS for Special Edition of ICID Journal – February | **Feb 2003** | **3** |

| | | | |
|---|---|---|---|
| | 2003<br>**6.** Special Edition of ICID Journal – Irrigation & Drainage<br>**7.** Annual Irrigation Benchmarking Status Report<br>**8.** Web site utilization report –December 2003 | <br>**Sept 2003**<br>**Dec 2003,**<br>**Dec 2003** | **3,4** |
| **c. Podium** | **1.** Improved PODIUM model for conducting scenario analysis at sub-units level<br>**2.** Training program for researchers in three Asian countries who are involved in adapting PODIUM to respective country conditions.<br>**3.** Training program for researchers in three SSA countries who are involved in adapting PODIUM to respective country conditions.<br>**4.** Improved PODIUM model to conduct analysis at sub unit level posted in IWMI web site<br>**5.** Brochure of the PODIUM Country level model and a training manual posted in IWMI web site<br>**6.** PODIUM models adapted for 3 Asian countries.<br>**7.** Water Supply and Demand in India: three future scenarios (draft in preparation). (*IWMI Research Report)*<br>**8.** Basin Level podium application in S. Africa (*IWMI Working paper*)<br>**9.** Basin Level podium application in Ethiopia and Tanzania (*IWMI Working paper*)<br>**10.** Report on country level PODIUM application in Ghana (*IWMI WORKING Paper*<br>**11.** Cross Country Analysis of Water and Food Security in SSA: Case Studies from Tanzania, Ethiopia and South Africa .*(Journal or IWMI Research Paper)*<br>**12.** Workshop for presenting results to Policy makers in Asian and SSA countries and training of policy makers/researchers in South Africa, Ethiopia and Tanzania for using PODIUM in policy analysis. | **Nov 2002**<br>**Nov 2002**<br>**2002**<br>**April 2003**<br>**March 2003**<br>**Dec 2002**<br>**May 2003**<br>**June 2003**<br>**August 2003**<br>**August 2003**<br>**November 2003**<br>**TBD** | **1 (Complete)**<br>**1 (Complete)**<br>**1 (Complete)**<br>**2**<br>**3**<br>**1 (Draft report)**<br>**3**<br>**3**<br>**3**<br>**3**<br>**3**<br>**4** |

| | | | |
|---|---|---|---|
| **d. WCA-infoNET** | **1.** Review of existing WCA-infoNet Institutions Contents<br>**2.** TOR and work plan for IWMI to become Chief Editor of WCA-infoNet<br>**3.** Edited content of WCA-infoNet Institutions tree<br>**4.** Addition of IWMI Reports on Institutional Aspects of water management as content to WCA-infoNet<br>**5.** Status Reports | **Aug 2002**<br><br>**April 2003**<br>**May 2003**<br>**Dec 2003**<br>**Dec 2003,**<br>**Jun 2004** | **1 (Complete)**<br><br>**2**<br>**1,2,3,4**<br>**2,3,4**<br>**3,4** |
| **e. Networking** | **1.** Final Report : Survey on Modernization of Irrigation Systems – A case study of the Tao-Yuan Irrigation Association, Taiwan<br>**2.** Contributions to IPTRID Mission Reports:<br>Turkey, November 2001<br>Egypt, January 2002<br>Additional reports as appropriate for subsequent missions<br>**3.** Contributions to IPTRID Newsletters<br>**4.** Inputs to IPTRID discussions and workshops as agreed on a case by case basis. | **July 2002**<br><br>**Nov 2001**<br>**Jan 2002**<br>**As appropriate**<br>**As appropriate** | **1 (Complete)**<br><br>**1 (Complete)**<br>**1 (Complete)**<br><br>**1,2,3,4**<br>**1,2,3,4** |
| | | | |

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# Annex 3 Draft Letter of Agreement LOA 2

Our Ref.: Your Ref.:

**DRAFT**

## LETTER OF AGREEMENT

Provision of funds from the Food and Agriculture Organization of the United Nations to the International Water Management Institute (IWMI)
(PR NO:.....)

1. Introduction

The Food and Agriculture Organization of the United Nations (hereinafter referred to as "FAO"), on behalf of the International Programme for Technology and Research in Irrigation and Drainage (IPTRID), will make available to the International Water Management Institute (hereinafter referred to as "Recipient Organization"), a financial contribution in the amount of US$ 160 000 (US Dollars One Hundred and Sixty Thousand) in support of the Recipient Organization to undertake research and technology transfer activities for IPTRID under the funding arrangement of the Government of the Netherlands for IPTRID-IWMI Collaborative Research in Irrigation and Drainage.

This is **LOA 2**, the 2nd LOA of a series of four LOA's between IPTRID and IWMI.

2. Purpose

(a) The purpose of this Letter of Agreement is to enable the Recipient Organization to undertake activities in collaboration with IPTRID in the following areas:

- **Smallholder irrigation** - research and technology transfer strategies and options for smallholder water management for countries in Africa and Asia, proposed are RSA, Tanzania, Kenya, West Africa (e.g. Senegal), Asia (Mekong Basin);
- **Benchmarking irrigation performance** - design, testing and launching a website on benchmarking, data analysis and providing technical support to benchmark irrigation schemes in countries in Asia, including: Sri Lanka, P.R. China, Pakistan (Punjab), Malaysia and India (Maharahstra);
- **Research and analytical tools in water, food and environment policy** - initiating action including desk studies in countries in Africa, including RSA, Tanzania, Ethiopia, West Africa (Senegal);
- **WCA-infoNET**: providing on-line quality controlled information on "Institutional Aspects of Irrigation Management" (including Water User Associations, Turnover and Participatory Irrigation Management) in the form of an elaborated subject tree, selected documentation on

the subject and identifying and linking related Website and data bases; performing the duties as chief editor (in collaboration with IPTRID Secretariat staff), proposing for a continuation or an "exit strategy" for the WCA-infoNET; and

- **Networking** - IWMI staff participation in IPTRID missions, attending IPTRID meetings and support to country and regional networks

*(hereinafter referred to as the "project").*

b) The background, the inputs to be provided by FAO and the budget of the project, is given in detail in the attached Annex 1, which constitutes an integral part of this Agreement.

3. General Conditions

a) Funds provided by FAO under this Agreement are to be used by the Recipient Organization exclusively in support of the project.

b) The Recipient Organization will be responsible for the organization and conduct of the project. FAO will not be held responsible for any accident, illness, loss or damage that may occur during the implementation of the project.

c) The use of the official emblem and name of FAO on any publication, document or paper is specifically prohibited without prior written approval from FAO.

d) All intellectual property rights (including copyright) in the work to be performed under this Agreement shall be vested in FAO, including, without any limitations, the right to use, publish, translate, sell or distribute, privately or publicly, any item or part thereof. FAO grants to the Recipient Organization a royalty-free license to use, publish, translate and distribute, privately or publicly, any item or part of the work to be performed under this Agreement for non-commercial purposes. Neither the Recipient Organization nor its personnel shall communicate to any other person or entity any confidential information made known to it by FAO in the course of the performance of its obligations under the terms of this Agreement nor shall it use this information to private or company advantage. This provision shall survive the expiration or termination of this Agreement.

e) The personnel assigned by the Recipient Organization to the running of the project shall not be considered as staff members of FAO and shall not be entitled to any privilege, immunity, compensation or reimbursement by FAO. Neither the Recipient Organization nor its personnel shall be allowed to incur any commitment or expense on behalf of FAO. Nothing in this Agreement or in any document relating thereto, shall be construed as constituting a waiver of privileges or immunities of FAO, nor as conferring any privileges or immunities of FAO on the Recipient Organization or its personnel.

f) The present Agreement shall be governed by general principles of law, to the exclusion of any single national system of law.

g) If, after meeting the costs of the project, there are unexpended funds under this Agreement, the Recipient Organization shall return such unexpended funds to FAO.

h) FAO shall have the right to terminate this Agreement, by written notice to this effect, if it considers that the continued implementation of the Agreement is impossible or impractical:

   i) for unforeseen causes beyond the control of FAO;

   ii) in the event of a default or delay on the part of the Recipient Organization.

i) In the event of the Recipient Organization's non-compliance or partial compliance with the terms of this Agreement, it will refund to FAO any payment already received in respect of activities that have not been performed by the Recipient Organization to a standard considered acceptable to FAO.

j) In the event of termination by FAO for unforeseen causes beyond its control, FAO shall complete all payments which may be due up to the effective date of termination.

4. Reporting

a) The Recipient Organization shall submit to Mr. O. Cogels, Programme Manager, IPTRID, an inception report containing a detailed work plan beginning 1 January 2003 to 30 April 2003 within four weeks of signature of the Agreement to enable the payment of the second instalment.

b) The Recipient Organization shall submit to Mr. O. Cogels, Programme Manager, IPTRID, an itemized statement of expenditures (certified by the Chief Accountant or similar officer) prior to receiving final payment for the services performed.

c) The Recipient Organization shall submit to Mr. O. Cogels, Programme Manager, IPTRID, a Final report of the Project containing the relevant technical documents including summary of achievements, conclusions and recommendations, no later than 30 April 2003.

d) The Recipient Organization shall submit to Mr. O. Cogels, Programme Manager, IPTRID a final audited statement of accounts showing the utilization of funds as determined under this Agreement within one month following the completion of the project. If the legal status of the Recipient Organization precludes the provision of audited financial statements, a statement certified as to its correctness by the officer responsible for maintaining them will be provided. In such cases the Organization shall have the right to review the relevant records.

5. Terms of Payment

a) For the execution of the project under this Agreement, IPTRID, through FAO, will make a financial contribution of US$ 160 000. The payments will be made as follows:

i) US$ 50 000 upon signature of the present Agreement;

ii) US$ 90 000 upon submission of an inception report as per 4(a) above; and

iii) US$ 20 000 upon acceptance by FAO of the statement of expenditures and the Terminal Report of the Project as mentioned under paragraphs 4 (b) and (c) above.

b) The above amounts will be paid in US Dollars.

c) The sum stipulated in paragraph 5(a) above represents the full amount to be paid by FAO, on behalf of IPTRID, for all services and activities to be provided by the Recipient Organization under this Agreement.

d) FAO will make the above-mentioned payments in accordance with the banking instructions provided below by the Recipient Organization.

6. Settlement of Disputes

Any dispute between FAO and the Recipient Organization arising out of the interpretation or execution of this Agreement shall be settled by mutual agreement. If FAO and the Recipient Organization are unable to reach agreement on any question in dispute or on a mode of settlement other than arbitration, either party shall have the right to request arbitration in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL), as at present in force. FAO and the Recipient Organization agree to be bound by any arbitration award rendered in accordance with the above, as the final adjudication of any such dispute.

7. Amendments

Any amendment to this Agreement shall be effected only on the basis of written mutual consent by the Parties.

8. Entry into Force

a) The present Agreement will enter into force upon signature by both Parties.

b) The Recipient Organization must sign two copies of this Agreement and return one to Mr. O. Cogels, Programme Manager, IPTRID, IPTRID Programme Office, Water Resources Development and Management

Service, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy.

**Signed on behalf of the Food and Agriculture Organization of the United Nations:**

Signature: .....
Louise O Fresco
Assistant Director-General, Agriculture Department

Date: .....

**Signed on behalf of the International Water Management Institute**

Signature: .....
Frank Rijsberman
Director General

Date: .....

---

**Detailed Banking Instructions** (including: the name of the account holder, account number, bank's name and its full address)

ANNEX 1

**Background**

The International Programme for Technology and Research in Irrigation and Drainage (IPTRID) is dedicated to enhancing the standard of irrigation and drainage research in developing countries. The ultimate aim is to increase the productivity of agriculture, enhance food security and assist in eliminating poverty, whilst giving due regard to the needs of the environment. IPTRID promotes its objective through a) synthesising knowledge, b) formulating research and development strategies and programmes, c) building national capacity and, d) networking.

The International Water Management Institute (IWMI) is a scientific research organization with a mission to improve water and land resources management for food, livelihoods, and nature. IWMI works with partners in the South to develop tools and methodologies to help these countries eradicate poverty through more effective management of their water resources. The Institute has a team of scientists representing more than 10 nationalities. It has ongoing research and development projects in about 20 countries in Asia, Africa, and Latin America.

The work of IWMI and IPTRID complements each other in many ways. The two institutions share at least three principles that guide their work.

The first is a dedication to sustainable agriculture that can contribute to long-term economic development, food security, and resource and environmental conservation.

The second is a commitment to capacity and institution building in the South through knowledge generation and networking.

Finally, they seek shared responsibility among all stakeholders for positive change. They actively work to facilitate collaborative ventures, seeking potential partners—from NARS, universities, governments, NGOs, and community groups to international development agencies and donors—on the basis of shared objectives and comparative advantage.

IWMI's strength lies in its multidisciplinary research in water resources, while IPTRID has its comparative advantage in outreach activities through its extensive network of partners.

Based on the unity of their purpose and mutual strengths, IWMI and IPTRID have agreed to forge a closer partnership with the objective of enhancing the value of their technical and information dissemination services (see MOU signed between FAO on behalf of IPTRID and IWMI - Annex 2).

**Funding Arrangement of the Government of the Netherlands for IPTRID-IWMI Collaborative Research in Irrigation and Drainage.**

The Government of the Netherlands has provided a grant to IPTRID for the exclusive purpose of supporting IPTRID-IWMI Collaborative Research in Irrigation and Drainage. This grant is provided to IPTRID, through FAO in the form of a Trust Fund. The agreement between FAO, on behalf of IPTRID and the Government of the Netherlands and the related project document are presented as Annex 3.

The Trust Fund under the IPTRID-IWMI Collaborative Research in Irrigation and Drainage provides for a total amount of USD 900,000 (with a maximum countervalue of NLG

2,340,000/EUR 1,061,846) for the period 1 July 2001 until 1 July 2004 (WW138710). This fund will be administered by FAO on behalf of IPTRID following Trust Fund management procedures.

The fund will be transferred to IWMI by means of four Letter of Agreements in the following manner:

| | Period covering the Agreement | Amount in US $ |
|---|---|---|
| LOA 1 | 15 October 2001 to 30 April 2002, extended until December 2002 | 145 000 |
| LOA 2 | 1 January to 30 April 2003 | 160 000 |
| LOA 3 | 1 May to 31 December 2003 | 280 000 |
| LOA 4 | 1 January to 30 June 2004 | 264 000 |
| 6% Support cost charged by FAO | | 51 000 |
| Total | | 900 000 |

**Areas of Collaboration and Joint Activities**

Under the framework of the The Netherlands Trust Fund for IPTRID-IWMI Collaborative Research in Irrigation and Drainage, research and technology transfer activities under the following themes will be covered:

Program Development. IWMI will contribute to joint research in developing strategies and options for smallholder water management systems in Asia and sub-Saharan Africa. The work will include providing strategic research input to national programmes on investment, performance evaluation and capacity and institution building in the area of smallholder water management. This includes work in water harvesting, low-cost drip irrigation, treadle pumps, and other innovative approaches that show promise for alleviating poverty among smallholder farmers.

Provision of Content. IWMI will contribute substantially to the IPTRID program on benchmarking irrigation performance. IWMI will assist in program design, helping national partners with the benchmarking program, and the maintenance of an electronic database on performance of irrigation systems. Web access to this information will be provided. IWMI will also provide content in the area of "Institutional Aspects" with special reference to Water User Associations, Turnover and Participatory Irrigation Management to IPTRID operated WCA-infoNet.

Research and Analytical tools. IWMI will provide support to IPTRID to promote the use of PODIUM and other models in at least 6 countries in Asia and sub-Saharan Africa. The activities will contribute to the knowledge to facilitate the dialogue on food on food and environmental security, a follow-up activity of the 2nd World Water Forum in preparation for the 3rd World Water Forum. Specifically, IWMI will assist host countries in selecting and integrating data sets needed to undertake useful and meaningful projections, simulations and scenario development for policy formulation. IWMI will train developing country scientists to adapt and use PODIUM to their area, state or national conditions.

WCA-infoNET. This an internet based information system developed by IPTRID. IWMI will provide for on-line quality controlled information on "Institutional Aspects of Irrigation Management" assuming the duties of Chief editor in collaboration with IPTRID Secretariat. IWMI may have an interest in proposing a follow-up of WCA-infoNET.

Networking. IWMI will facilitate the IPTRID – IWMI partnership. This will include IWMI participation of IWMI staff in IPTRID fieldwork. In IWMI will support communication, including participation in meetings and seminars, between IWMI and IPTRID Secretariat, between IWMI and other partner institutions of IPTRID, between IWMI and IPTRID Country/Regional networks. Participation by IWMI in IPTRID network activities and those of its partner institutions.

**Activities and Budget under the 2nd Letter of Agreement (LOA 2: 1 January to 30 April 2003)**

The purpose of this Letter of Agreement (**LOA 2**) is to enable the Recipient Organization to undertake activities in collaboration with IPTRID in the following areas:

- **Smallholder irrigation** - research and technology transfer strategies and options for smallholder water management in countries in Africa and Asia: RSA, Tanzania, Kenya, West Africa (Senegal), Asia (Mekong Basin);
- **Benchmarking irrigation performance** – updating the design, testing and launching a OIBS Website version 3 on benchmarking, data analysis, establishing a CDPU, providing technical support to benchmark irrigation schemes in countries in Asia (e.g. Sri Lanka, P.R. China, Pakistan, Malaysia, India (Maharashtra);
- **Research and analytical tools in water, food and environment policy** - initiating action including desk studies in countries in Africa, including RSA, Tanzania, Ethiopia, West Africa (Senegal);
- **WCA-infoNET**: providing on-line quality controlled information on "Institutional Aspects of Irrigation Management" (including Water User Associations, Turnover and Participatory Irrigation Management) in the form of an elaborated subject tree, selected documentation on the subject and identifying and linking related Website and data bases; assuming the duties of Chief editor in collaboration with IPTRID Secretariat, proposing an exit strategy and/or follow-up of WCA-infoNET;
- **Networking** - IWMI staff participation in IPTRID missions, attending IPTRID meetings and support to country and regional networks

**Budget**

The total budget under this Agreement is US Dollars 160 000. Payment will be made in three installments in the following manner:

ii) US$ 50 000 upon signature of the present Agreement;

ii) US$ 90 000 upon submission of an inception report.

iv) US$ 20 000 upon acceptance by FAO of the statement of expenditures and the final report covering the period of the Letter of Agreement.

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# Annex 4 LOA 1 between FAO on behalf of IPTRID and IWMI (October 2001 – December 2002)

**DRAFT**

## LETTER OF AGREEMENT

Provision of funds from the Food and Agriculture Organization of the United Nations to the International Water Management Institute (IWMI)
(PR NO:.....)

1. Introduction

The Food and Agriculture Organization of the United Nations (hereinafter referred to as "FAO"), on behalf of the International Programme for Technology and Research in Irrigation and Drainage (IPTRID), will make available to the International Water Management Institute (hereinafter referred to as "Recipient Organization"), a financial contribution in the amount of US$ 145 000 (US Dollars One Hundred and Forty Five Thousand) in support of the Recipient Organization to undertake research and technology transfer activities for IPTRID under the funding arrangement of the Government of the Netherlands for IPTRID-IWMI Collaborative Research in Irrigation and Drainage.

2. Purpose

(a) The purpose of this Letter of Agreement is to enable the Recipient Organization to undertake activities in collaboration with IPTRID in the following areas:

- **Smallholder irrigation** - research and technology transfer strategies and options for smallholder water management in two countries in Africa;
- **Benchmarking irrigation performance** - design, testing and launching a website on benchmarking, data analysis and providing technical support to benchmark irrigation schemes in three country (Sri Lanka, China and India);
- **Research and analytical tools in water, food and environment policy** - initiating action including desk studies in two countries;
- **WCA-infoNET**: proving on-line quality controlled information on "Institutional Aspects of Irrigation Management" (including Water User Associations, Turnover and Participatory Irrigation Management) in the form of an elaborated subject tree, selected documentation on the subject and identifying and linking related Websites and data bases; and

- **Networking** - IWMI staff participation in IPTRID missions, attending IPTRID meetings and support to country and regional networks

(hereinafter referred to as the "project").

b) The background, the inputs to be provided by FAO and the budget of the project are given in detail in the attached Annex 1, which constitutes an integral part of this Agreement.

3. General Conditions

a) Funds provided by FAO under this Agreement are to be used by the Recipient Organization exclusively in support of the project.

b) The Recipient Organization will be responsible for the organization and conduct of the project. FAO will not be held responsible for any accident, illness, loss or damage which may occur during the implementation of the project.

c) The use of the official emblem and name of FAO on any publication, document or paper is specifically prohibited without prior written approval from FAO.

d) All intellectual property rights (including copyright) in the work to be performed under this Agreement shall be vested in FAO, including, without any limitations, the right to use, publish, translate, sell or distribute, privately or publicly, any item or part thereof. FAO grants to the Recipient Organization a royalty-free license to use, publish, translate and distribute, privately or publicly, any item or part of the work to be performed under this Agreement for non-commercial purposes. Neither the Recipient Organization nor its personnel shall communicate to any other person or entity any confidential information made known to it by FAO in the course of the performance of its obligations under the terms of this Agreement nor shall it use this information to private or company advantage. This provision shall survive the expiration or termination of this Agreement.

e) The personnel assigned by the Recipient Organization to the running of the project shall not be considered as staff members of FAO and shall not be entitled to any privilege, immunity, compensation or reimbursement by FAO. Neither the Recipient Organization nor its personnel shall be allowed to incur any commitment or expense on behalf of FAO. Nothing in this Agreement or in any document relating thereto, shall be construed as constituting a waiver of privileges or immunities of FAO, nor as conferring any privileges or immunities of FAO on the Recipient Organization or its personnel.

f) The present Agreement shall be governed by general principles of law, to the exclusion of any single national system of law.

g) If, after meeting the costs of the project, there are unexpended funds under this Agreement, the Recipient Organization shall return such unexpended funds to FAO.

h) FAO shall have the right to terminate this Agreement, by written notice to this effect, if it considers that the continued implementation of the Agreement is impossible or impractical:

i) for unforeseen causes beyond the control of FAO;

ii) in the event of a default or delay on the part of the Recipient Organization.

i) In the event of the Recipient Organization's non-compliance or partial compliance with the terms of this Agreement, it will refund to FAO any payment already received in respect of activities that have not been performed by the Recipient Organization to a standard considered acceptable to FAO.

j) In the event of termination by FAO for unforeseen causes beyond its control, FAO shall complete all payments which may be due up to the effective date of termination.

4. Reporting

e) The Recipient Organization shall submit to Mr. A. Kandiah, Programme Manager, IPTRID, an inception report containing a detailed work plan beginning 1 July 2001 to 31 March 2002 within four weeks of signature of the Agreement to enable the payment of the second instalment.

f) The Recipient Organization shall submit to Mr. A. Kandiah, Programme Manager, IPTRID, an itemized statement of expenditures (certified by the Chief Accountant or similar officer) prior to receiving final payment for the services performed.

g) The Recipient Organization shall submit to Mr. A. Kandiah, Programme Manager, IPTRID, a Final report of the Project containing the relevant technical documents including summary of achievements, conclusions and recommendations, no later than 30 April 2002.

h) The Recipient Organization shall submit to Mr. A. Kandiah, Programme Manager, IPTRID a final audited statement of accounts showing the utilization of funds as determined under this Agreement within one month following the completion of the project. If the legal status of the Recipient Organization precludes the provision of audited financial statements, a statement certified as to its correctness by the officer responsible for maintaining them will be provided. In such cases the Organization shall have the right to review the relevant records.

5. Terms of Payment

a) For the execution of the project under this Agreement, IPTRID, through FAO, will make a financial contribution of US$ 145 000. The payments will be made as follows:

i) US$ 45 000 upon signature of the present Agreement;

ii) US$ 90 000 upon submission of an inception report as per 4(a) above; and

v) US$ 10 000 upon acceptance by FAO of the statement of expenditures and the Terminal Report of the Project as mentioned under paragraphs 4 (b) and (c) above.

c) The above amounts will be paid in US Dollars.

c) The sum stipulated in paragraph 5(a) above represents the full amount to be paid by FAO, on behalf of IPTRID, for all services and activities to be provided by the Recipient Organization under this Agreement.

d) FAO will make the above-mentioned payments in accordance with the banking instructions provided below by the Recipient Organization.

6. Settlement of Disputes

Any dispute between FAO and the Recipient Organization arising out of the interpretation or execution of this Agreement shall be settled by mutual agreement. If FAO and the Recipient Organization are unable to reach agreement on any question in dispute or on a mode of settlement other than arbitration, either party shall have the right to request arbitration in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL), as at present in force. FAO and the Recipient Organization agree to be bound by any arbitration award rendered in accordance with the above, as the final adjudication of any such dispute.

7. Amendments

Any amendment to this Agreement shall be effected only on the basis of written mutual consent by the Parties.

8. Entry into Force

a) The present Agreement will enter into force upon signature by both Parties.

b) The Recipient Organization must sign two copies of this Agreement and return one to Mr. A. Kandiah, Programme Manager, IPTRID, IPTRID Programme Office, Water Resources Development and Management

Service, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy.

**Signed on behalf of the Food and Agriculture Organization of the United Nations:**

Signature: .....
Louise O Fresco
Assistant Director-General, Agriculture Department

Date: .....

**Signed on behalf of the International Water Management Institute**

Signature: .....
Frank Rijsberman
Director General

Date: .....

---

**Detailed Banking Instructions** (including: the name of the account holder, account number, bank's name and its full address)

ANNEX 1

**Background**

The International Programme for Technology and Research in Irrigation and Drainage (IPTRID) is dedicated to enhancing the standard of irrigation and drainage research in developing countries. The ultimate aim is to increase the productivity of agriculture, enhance food security and assist in eliminating poverty, whilst giving due regard to the needs of the environment. IPTRID promotes its objective through a) synthesising knowledge, b) formulating research and development strategies and programmes, c) building national capacity and, d) networking.

The International Water Management Institute (IWMI) is a scientific research organization with a mission to improve water and land resources management for food, livelihoods, and nature. IWMI works with partners in the South to develop tools and methodologies to help these countries eradicate poverty through more effective management of their water resources. The Institute has a team of scientists representing more than 10 nationalities. It has ongoing research and development projects in about 20 countries in Asia, Africa, and Latin America.

The work of IWMI and IPTRID complements each other in many ways. The two institutions share at least three principles that guide their work.

The first is a dedication to sustainable agriculture that can contribute to long-term economic development, food security, and resource and environmental conservation.

The second is a commitment to capacity and institution building in the South through knowledge generation and networking.

Finally, they seek shared responsibility among all stakeholders for positive change. They actively work to facilitate collaborative ventures, seeking potential partners—from NARS, universities, governments, NGOs, and community groups to international development agencies and donors—on the basis of shared objectives and comparative advantage.

IWMI's strength lies in its multidisciplinary research in water resources, while IPTRID has its comparative advantage in outreach activities through its extensive network of partners.

Based on the unity of their purpose and mutual strengths, IWMI and IPTRID have agreed to forge a closer partnership with the objective of enhancing the value of their technical and information dissemination services (see MOU signed between FAO on behalf of IPTRID and IWMI - Annex 2).

**Funding Arrangement of the Government of the Netherlands for IPTRID-IWMI Collaborative Research in Irrigation and Drainage.**

The Government of the Netherlands has provided a grant to IPTRID for the exclusive purpose of supporting IPTRID-IWMI Collaborative Research in Irrigation and Drainage. This grant is provided to IPTRID, through FAO in the form of a Trust Fund. The agreement between FAO, on behalf of IPTRID and the Government of the Netherlands and the related project document are presented as Annex 3.

The Trust Fund under the IPTRID-IWMI Collaborative Research in Irrigation and Drainage provides for a total amount of USD 900,000 (with a maximum countervalue of NLG

2,340,000/EUR 1,061,846) for the period 1 July 2001 until 1 July 2004 (WW138710). This fund will be administered by FAO on behalf of IPTRID following Trust Fund management procedures.

The fund will be transferred to IWMI by means of four Letter of Agreements in the following manner:

| | Period covering the Agreement | Amount in US Dollars |
|---|---|---|
| 1st LA | 15 October 2001 to 31 March 2002 | 145 000 |
| 2nd LA | 1 April to 31 December 2002 | 280 000 |
| 3rd LA | 1 January to 31 December 2003 | 280 000 |
| 4th LA | 1 January to 31 June 2004 | 144 057 |
| | 6% Support cost charged by FAO | 50 943 |
| | Total | 900 000 |

**Areas of Collaboration and Joint Activities**

Under the framework of the The Netherlands Trust Fund for IPTRID-IWMI Collaborative Research in Irrigation and Drainage, research and technology transfer activities under the following themes will be covered:

Program Development. IWMI will contribute to joint research in developing strategies and options for smallholder water management systems in Asia and sub-Saharan Africa. The work will include providing strategic research input to national programmes on investment, performance evaluation and capacity and institution building in the area of smallholder water management. This includes work in water harvesting, low-cost drip irrigation, treadle pumps, and other innovative approaches that show promise for alleviating poverty among smallholder farmers.

Provision of Content. IWMI will contribute substantially to the IPTRID program on benchmarking irrigation performance. IWMI will assist in program design, helping national partners with the benchmarking program, and the maintenance of an electronic database on performance of irrigation systems. Web access to this information will be provided. IWMI will also provide content in the area of "Institutional Aspects" with special reference to Water User Associations, Turnover and Participatory Irrigation Management to IPTRID operated WCA-infoNet.

Research and Analytical tools. IWMI will provide support to IPTRID to promote the use of PODIUM and other models in at least 6 countries in Asia and sub-Saharan Africa. The activities will contribute to the knowledge to facilitate the dialogue on food on food and environmental security, a follow-up activity of the 2nd World Water Forum in preparation for the 3rd World Water Forum. Specifically, IWMI will assist host countries in selecting and integrating data sets needed to undertake useful and meaningful projections, simulations and scenario development for policy formulation. IWMI will train developing country scientists to adapt and use PODIUM to their area, state or national conditions.

Networking. IWMI will facilitate the IPTRID – IWMI partnership. This will include IWMI participation of IWMI staff in IPTRID fieldwork. In IWMI will support communication,

including participation in meetings and seminars, between IWMI and IPTRID Secretariat, between IWMI and other partner institutions of IPTRID, between IWMI and IPTRID Country/Regional networks. Participation by IWMI in IPTRID network activities and those of its partner institutions.

**Activities and Budget under the 1st Letter of Agreement (15 October 2001 to 15 April 2002)**

The purpose of this Letter of Agreement is to enable the Recipient Organization to undertake activities in collaboration with IPTRID in the following areas:

- **Smallholder irrigation** - research and technology transfer strategies and options for smallholder water management in two countries in Africa;
- **Benchmarking irrigation performance** - design, testing and launching a Website on benchmarking, data analysis and providing technical support to benchmark irrigation schemes in one country (e.g. Sri Lanka);
- **Research and analytical tools in water, food and environment policy** - initiating action including desk studies in two countries;
- **WCA-infoNET**: proving on-line quality controlled information on "Institutional Aspects of Irrigation Management" (including Water User Associations, Turnover and Participatory Irrigation Management) in the form of an elaborated subject tree, selected documentation on the subject and identifying and linking related Website and data bases;
- **Networking** - IWMI staff participation in IPTRID missions, attending IPTRID meetings and support to country and regional networks

Activities undertaken in the areas above, from 1 July 2001 can be included in this Letter of Agreement.

**Budget**

The total budget under this Agreement is US Dollars 145 000. Payment will be made in three instalments in the following manner:

ii) US$ 45 000 upon signature of the present Agreement;

iii) US$ 90 000 upon submission of an inception report.

vi) US$ 10 000 upon acceptance by FAO of the statement of expenditures and the final report covering the period of the Letter of Agreement.

联合国粮食及农业组织
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION
منظمة الأغذية والزراعة للأمم المتحدة
Cables: FAODAGRI ROME
Telex: 625852 FAO I 610181 FAO I
Facsimile: +39 0657

# Annex 5 Agreement between FAO, on behalf of IPTRID and the Government of the Netherlands

BVO: 27.9.2001
File: GCP/INT/705/MUL (Baby Project 5)

GCP/INT/705/HUL (5)
XIL 46/2
PR3/11 IWMI

cc: Archives + Arrangement (please acknowledge receipt)
Kalfdijk, AGLW + cc. Arrangement
Florin, AGLW + cc. Arrangement
Baugh, AFFC + cc. Arrangement
Pérez de Vega, TCOD
Vroegop, TCDM
Carsalade chrono
Lehel/Van Ommen, TCDM
TCDM chrono
TCD Reg.

04.10.01

Excellency,

I refer to your letter of 21 September 2001 concerning the Dutch contribution to "IPTRID-IWMI Collaborative Research in Irrigation and Drainage" (WW138710), and have the pleasure to return to you, as requested, an original copy of the related Arrangement, duly signed on behalf of FAO.

Kindly note that the contribution has been administratively incorporated in the IPTRID Programme and will be referred to as GCP/INT/705/MUL – Baby Project 5.

Accept, Excellency, the assurance of my highest consideration.

Henri Carsalade
Assistant Director-General
Technical Cooperation Department

MINISTRY
CAB/DIR
FLORIN

His Excellency
Jan Berteling
Ambassador
Permanent Representation of the Netherlands
to FAO
Via delle Terme Deciane 6
00153 Rome

## Annex 6 Outputs Produced during LOA 1

1. ***Contribution to Mission Report to Turkey, November 2001 on GAP – Southeastern Anatolia Project Regional Development Administration***

Not enclosed – IPTRID Secretariat produced report

2. ***Contribution to Mission Report to Egypt, January 2002 - Regional Cooperation Potential in the North Mediterranean-Sea Area***

Not enclosed– IPTRID Secretariat produced report

3. ***Final Report – Survey on Modernization of Irrigation Schemes. Selected Case of Tao-Yuan Irrigation Association, Taiwan. June 2002 by Agricultural Engineering Research Center, Taiwan***

Copy Enclosed

4. ***Background Paper – Agricultural Water Use And Improving Rural Livelihoods In Sub-Saharan Africa: Current Status, Future Directions, And The Role Of IPTRID. A Contribution to the IPTRID Session at ICID, Montreal July, 2002***

Copy Enclosed

5. ***On-line Irrigation Benchmarking System (OIBS) at http://www.lk.iwmi.org:82/oibs/main.htm***

Not enclosed – see web site.

6. ***Water supply and demand of India: Future scenarios Upali Amarasinghe, Noel Aloysius, David Molden Draft Report – Dec 2002***

Copy enclosed

7. ***PODIUM Model – Version II – Excel Spreadsheet and Revised data set***

Enclosed – electronic version

# OUTPUT 1

Contribution to Mission Report to Turkey, November 2001 on GAP – Southeastern Anatolia Project Regional Development Administration

International Programme for Technology and Research in Irrigation and Drainage

Republic of Turkey
Prime Ministry
GAP – Southeastern Anatolia Project
Regional Development Administration

*R&D Opportunities on Agricultural Water Management*

# *Report of the IPTRID Identification Mission to the GAP Region, Turkey*

***15-26 October 2001***



**IPTRID Secretariat**
**Food and Agriculture Organisation of the United Nations**
**Rome, Italy**
**November 2001**

## Acronyms

| | |
|---|---|
| AFEID | Association Française pour l'Etude des Irrigations et du Drainage (French National Committee of ICID) |
| DSI | Devlet Su Isleri = State Hydraulics Works |
| EU | European Union |
| FAO | Food and Agriculture Organisation of the United Nations |
| GAP | Güneudoğu Anadolu Projesi = Southeastern Anatolia Project |
| GDRS | General Directorate of Rural Services |
| GIS | Geographic Information System |
| IA | Irrigation Association (same as WUA) |
| IAM | Institut Agronomique Méditerranéen of Bari, Italy |
| ICID | International Commission on Irrigation and Drainage |
| IPTRID | International Programme for Technology and Research in Irrigation and Drainage |
| IU | Irrigation Union (same as WUA) |
| IWMI | International Water Management Institute |
| MOM | (GAP-MOM) GAP Monitoring, Operation and Management Project |
| NGO | Non-governmental organisation |
| R&D | Research and Development |
| RDA | (GAP-RDA) GAP Regional Development Administration |
| SME | Small and Medium Entreprise |
| TKV | Türkiye Kalkınma Vakfı = Development Foundation of Turkey |
| UNDP | United Nations Development Programme |
| WUA | Water Users Assocation |

*Cover page : Okeanos and his wife Tethis, head gof of rivers. Floor mosaic, Roman period, 2nd Century A.D., Belkis-Zeugma.Gaziantep Museum, Photo A. Vidal*

## Executive summary

The GAP Regional Development Administration (GAP-RDA) is aiming at the socio-economic development of the Southeastern Anatolia Region by means of sustainable agricultural development and water resources management. To achieve this, the Administration has initiated a number of activities including the promotion of research and development and technology transfer to **improve water use and conserve and protect the quality of water resources.** In this context, the GAP-RDA has requested IPTRID's assistance to identify research and development (R&D) needs and propose a plan of action to implement an R&D programme in agricultural water management in the Southeastern Anatolia Region. For this purpose, an IPTRID Identification Mission was undertaken during the period 15 to 26 October 2001. The mission provided a good overview of the prevailing issues and priorities for research and development (R&D) in the GAP region of Turkey.

While acknowledging the relative dynamism of irrigated agriculture in the GAP region, the mission as well as people and institutions visited identified a substantial potential for improving agricultural and water productivities. Such an improvement would require R&D activities focused on a better assessment of the present agricultural, technical, environmental, and socio-economic conditions and impacts of irrigation in the region, along the following issues:

- The Şanlı Urfa – Harran irrigation scheme presently represents the major part of irrigation within the GAP region as well as a pilot case for the forthcoming irrigation projects. Besides acknowledgeable achievements, a deviation from expectations can be observed on many aspects, which is worth being assessed.
- The GAP region still has room for improvement in the management of irrigation and drainage facilities that can lead to higher values of water productivity and maximise the total number of beneficiaries from the large investments still being made.
- The recent extension of irrigated surfaces under the Şanlı Urfa – Harran irrigation scheme with overirrigation and without subsurface drainage has increased already existing waterlogging and sometimes salinity. Outside the Harran Plain there are significant areas where groundwater is already being used for irrigation, and there are plans for intensifying groundwater use in favourable locations. Insufficient management of groundwater leads to competition and increased pumping cost, up to a point where it becomes uneconomical to grow many crops.
- Eight years after the start of the project, an overall evaluation of the GAP socio-economic impact is necessary. What is needed in fact is a mid-term cost-benefit analysis, with a clear identification of all the costs and benefits and a clear accounting system of economic prices on which all stakeholders could agree.

In considering these issues, the mission identified four R&D priority topics, each including two projects:

- **Topic 1 Planning, monitoring and evaluating Şanlı Urfa – Harran irrigation project**
  - Project 1.1 Revisiting and acquiring technical and economical data on irrigated agriculture
  - Project 1.2 Development of decision support tools
- **Topic 2 Introducing Performance Oriented Management in GAP Irrigation Systems**
  - Project 2.1 Strengthening Participatory Operation of Irrigation Systems
  - Project 2.2 Strengthening Maintenance by Irrigation Associations
- **Topic 3 Environmental Impact Assessment and Monitoring**
  - Project 3.1 Development of a sustainable salinity and waterlogging management system for Harran Plain
  - Project 3.2 Sustainable management of groundwater
- **Topic 4 Assessing and monitoring the agro-socio-economic impact of irrigation projects**
  - Project 4.1 Evaluation of the socio-economic impact of irrigation
  - Project 4.2 Land Tenure, Social Organisations and Farming

The present draft report will be submitted to GAP-RDA for comments, modifications then approval. After approval and publication of the report by IPTRID, identified R&D projects will be prioritised by GAP-RDA in relation with national institutions, and contacts will be taken with donors, already identified by the mission and others, to check for their interest in the prioritised projects and topics. An IPTRID formulation mission could then take place upon request of GAP-RDA to formulate full proposals of the prioritised projects for which an expression of interest from donors will have been identified.

## Résumé et conclusions

L'Administration Régionale de Développement du GAP (GAP-RDA) a pour mission le développement social et économique de l'Anatolie du Sud-Est par le développement agricole durable et la gestion des ressources en eau. Pour remplir sa mission, cette administration a mis en oeuvre un certain nombre d'activités notamment la promotion de la recherche-développement (R&D) et du transfert de technologie pour améliorer l'utilisation de l'eau et conserver et protéger la qualité des ressources en eau. Dans ce contexte, le GAP-RDA a demandé l'assistance de l'IPTRID pour identifier les besoins en recherche-développement et proposer un plan d'action pour mettre en place en programme de R&D en gestion de l'eau agricole en Anatolie du Sud-Est. A cette fin, une mission d'identification de l'IPTRID a été mise en place du 15 au 26 octobre 2001. Cette mission a permis de dresser un panorama des principales questions et des priorités en matière de R&D dans la région du GAP.

Tout en reconnaissant le dynamisme relatif de l'agriculture irriguée dans la région du GAP, la mission, de même que les personnes et institutions rencontrées, ont identifié une marge importante d'amélioration des productivités de l'agriculture et de l'eau. Une telle amélioration nécessiterait la mise en place d'action de R&D centrées sur une meilleure évaluation des conditions et des impacts de l'irrigation dans les domaines de l'agriculture, de l'environnement et des conditions techniques et socio-économiques, qui peut se décliner selon les axes suivants :

- Le périmètre irrigué de Şanlı Urfa – Harran représente aujourd'hui la majeure partie de l'irrigation dans la région du GAP, ainsi qu'un périmètre pilote pour les projets d'irrigation à venir. Outre une réussite tangible, on observe un certain nombre de dérives par rapport aux attentes initiales qu'il est intéressant de caractériser.
- La région du GAP dispose d'une marge importante pour l'amélioration de la gestion des ouvrages d'irrigation et de drainage, qui peuvent conduire à une meilleure productivité de l'eau et maximiser le nombre total de bénéficiaires des investissements en cours et à venir.
- L'extension récente des surfaces irriguées dans le périmètre de Şanlı Urfa – Harran, associée à une sur-irrigation et une absence de drainage souterrain a considérablement accru les excès d'eau existants et parfois la salinité. En dehors de la plaine d'Harran, de nombreuses zones sont irriguées à partir d'eau souterraine, et il est projeté d'intensifié l'utilisation de l'eau souterraine dans les zones favorable. Une gestion insuffisante de l'eau souterraine conduit à des conflits et des coûts pompages de plus en plus élevés, jusqu'au point où il ne devient plus rentable de produire certaines cultures.
- Huit ans après le démarrage du projet, une évaluation générale de l'impact socio-économique du GAP est nécessaire, sous la forme d'une analyse coûts-bénéfices à mi-parcours, incluant une identification claire de tous les coûts et bénéfices, et un système clair de comptabilité des prix économiques faisant l'unanimité parmi les différents acteurs locaux et nationaux.

Considérant ces questions, la mission a identifié quatre thèmes de recherche prioritaires, chacun comprenant deux projets :

- **Thème 1 Planification, gestion et évaluation du périmètre irrigué de Şanlı Urfa – Harran**
  - Projet 1.1 Réévalutation et acquisition de références techniques et économiques sur l'agriculture irriguée
  - Projet 1.2 Développement d'outils d'aide à la décision
- **Thème 2 Introduction d'une gestion orientée vers la performance dans les périmètres irrigués du GAP**
  - Projet 2.1 Renforcement de la gestion participative des périmètres irrigués
  - Projet 2.2 Renforcement de la maintenance par les associations d'irrigants
- **Thème 3 Evaluation et gestion des impacts environnementaux**
  - Projet 2.1 Développement d'un système de gestion durable de la salinité et de l'excès d'eau
  - Projet 2.2 Gestion durable de l'eau souterraine
- **Thème 4 Evaluation et gestion des impacts agro-socio-économiques des projets d'irrigation**
  - Projet 4.1 Evaluation de l'impact socio-économique de l'irrigation
  - Projet 4.2 Organisations foncière et sociale et agriculture

Ce rapport provisoire sera soumis au GAP-RDA pour commentaires, modifications puis approbation. Après approbation et publication du rapport par l'IPTRID, les projets de R&D identifiés seront classés par ordre de priorité par le GAP-RDA en lien avec les institutions nationales, et des contacts seront pris avec les bailleurs de fonds, qu'ils aient été ou non identifiés par la mission, afin d'évaluer leur intérêt sur les thèmes et projets ainsi hierarchisés. Une mission de formulation IPTRID pourrait alors avoir lieu à la demande du GAP-RDA pour formuler les propositions des projets prioritaires pour lesquelles une expression d'intérêt des bailleurs aura été identifiée.

# Table of Contents

# Table of Figures

# 1. Rationale and objectives of the mission

The GAP Regional Development Administration (GAP-RDA) is aiming at the socio-economic development of the Southeastern Anatolia Region by means of sustainable agricultural development and water resources management. To achieve this, the Administration has initiated a number of activities including the promotion of research and development and technology transfer to **improve water use and conserve and protect the quality of water resources.** In this context, the GAP-RDA has requested IPTRID's assistance to identify research and development (R&D) needs and propose a plan of action to implement an R&D programme in agricultural water management in the Southeastern Anatolia Region.

An IPTRID Identification Mission was undertaken during the period 15 to 26 October 2001. The purpose of the IPTRID mission was to identify R&D needs and opportunities and prepare a plan of action to implement an R&D programme in agricultural water management in the Southeastern Anatolia Region. The mission was undertaken jointly by the IPTRID Secretariat and IPTRID Partner Institutions, such as IWMI, HR Wallingford, FAO, and AFEID through the support of the French Government. The mission was lead by Mr. Alain Vidal, IPTRID Theme Manager, Water Conservation Technology. The mission team will also include a certain number of national consultants. The FAO Representation in Turkey will provide the necessary operational support to the mission

The duties of the mission were:

1. Holding discussion with relevant staff in the GAP-Regional Development Administration and other relevant institutions in the Southeastern Anatolia Region and in the Country.
2. Reviewing relevant documents related to the GAP Project with particular reference to past and on-going R&D activities, policies and institutional issues and other aspects related to water management.
3. Identifying gaps in research and knowledge, R&D needs and opportunities to improve water use and conserve and protect the quality of water resources.
4. Preparing a draft framework proposal on R&D and technology transfer programme on agricultural water management in the Southeastern Anatolia Region.
5. Presenting the draft framework proposal to the GAP-Regional Development Administration and seeking comments for revision and preparation of a final version of the proposal.
6. Preparation of a final version of the framework proposal.



The present identification mission to the GAP Region was coordinated and led by Mr Alain Vidal, IPTRID Theme Manager, IPTRID Programme Office, Rome. Mr. Vidal was accompanied by a team of 8 experts, 5 international (Mr. Nico van Leeuwen, FAO Water Resources, Development and Management Service; Mr. Hammond Murray-Rust, IWMI Regional Office for Asia; Mr. Geoff Pearce, HR Wallingford, Messrs. François Prévost and Bernard Préfol, AFEID) and 3 national (Ms. Melek Çakmak and Ms. Özlem Çetinkökü, GAP-RDA Ankara, Mr. Fatih Yildiz, GAP-RDA Şanlı Urfa). Also, Mr. Pasquale Steduto, IAM Bari, followed the mission in the frame of a joint GAP-IAM cooperation programme and participated to some of the meetings and field visits.

# 2. General results of the mission

## *2.1 Organisation of the mission and identification methodology*

Appointments and field visits were competently organised by Ms. Melek Çakmak, GAP-RDA Ankara, and Mr. Fatih Yildiz, GAP-RDA Şanlı Urfa. The local organisation of the mission efficiently allowed consultations to be held with a large number of relevant institutions and persons. The map below shows the places visited by the mission.

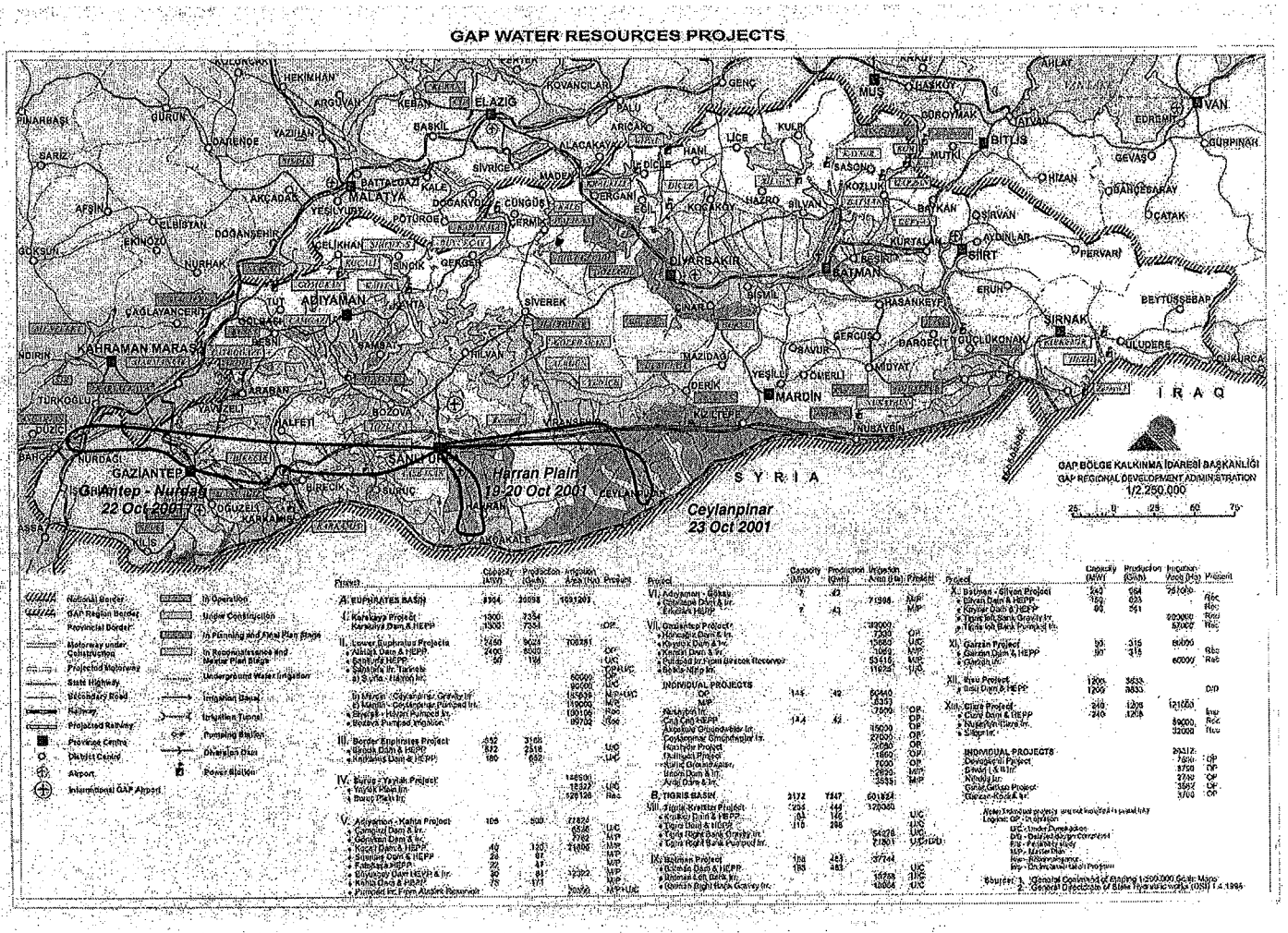


**Figure 1: Map presenting the present development stage GAP water resources projects and the itinerary of the mission field visits (Source: GAP-RDA)**

Persons met at the main offices of research institutes and at field stations were briefed on IPTRID, the mission objectives and contents, and asked to present their on-going and future R&D programmes, and to suggest any new R&D activity or any relevant reinforcement of existing activities in the field of agriculture water management. Most of the information collected was useful and contributed to identification of the R&D projects detailed in this report. The main outputs of the mission were discussed with GAP representatives, both at GAP regional office in Şanlı Urfa and at headquarters in Ankara.

## 2.2 *Situation of irrigated agriculture in the GAP Region and future trends*

### *Situation and trends in Turkey*

Turkey has a subtropical, semi-arid climate with extremes in temperatures. In the east, summers are hot and dry; winters are cold, rainy and snowy. Along the coastal area, a Mediterranean climate is dominant with long, hot, dry summers and short, mild, rainy winters. Rainfall shows great differences from one region to another. Average annual rainfall is 643 mm, ranging from 250 mm in the Southeast to over 3 000 mm in the northeast Black Sea area. About 70% of the rain falls in the winter and spring seasons. Droughts are frequent and without irrigation the agricultural production will remain subject to important variations.

Of the total surface runoff of the country, estimated at 192.8 km3/year, almost one-fourth comes from the Euphrates and the Tigris rivers, that both have their sources in the eastern part of the country. Turkey contributes about 90% of the total annual flow of the Euphrates, while the remaining part originates in Syria and nothing is added further downstream in Iraq. Turkey contributes 38% directly to the main Tigris river and another 11% to its tributaries that join the main stream of the Tigris further downstream in Iraq. In January 2000, the State Hydraulic Works (DSI) had 204 large dams and 339 small dams, mostly rock-fill or earth-fill dams, put into service in the country for water supply, irrigation, hydropower and flood control. The Atatürk Dam on the Euphrates river in the southeastern part of the country, with a total storage capacity of 48.5 km3, is one of the 10 largest dams in the world. With another 111 large dams and 159 small dams that were under construction, a total of 40 % of the water resources of the country will be captured.

Out of the total area of 78 million ha of the country, about 28 million ha, or 36% of the total area, are classified as agricultural land while the remaining area consists of forest, grazing land, open water bodies and others. The area that can economically be irrigated covers 8.5 million ha out of which 7.9 million ha is to be irrigated from surface water resources and the remaining 0.6 million ha from groundwater. Out of this potential, 4.7 million ha (55 %) were irrigated in the year 2000 with 4.1 million ha from surface water and 0.6 million ha with groundwater. Compared to 1004, the area increased by 0.5 million ha or 6 % of the potential.

Irrigation development in Turkey is carried out by the public sector, represented by DSI (State Hydraulic Works) and GDRS (General Directorate of Rural Services), and by the private sector (farmers and groups of farmers). The State Hydraulic Works (DSI) was established in 1954 as a legal entity and brought under the aegis of the Ministry of Public Works and Settlement and is responsible for the planning, design, construction and operation of water resources development for various purposes like irrigation, flood control, swamp reclamation, hydropower development, navigation and water supply to cities with over 100 000 inhabitants. The General Directorate of Rural Services (GDRS) was established in 1984 by incorporating the soil conservation and irrigation organisation, the rural settlement organisation and the rural roads, water and electricity organisation into one organisation. It is responsible for the development of small-scale irrigation schemes and small reservoirs, rural roads and water supply to rural areas. It is also responsible for land consolidation and the on-farm development of all irrigation projects, including the projects developed by DSI. It was formerly under the Ministry of Agriculture and Rural Affairs, but now falls under the Prime Minister's Office. DSI and GDRS have developed a large part (77%) of these irrigation schemes: 1.094 million ha irrigated by surface water and 0.487 ha by ground water. Private irrigation schemes cover some 1 million ha irrigated by surface water and 0.080 million ha by groundwater.

Almost 94% of the total area are irrigated using surface irrigation methods (furrow, basin, and border, wild flooding). The remaining part is under sprinkler irrigation (mainly hand-move) and some micro-irrigation, mainly in the Aegean and Mediterranean regions. The conventional (hand-move) sprinkler irrigation is common all over Turkey among the farmers and an estimated 200 000 ha are irrigated using this method. On DSI schemes, 63 849 ha are irrigated by sprinklers, mainly for sugar beet, cereals, beans, alfalfa, cotton, sunflowers, water melons and vegetables. Micro-irrigation is practised on 386 ha of DSI schemes, mainly for citrus fruits, vineyards, vegetables, strawberries and watermelons. During the last three decades GDRS has carried out a lot of on-farm water development works, for example the reclamation of saline and alkaline soils on 803 000 ha and open drains on 3 143 000 ha.

***Situation and trends in the GAP Region***

The GAP project is a regional development project focused on the socio-economic development of Southeastern Anatolia. As well as its major objectives of utilising the waters of the Euphrates and Tigris rivers for hydropower and irrigation development, it covers investment in areas as urban and rural infrastructure, transportation, industry, education, health, housing, tourism and other sectors. Major construction already well progressed comprises dams, hydraulic power plants and irrigation system infrastructure. But the project also has a major social objective which is to substantially improve the quality of life of local people and to close the developmental and economic gap that exists between this region and the rest of Turkey.

The GAP Regional Development Administration (established 1989 under the Office of Turkey's Prime Ministry) is responsible for the integrated regional planning and coordination of implementation. The GAP Administration has its head office in Ankara and it has also a Regional Directorate in Şanlı Urfa.

**Project components**

*GAP Water Resources Development Programme*

The programme comprises two groups of projects built in the upper catchments of the Euphrates and Tigris rivers. Some 22 dams, 19 hydraulic power plants and irrigation canals delivering water to 1.7 million hectares of land will eventually be built (mainly by DSI, Turkey's State Hydraulic Works Department). These facilities will enable Turkey to control the flow of over 50 billion cubic meters of water that flow each year down the Euphrates and Tigris, and which represent 28% of the country's total water potential. The area to be irrigated in the region corresponds to 20% of total irrigable land in Turkey, and its annual energy production to 22% of the country's total. The Turkish Ministry of Rural Development (GDRS) is responsible for the agricultural and rural infrastructure aspects of the project.

*GAP and Agriculture*

The GAP region extends over an area of 7.5Mha and includes diverse crops such as olives, pistachio, hazelnuts and citrus fruits. The land use pattern comprises 3.1 million hectares of cropland, 1.1 million hectares of forest and 2.4 million hectares of rangeland and pasture. The GAP strives to use these resources efficiently. For the first time in Turkey, the management, operation and maintenance of irrigation systems have been transferred to "farmers'" irrigation districts. Cotton is the main crop grown and makes up a third of the national cotton output. Other objectives of rural development in the GAP region include raising the level of income

in rural areas, providing inputs for industry, minimising migration from rural to urban areas, stock breeding, generating employment and enhancing export oriented production.

*GAP and Industry*

One of the objectives of the GAP Master Plan is to transform the region into an "agro-based export center". This requires investments to create a potential for industry and services and enhancement of private sector investments. GAP Entrepreneur Support and Guidance Centers (GAP-GIDEM) have been set up to provide information and consulting services to both local and external investors. Industrial areas so far completed in the GAP region represent 11% of the national total.

*GAP and Infrastructure*

Urban infrastructure works are an important component of spatial development in the GAP region. Examples of infrastructure development include rural water provision which rose from 57% to 67% and urban water provision which increased from 15% (low) to 57%. Village electrification also rose from 66% to 99% and main road connections rose from 71% to 98% of all villages.

*Social Aspects of GAP*

The GAP Social Action Plan was phased in to ensure people's participation to sustainable development. Recent surveys and studies include "Trends of Social Change", "Population Movements", "Status of Women and Their Integration to Process of Development", and "Problems of Resettlement and Employment of People from Areas to Remain Under Dam Lakes". One of the objectives of GAP-SAP has been to raise the status of local women. In cooperation with various governmental and non-governmental organisations and such international organisations (like UNICEF), multi-purpose community centers (ÇATOM) for women are being expanded further. At the end of 1999, there were 22 such ÇATOMs in the GAP region. Under the Social Action Plan, the resettlement programme for people affected by dam construction is taking place in a participatory way. In consultation with the communities to be displaced, the GAP Project has organised resettling the people concerned, selected sites for their resettlement, arranged investments for their employment, assisted in their adaptation to new settlements and helped them to be self-supporting.

*GAP, Environment and Culture*

The gradual implementation of 1.7 Mha of land and new dams and reservoirs will substantially change the water and land regime in the region. At the same time, population movements, rapid urbanisation and industrialisation will result in manor transformations of both urban and rural areas. Inherent environmental problems include: the negative consequences of irrigation; impact of climatic changes on the flora and fauna of the region; erosion and adverse effects of uncontrolled development on natural, historical and cultural properties.

*Gap and International Cooperation*

In 1997, the "Program for Sustainable Development in GAP" was launched in cooperation with the UNDP, to reduce socio-economic disparities in the GAP region. The program includes components on basic social services (education, health and housing), gender equity, urban management, environmental sustainability, institutional and social capacity building and grassroots participation. The GAP-RDA also has strong links with the World Bank, USDA, various US institutions, and links have been opened recently with Syria General Organisation for Land Development.

*Finance*

The GAP has a financial profile of about 32 billion US Dollars. Approximately 14 billion US Dollars spent by the end of 1999 has been largely raised from domestic resources. International interest in the project has resulted in support from countries including USA, Canada, Israel, France and some other European countries; international organisations including the World Bank; and some foreign funds and credit agencies. The GAP Administration has secured 2.9 million US Dollars worth of grant from some finance agencies to be used for the project. In addition, the EC will shortly implement a 43M€ project that will support: (i) development of small/medium enterprises, (ii) rural development and micro-credit, (iii) conservation of cultural heritage.

**Present situation**

The cash realisation rate of the GAP project is 44%. Analysed by sector, the rate of cash realisation is 75% for energy, 13% for irrigation projects and 55% for social projects. Thus the project has already created economic benefits to the region and the country.

*Water Resources Development Projects*

The Southeastern Anatolia Project (GAP) covers an area of 74,000 square kilometres of the lower parts of the Euphrates and Tigris catchments in Turkey, and the plains between them. The project consists of 13 sub-projects related to irrigation and energy production. Seven of these packages are in the Euphrates Basin and six in the Tigris Basin. Upon the completion of the project about 1.7 million hectares of land will be brought under irrigation, and the energy production capacity of the region will be 23 billion kWh after irrigation (27 billion kWh without irrigation).

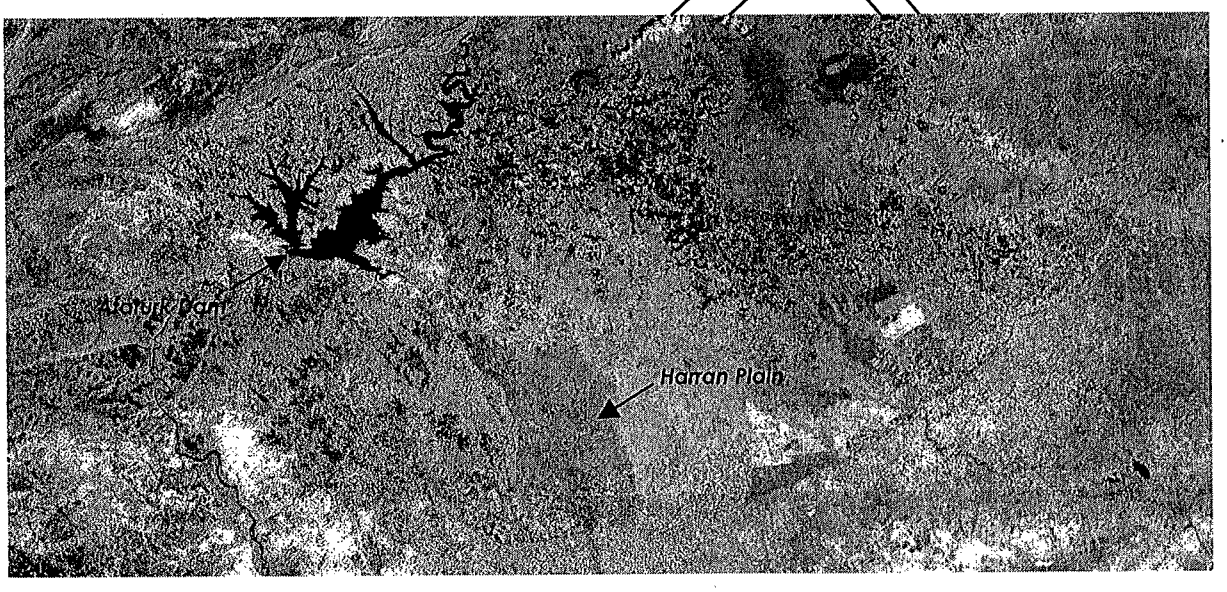


**Figure 2: Mosaic of 3 Landsat TM7 quick-look images on the western GAP region acquired on 24 July, 9 August and 1 September 1999 (Source: Landsat TM 7 database)**

# SOUTHEASTERN ANATOLIA PROJECT – GAP
## Water Resources Development Projects

| | Euphrates | Tigris | Combined |
|---|---|---|---|
| Irrigation Area | 1,091,203 ha | 601,824 ha | 1,693,027 ha |
| Capacity | 5,304 MW | 2,172 MW | 7,476 MW |
| Total Dams | 14 | 8 | 22 |
| Total HEPPs | 11 | 8 | 19 |

### *Euphrates River Projects*

| | Project | Irrigated Area (ha) | Present Capacity (MW) | Status |
|---|---|---|---|---|
| I | **Karakaya Dam Project** | | **1 800** | |
| | Kaya Dam & HEPP | | 1 800 | O |
| II | **Lower Euphrates Project** | **706 281** | **2 450** | |
| | Ataturk Dam & HEPP | | 2 400 | O |
| | Şanliurfa HEPP | | 50 | C |
| | Şanliurfa Irrig Tunnels | | | O+C |
| | ·Şanliurfa-Harran Irrig | 120 000 | | O |
| | · | 47 729 | | C |
| | ·Mardin-Ceylanpinar Grav Irr | 94 929 | | PR |
| | ·Mardin-Ceylanpinar Pump Irr | 118 264 | | PR |
| | ·Groundwater irrigation | 104 589 | | PR |
| | Siverek-Hilvan Pump Irr | 188 778 | | PS |
| | Bozova Pumped Irrigation | 47 368 | | PL |
| III | **Border Euphrates Project** | | **852** | |
| | Birecik Dam & HEPP | | 672 | C |
| | Karkamiş Dam & HEPP | | 180 | O |
| IV | **Suruç-Yaylak Project** | **146 500** | | |
| | Yaylak Plain Irrigation | 18 322 | | PR |
| | Suruç Plain Irrigation | 128 178 | | PR |
| V | **Adiyaman-Kahta Project** | **77 824** | **195** | |
| | Çamgazi Dam & Irrigation | 7 430 | | C |
| | Gömikan Dam & Irrigation | 6 868 | | MP |
| | Koçali Dam & HEPP | 21 605 | 40 | MP |
| | Sirimtaş Dam & HEPP | | 28 | MP |
| | Fatopaşa HEPP | | 22 | MP |
| | Büyükçay Dam, HEPP & Irrig | 12 322 | 30 | MP |
| | Irr pumped from Atatürk Resv | 29 599 | | PL+C |
| VI | **Adiyaman-Göksu-Araban** | **71 598** | **7** | |
| | Cataltepe Dam Irrigation | 71 598 | | PL |
| | Erkenk HEPP | | 7 | PL |
| VII | **Gaziantep Project** | **89 000** | | |
| | Hancağiz Dam & Irrigation | 7 330 | | O |
| | Kayacik Dam & Irrigation | 14 746 | | C |
| | Kemlin Dam & Irrigation | 1 969 | | PL |
| | Irrig pumped from Birecik | 53 030 | | PL |
| | Belkis-Nizip Pumped Irrigation | 11 925 | | C |
| | **INDIVIDUAL PROJECTS** | | | |
| | In Operation: | 60 440 | 14.4 | |
| | Planned: | 6 355 | | |
| | Nusaybin Irrigation | 7 500 | | O |
| | Çağ Çağ HEPP | | 14.4 | O |
| | Akçakale Groundwater | 15 000 | | O |
| | Ceylanpinar Irrigation | 27 000 | | O |
| | Hacihidir Project | 2 080 | | O |
| | Dumluca Project | 1 860 | | O |
| | Suruç Groundwater | 7 000 | | O |
| | Besni Dam & Irrigation | 2 820 | | P |
| | Ardil Dam & Irrigation | 3 535 | | P |

### *Tigris River Projects*

| | Project | Irrigated Area (ha) | Present Capacity (MW) | Status |
|---|---|---|---|---|
| VIII | **Tigris-Kralkizi Project** | **130 159** | **204** | |
| | Kralkizi Dam & HEPP | | 94 | O |
| | Tigris Dam & HEPP | | 110 | O |
| | Tigris Right Bank Irrig | 54 279 | | C+PR |
| | Tigris Right Bank Irrig | 75 880 | | C+PR |
| IX | **Batman Project** | **37 351** | **198** | |
| | Batman Dam & HEPP | 483 | 198 | O |
| | Batman Left Bank Irrig | 18 758 | | C |
| | Batman Right Bank Irrig | 18 593 | | C |
| X | **Batman-Silvan Project** | **257 000** | **240** | |
| | Silvan Dam & HEPP | | 150 | PS |
| | Kayser Dam & HEPP | | 90 | PS |
| | Tigris Left Bank Irrig | 200 000 | | PS |
| | Tigris Left Bank Irrig | 57 000 | | PS |
| XI | **Garzan Project** | **60 000** | **90** | |
| | Garzan Dam & HEPP | | 90 | PS |
| | Garzan Irrigation | 60 000 | | PS |
| XII | **Ilisu Project** | | **1 200** | |
| | Ilisu Dam & HEPP | 1 200 | | PR |
| XIII | **Cizre Project** | **121 000** | **240** | |
| | Cizre Dam & HEPP | | 240 | PR |
| | Nusaybin-Cizre-Idil Irrig | 89 000 | | PS |
| | Silopi Plain Irrigation | 32 000 | | PS |
| | **INDIVIDUAL PROJECTS** | | | |
| | In Operation: | 26 312 | | |
| | Planned | 3 575 | | |
| | Devegeçidi Project | 7 500 | | O |
| | Silvan | 8 790 | | O |
| | Nerdüs | 2 740 | | O |
| | Çinar-Göksu | 3 582 | | O |
| | Garzan-Kozluk | 3 700 | | O |
| | Çinar-Dilaver | 3 575 | | PL |

Note: Individual projects are not included in the grand total above.

**Status Codes:**

| | |
|---|---|
| C | Under Construction |
| MP | Master Plan |
| O | In Operation |
| P | Project |
| PL | Planned |
| PS | Preliminary Study |
| PR | In Program |

**Source:** General Directorate of State Hydraulic Works (DSI)

**Last revision:** June 2000

*Irrigation*

Irrigation on the Harran Plain started in 1995. The monetary value of full irrigation in the region is estimated as US$ 3 billion, the economic benefits of irrigation on 90,000 hectares of land in the Harran Plain had reached US$ 368.3 million by the end of 1998. The total land under irrigation had reached 201,080 ha by 1999.

*Hydropower*

Atatürk and Karakaya Dams generate a substantial part of the energy produced by interconnected system. The monetary value of the project is valued at US$ 9.6 billion. The hydroelectric energy produced by these dams from their phasing in up to end of 1999 reached 160.3 billion kWh.

*Project implementation and institutional aspects*

Covering 152,409 ha of land, the project area has already received many investment services but producing less than the desired level of expected improvement. In the investment activities undertaken to date, various General Directorates from different Ministries, participated under the coordination of GAP-RDA including the State Hydraulic Works (DSI), Rural Services, Agricultural Reform, Land Registry and Cadastre, and Ministry of Agriculture General Directorate of Organisation and Support.

Observed among the important factors that caused less-than desired and expected improvement in these investments, are the insufficient level of investments and the failure on the part of users to participate in the project and assume responsibility. From this point of view, certain institutional and implementation arrangements and policies are being established to ensure success of the project.

So far, the above-mentioned agencies (GAP-RDA, GDRS, DSI) have made and are still making a variety of investments within their field of mission. The total value of investments completed or needed in all fields is given in the respective sections of the report. However, it is observed that the investments already made have not brought the benefit expected and that, this was caused by inter-agency rivalry. An investment accomplished by an agency can be fully serviceable only if it is complemented by an investment of another agency. In the project area, it is difficult to encounter activities where all agencies have completed their investments. This is caused by the fact that agencies cannot complete their investments at the same time and suffer from delays in implementation due to the lack of coordination. As has been revealed by sociological assessments and interviews carried out within the framework of this project, farmers complain about the investments made, the operations and the inadequacy of utilities in the village communities and generally have very poor relationships with the concerned agencies.

It is understood that the disagreement between the institutions themselves and between the institutions and farmers cause poor effectiveness of investments. Since farmers' associations and the beneficiary village communities have not taken part in the projects since the very beginning, they remain uninformed of and therefore uninterested in what is being done and, consequently, they do not feel responsible for the maintenance of facilities.

According to GAP-RDA, these adversities must be alleviated and, to reap the benefits expected from the project, implementation arrangements must be established in order to render investments effective and ensure the users to assume responsibilities. For this to happen, the following basic principles are emphasised:

- Farmers, Water User Associations (WUAs) and the Village Communities must be urged to participate in the project, share the costs and assume responsibilities from the initial stages of works.
- Proper implementation arrangements should be set up to render investments effective and facilitate coordination among agencies as much as possible.

There are 15 Water Users' Associations (WUA) which may be considered as farmers' organisations in the project area. They are responsible for the irrigation of a total area of 96000 hectares, and are established to provide for operation and maintenance of the irrigation network. Annex 3 p. 39 provides information on existing Water Users Associations.

Given the current status of these associations, one may find it difficult to regard these as genuine farmers' organisations: farmers are not eligible to be elected directly to become members of the assembly or chairman; and the statute of the Association is formulated by the Ministry of Interior and may be amended only by the approval of the Provincial Governor. The fact that farmers are not adequately represented at the Association and that they are not entitled to amend the provisions of statute as they deem necessary constitutes two major barriers. In spite of this, irrigation associations are the best among existing organisations provided that certain conditions are fulfilled:

- Farmers should be entitled to elect the members of the assembly of the Association by making amendments to relevant laws.
- Associations should be able to establish their own operating rules and policies.
- Associations should be able to establish higher unions and sub-units at every village.

Toward mitigating the negative aspects, a "Draft Law on Water Users' Associations" has been prepared by State Hydraulic Works (DSI) taking into account the above mentioned aspects related to existing associations, and forwarded to relevant organisations and Ministries, inviting them to express their opinion. Further to the discussions held with DSI officials, it has been noted that opinions were received from other organisations and the draft law took its final form to be presented to the Ministry to be sent to the Council of Ministers. The draft so prepared envisages to solve the problems related to Water Users Associations and provides that Associations be subject to financial, legal and technical inspections to be carried out by the relevant ministry and by the board of inspectors to be established by Associations themselves. The law further provides that responsibility for the operation, maintenance and management of drinking-domestic and industrial water facilities in addition to irrigation water facilities may also be assumed by the Association.

### *2.3 Background for R&D projects definition*

While acknowledging the relative dynamism of irrigated agriculture in the GAP region, the mission as well as people and institutions visited identified a substantial potential for improving agricultural and water productivities. Such an improvement would require R&D activities focused on a better assessment of the present agricultural, technical, environmental and socio-economic conditions and impacts of irrigation in the region. This lead to the definition of 4 main R&D topics :

- The Şanlı Urfa – Harran irrigation scheme presently represents the major part of irrigation within the GAP region as well as a pilot case for the forthcoming irrigation projects. Besides acknowledgeable achievements expressed through the dynamism of agriculture and the management transfer to irrigation unions, a deviation from expectations can be observed on many aspects. There is a need for a first **Topic on Planning, Monitoring and Evaluation of Şanlı Urfa – Harran Irrigation Project.**

- Although the irrigated areas in the GAP region have become productive and are generating good farm incomes, there is still room for improvement in the management of irrigation and drainage facilities that can lead to higher values of water productivity and maximise the total number of beneficiaries from the large investments still being made. It is therefore proposed to introduce an R&D **Topic on Introducing Performance Oriented Management in GAP Irrigation Systems.**

- The recent extension of irrigated surfaces under the Şanlı Urfa – Harran irrigation scheme with overirrigation and without subsurface drainage has increased already existing waterlogging. Soil salinity and sodicity are sometimes mentioned due to the appearance of salt efflorescences on soil surface, but do not seem to be yet quantified. Moreover, farmers awareness of these reasons is poor if not absent. Outside the Harran Plain there are significant areas where groundwater is already being used for irrigation, and there are plans for intensifying groundwater use in favourable locations. Insufficient management of groundwater leads to competition and increased pumping cost, up to a point where it becomes uneconomical to grow many crops. This suggests developing action under a third R&D **Topic on Environmental Impact Assessment and Monitoring.**

- Eight years after the start of the project, an overall evaluation of the GAP socio-economic impact is necessary. What is needed in fact is a mid-term cost-benefit analysis, with a clear identification of all the costs and benefits and a clear accounting system of economic prices on which all stakeholders could agree. Furthermore and beside the overall feeling of a significant local development pace, the two most striking aspects of the Harran Plain which are the quasi monoculture of cotton and the sub-optimal use of water call for some investigation into the decision making process at the farm as well as the IU levels. This supports the proposal of developing an R&D **Topic on Assessing and monitoring the agro-socio-economic impact of irrigation projects.**

# 3. Identification of R&D projects

## *3.1 R&D Projects identified*

| R&D projects identified | | Implementing institutions |
|---|---|---|
| **Topic 1** | **Planning, monitoring and evaluating Şanlı Urfa – Harran irrigation project** | |
| Project 1.1 | Revisiting and acquiring technical and economical data on irrigated agriculture | GAP, DSI, IUs, GDRS, Ministry of Agriculture, private sector |
| Project 1.2 | Development of decision support tools | GAP MOM, GDRS, Ankara University, IUs |
| **Topic 2** | **Introducing Performance Oriented Management in GAP Irrigation Systems** | |
| Project 2.1 | Strengthening Participatory Operation of Irrigation Systems | GAP, especially GAP MOM project, DSİ, Irrigation Associations |
| Project 2.2 | Strengthening Maintenance by Irrigation Associations | GAP, GAP MOM, DSİ, IUs, Private Sector Service Providers |
| **Topic 3** | **Environmental Impact Assessment and Monitoring** | |
| Project 3.1 | Development of a sustainable salinity and waterlogging management system for Harran Plain | GAP, GDRS, Irrigation Unions |
| Project 3.2 | Sustainable management of groundwater | GAP, DSİ, GDRS, Irrigation Unions |
| **Topic 4** | **Assessing and monitoring the agro-socio-economic impact of irrigation projects** | |
| Project 4.1 | Evaluation of the socio-economic impact of irrigation | GAP-RDA with university |
| Project 4.2 | Land Tenure, Social Organisations and Farming | GAP-RDA with national and international socio-economists |

### *3.2 R&D Projects Enabling Conditions and Commonalties*

When evaluating R&D needs, the mission felt necessary to express several recommendations which, if they would be difficult to be implemented as R&D activities, deserve consideration as enabling conditions of the proposed R&D projects, or commonalties which most if not all project should include.

***Enabling Conditions***

Considering the recently conducted revision of the GAP Master Plan which covered all the subject of the regional development, the mission recognised the need to implement a process of **shared diagnosis of the GAP project** focused on irrigation and drainage. The objective of this diagnosis would be to reach a common vision of all the stakeholders of regional agriculture (especially the Harran Plain) that would constitute the basis for a possible redefinition of (some of) the priorities, objectives, methods of the project. At present, indicators collected or estimated by the mission (see Annex 2 p. 38) show an important variability depending on the agency or irrigation union providing the information. One of the possible questions within this approach would be : 'If the Şanlı Urfa – Harran irrigation scheme was built today, would the same technical choices be made ?'.

Such a process should avoid to directly question institutions or individuals, but should rather achieve a shared analysis of the realities of the regional agriculture and of its development, and a shared assessment of its present needs hence on the actions to implement to support this development. After 10 years of implementation, it is normal to question the relevance of objectives, means and methods of the project from a detailed analysis of the regional agriculture and of its environment, which seems to be missing. From this point of view, the slow down of the development process due to the national economic crisis is an opportunity that could be used to redefine given aspects of the project.

The mission recommends that this process be implemented by a task force composed by representatives of the various stakeholders : GAP-RDA, DSI, GDRS, Ministry of Agriculture, Irrigation Unions, Agro-business, Local authorities, ... A methodological support from international expertise might be useful. This diagnosis would be from field surveys and available data from the participating institutions. It should focus on giving a functional description of the present situation, and cover all the aspects (technical, economic and social) of the agricultural activity. It would then be validated and endorsed by all stakeholders through adapted workshops. At the term of this process, possible adaptations of the project would be envisaged.

***Project Commonalties***

Results of different research conducted since the project implementation, especially those on the topic of agricultural water management, have hardly been extended and *a fortiori* adopted by users, i.e. extensionists and farmers, except in a limited number of cases such as those concerned by the GAP-MOM (Management, Operation & Maintenance). The regional Department of Agriculture in charge of extension to farmers has declared itself to make innovation and references reach farmers, due to a strong lack of financial and human means. As proved by other R&D projects all around the world, the involvement of users in R&D projects will enable the further availability of research results and their use by beneficiaries.

The mission therefore recommends to involve users in the definition of R&D projects from early stages and to associate them to the projects themselves.

The private sector has appeared to be dynamic and willing to participate in the development of the region. Overall good results of regional agriculture supports a market for private equipment and service providers. The mission recommends that R&D project evaluate the potential to increase the role of private actors. This evaluation could be initiated at the project formulation stage, which could eventually lead to their involvement in some projects.

### *3.3 R&D project descriptions*

#### *Topic 1 Planning, monitoring and evaluating Şanlı Urfa – Harran irrigation project*

The Southeast Anatolia Project is a very ambitious development project. Judging by its geographic area, the economic, social and environmental challenges at stake, the number and diversity of the planned actions, the variety of institutions and stakeholders and the progress envisaged, it is probably Turkey's, and one of the world's, most ambitious projects.

The hydroagricultural development of Harran Plain, and the overall development that it has brought, are a core aspect of this vast undertaking. Harran Plain constitutes both a project show and a test zone for the entire GAP project, involving the largest investments and the most advanced achievements.

It already accounts for many positive results:

- the 100,000 ha hydroagricultural project is operating
- land is being farmed and the agricultural impetus is obvious
- Irrigation Unions are already in place and operate and maintain secondary and tertiary hydraulic works
- the Sanli Urfa region's economy is being boosted by the agricultural development

But many discrepancies between the original plans and the present situation jeopardise the sustainability of the development, among which are soil salinity, wasteful irrigation practices, short term horizons for IU asset management, almost no extension of research results, insufficient technical assistance and farmer training, or farmer involvement in project design and implementation.

Two R&D projects can be derived from these observations :

1. Revisiting and acquiring technical and economic data on irrigated agriculture
2. Development of decision support tools

#### Project 1.1 Revisiting and acquiring technical and economical data on irrigated agriculture

*Rationale*

This project aims are to revisit and acquire a whole series of technical and economic data needed to improve irrigation management, particularly in two fields : (i) Water supply and demand, (ii) Water price and irrigation sustainability.

As to the first one, it seems that the project institutions as well as the irrigators have insufficient reliable data on water supply and water demand. There is a case for assessing the existing water resources, both in terms of quantity and quality, for the entire Harran Plain and for each of the schemes and sub-schemes. For major infrastructure, DSI data should be collected and checked, and a new measurement program will have to be undertaken for the downstream works, covering both the volumes and water quality (salt content). At the same time, all IUs' current water demand should be checked. As on the MOM Project, a GIS system for monitoring water consumption should be set up (cf. Project 1.2).

As to the project's second R&D field of interest, it seems that the present low water price and the lack of up-to-date data on irrigation results do not give clear indications for project management and farmer decision making. In order to obtain the real cost of irrigation water, a number of 'reference farms' (covering a range of different situations in land tenure, machinery, cropping pattern,...) should be monitored for a few seasons, and the profitability of irrigation computed accordingly. Cotton occupies 90% of the irrigated land and will of course stand at the centre of this project, but other crops should not be overlooked (wheat, egg plant, pepper, tomatoes, etc.).

*Objectives*

This project will have the following general objectives:

- Provide all the institutional actors involved in the management of the irrigated irrigation areas with reliable data on the water supply in the various schemes and subschemes, and its changes occurring throughout the year.
- To provide these same actors with accurate data on water demand for each irrigated area, and its changes during the irrigation season.
- Make reliable economic data on the real cost of water for each Irrigation Union available to all the partners involved in order to ensure price transparency.
- Provide the farmers with the technical and economic references on the break-even points for irrigation according to the types of crops and production systems. This will help them in their choice of crops, irrigation methods and materials.

The final aim is to arrive at more rational technical and economic management of the irrigated areas and better use of water by farmers.

*Methodology*

- <u>Quantitative and qualitative data acquisition for water supply and demand</u>
  On the main scheme, checking the DSI-supplied flow data and any supplementary measurements, in particular on the secondary and distribution schemes. Monitoring of these measurements over an entire irrigation season.
  Samples and analyses of the quality of water (in particular of the salt content) at various points on the network and changes occurring during the irrigation season.
  Supplied discharge quantities will have to be measured daily and undoubtedly at various times of the day and the night.
  Samples and qualitative analyses will have to be performed less frequently, around once a month, during the irrigation season.
  An evaluation of the demand for water will be made at the scale of each Irrigation Union. We will seek to forecast the demand for water and its fluctuations on each area using a system of computer monitoring (GIS) set up in each Irrigation Union.

- Reference acquisition on the price of water and the economic viability of irrigation
  This consists in acquiring economic references on the real price of water on the one hand, and on the economic viability of irrigation on the other.
  The real price of water will have to be calculated for each irrigated area (Irrigation Union) and include the equipment renewal, operation and maintenance charges.
  The break-even point for irrigation will be assessed for the farms. With this in mind, a network of a score of references farms will be set up representing various land tenure situations, types of equipment and irrigation on which technical and economic recordings "in actual situations" will be carried out during at least one irrigation season. The break-even point of irrigation based on the situation and the type of crops will be calculated for these reference farms. Obviously we will concentrate on cotton, but we will also work on the crops which constitute potential economic alternatives to cotton.

*Expected outputs*

- Achieve more rational technical and economic management of the irrigated areas thanks to better knowledge and the better monitoring of supply and demand for water in each Irrigation Union.
- Sustainable management of hydraulic installations thanks to improved knowledge of the real price of water for the Irrigation Unions.
- More economically viable use of water by farmers by advising them in their choice of crops, equipment and methods of irrigation thanks to the technical and economic references acquired on the reference farms.

*Implementing agency*

For the first aspect: GAP, DSI, Irrigation Unions
For the second aspect: GAP, GDRS, Ministry of Agriculture, private sector

*Potential donors*

EU (Euromed Water Action Plan)



**Project 1.2 Development of decision support tools**

*Rationale*

The sustainability of hydro-agricultural installations depends directly on the rigour and the quality of their management and the maintenance of the collective infrastructures. However, the management of these installations is a complex task because it has to satisfy three different and sometimes opposing rationales: a hydraulic rationale, a financial rationale and an agricultural production rationale. We note that the Irrigation Unions responsible for hydro-agricultural management do not have the tools for ensuring sustainable management which associates technical efficiency (hydraulic rationale), financial equilibrium (financial rationale) and efficient agricultural production (agricultural rationale).

In this project we propose to develop a computer-based information system for irrigated area management (Irrigation Management System – IMS). This tool will provide assistance to financial and hydraulic management of the scheme, and constitute a background for discussion and dialogue between farmers and the persons in charge of the area (in the Irrigation Union).

*Objectives*

The aim of this project is to fine tune and make available to the Irrigation Unions an instrument for controlling and managing the irrigated areas, the IMS.

This instrument will rely on a system for information processing and representation of the operation of the irrigated area. It will bring information transparency and will allow the technical and financial impacts of various irrigation season scenarios to be evaluated.

Thanks to this tool, the Irrigation Unions should be able to discuss and negotiate the decisions to be taken for sustainable management of the installations, the allocation of water resources, and the pricing of water with the farmers.

In addition to assistance to technical and financial management of irrigated areas, it is a tool to be used for concertation and negotiation between the persons in charge of the Irrigation Unions and the farmers.

*Methodology*

The operation of a hydro-agricultural scheme depends on the combination of three different rationales:

- Hydraulic rationale, determined by the activities related to the harnessing of the water resource, the operation of the networks and the maintenance of the infrastructures,
- Financial rationale, determined by budgetary and accounting constraints,
- Agricultural rationale, determined by the crop systems applied by the farmers.

There is often conflict between these three rationales. The viability of the irrigated areas depends on solving these conflicts and the capacity to negotiate with the participants who implement them.

In this complex system of operation, the development of a management-assistance instrument requires:

- the acquisition of the data necessary for rational management of the scheme (the data collected as part of project 1.1 will be extremely useful in this case).
- design of a data processing system for irrigated area management (IMS).
- thanks to the IMS, development of scenarios for operation of the irrigated area to allow the manager (IU) to discuss and negotiate the decisions to be taken concerning the scheme management, the pricing of water, the supply (water tower), the crop patterns and the estimated crop calendar, with the farmers.

Research facilities (University of Ankara, GDRS) will be involved in the development of this tool.

*Expected outputs*

- Improvement of the quality of the service to farmers thanks to better forecasting of the demand for crop water.
- Improvement of irrigated area operation thanks to the possibility of evaluating the technical and financial impacts of the various irrigation season scenarios.
- Improvement of irrigated area management thanks to the dialogue between farmers and persons in charge for Irrigation Unions regarding the decisions to be taken.

*Implementing agency*

GAP MOM, GDRS, Ankara University, Irrigation Unions.

*Potential donors*

EU (MEDA GAP component on rural development), France (FASEP)

## *Topic 2 Introducing Performance Oriented Management in GAP Irrigation Systems*

The key to effective irrigation and drainage is a transparent and participatory process of water allocation and distribution whereby water users can be assured a guaranteed supply of irrigation and adequate drainage. Although the irrigated areas in the GAP region have become productive and are generating good farm incomes, there is still room for improvement in the management of irrigation and drainage facilities that can lead to higher values of water productivity and maximise the total number of beneficiaries from the large investments still being made.

### Project 2.1 Strengthening Participatory Operation of Irrigation Systems

*Rationale*

Current water management practices at secondary and tertiary level remain below optimal levels. Because water distribution is inequitable, farmers express frustration over unpredictable water deliveries and water is used less efficiently and less productively than anticipated.

These overall concerns reflect a need to improve both on technical elements of water allocation and distribution techniques and on the involvement of all concerned parties in the development of mutually acceptable and verifiable operational plans. The overriding priority is to transform water management at all levels of the system into a transparent process where water deliveries become secure, more predictable and more reliable.

Identified constraints within GAP irrigation systems in the Harran Plain include:

- water delivery scheduling is around calculated requirements that no longer reflect current cropping patterns and did not involve participation of water users so that they do not have a sense of ownership of the process of water allocation and distribution;
- the level of service conditions at the interface between DSI and IAs are not clearly defined so there are disagreements over how much water has been delivered, and no effective mechanisms exist for trying to make water deliveries to IAs more reliable;
- variable discharges at the head of IA areas makes it hard to develop and implement proper level of service agreements between an IA and its constituent members;
- those responsible for operation of the irrigation system do not have effective decision-support tools to help them evaluate current levels of performance;
- there is a lack of an effective monitoring and evaluation process for comparing levels of performance between different IA areas that can be used to assist them in upgrading their performance.

The project, in collaboration with current GAP MOM efforts, aims to introduce a set of institutional and technical innovations that will result in more secure water supplies. Once water users have confidence that they will receive sufficient water on a timely basis then the foundation for more precise water application and utilisation will be present, and significant improvements in water productivity can be obtained at both farm and system level.

*Objectives*

This project will have the following overall objectives:

- to develop and implement a mutually acceptable and verifiable level of service agreement between DSI and each IA at the points of transfer of water from the main canals to secondary canals that will result in more stable water deliveries to each IA area;
- to develop and implement a plan of water deliveries agreed between the IA officers and water users that includes information on start and finish of the irrigation season, target water levels and discharges at the head of each secondary and sub-secondary canal, and mechanisms for coping with inevitable deviations from the plan, so that water deliveries to each secondary and tertiary canal will be more secure;
- to undertake a detailed analysis of the actual operational costs for IAs, including those where there are pumping costs to develop low-head pressurised irrigation, so that new IAs will have a clear understanding of likely irrigation fees before irrigation commences for the first time
- to improve current levels of monitoring of water deliveries and combine this with information on locations of over-irrigation, water shortage and water conditions in drainage canals to be used in a GIS-based MIS system such as NAGA to monitor daily, weekly and monthly water deliveries to each sub-section of IA areas and produce within-season performance reports that identify where deviations from the plan have occurred;
- to develop and implement a benchmarking activity that allows system managers to evaluate their water delivery performance at the end of each season using the IPTRID/IWMI Benchmarking methodology which will permit comparative assessment between IA areas, and between GAP and other irrigation projects;

*Methodology*

The project would have the following components:

- an assessment of current water distribution practices and an assessment of actual water distribution patterns in relation to current crop water requirements;
- formulation of a series of workshops and discussion meetings among water users at different levels to develop level of service agreements that specify the water delivery conditions at each point of handover where responsibility for water management changes;
- review of existing irrigation fees among established IAs and estimation of real costs to irrigators of installation of low-head pressurised systems so that real irrigation costs can be determined ;
- participatory development of modified water delivery plans within each IA that enable water users and water management to discuss their needs and constraints and come up with mutually agreed water distribution plans that include specific water delivery targets;
- training of water managers in the use of data management and monitoring software that allows then to quickly assess current levels of water distribution performance and compare these results with targeted conditions;
- involvement of IA and system level managers in the IPTRID/IWMI Benchmarking project that allows performance in any given system to be tracked seasonally and annually, and allows for comparison of performance between similar systems.

*Expected Outputs*

- Higher levels of irrigation performance and greater water productivity within irrigated areas of the GAP

- Greater clarity and transparency over water allocation and distribution between DSİ and Irrigation Associations, and between IAs and their constituent water users.
- Established performance-oriented monitoring techniques that permit year-to-year assessment of accomplishments of each IA
- Established IPTRID benchmarking procedures that permit comparison of performance between different IAs and with other systems in Turkey and elsewhere.

*Implementing agency*

GAP, especially GAP MOM project, DSİ, Irrigation Associations

*Potential donors*

EU (MEDA GAP component on rural development), UNDP (Project 10)

### Project 2.2 Strengthening Maintenance by Irrigation Associations

*Rationale*

In many locations around the world, systems that have experienced management transfer are struggling with the issue of how to maintain their water delivery infrastructure and other assets on a sustainable.

Two main concerns have been identified:

- the lack of effective management support tools for understanding the likely replacement cycle for different types of physical asset, and implementing proper management procedures for asset maintenance;
- the lack of clarity over who will has to contribute what resources so that assets can be maintained, replaced or modernised when necessary.

All assets of irrigation systems have finite life lengths, which varies depending on the nature of the asset and on the amount of maintenance and repairs that managers are willing to expend on a recurrent basis.

Asset management requires a full inventory of what capital infrastructure an IA has, or inherited from another agency at the time of turnover, an assessment of the condition of each item in terms of its current functionality, and an assessment of the replacement time and value in order that a multi-year investment strategy can be developed.

Few IA officials have been given the skills and tools to undertake these tasks in a systematic manner, and almost none have any plans developed for dealing with the daily wear and tear of their basic facilities. In systems in the GAP much of the basic infrastructure was in good condition at the time of transfer, but even now there is evidence of neglected maintenance: control gates are broken, canalets damaged and leaking, underground pressure systems requiring new valves and hydrants, drains becoming filled with weeds. To date these costs have been postponed because the infrastructure still functions, but it will not be long before significant repair and replacement costs will be required.

There is also little serious discussion of who has to pay for repairs and replacement. To date most fees collection has been at levels that only pay for routine operations, staff, and minor maintenance and repairs. There would have to be significant increases in fees if replacement

of all capital assets were required to be paid by IAs (see Annex 3 p.39 describing the main features of IAs in Harran Plain).

A serious issue is the extent to which the current IAs can really be expected to transform themselves into viable commercial enterprises that can operate according to business principles. In other countries IAs limit themselves to the task of water allocation and distribution, leaving the more complex issues of asset management to more commercial organisations. In either scenario the transformation is a long-term process, and one that needs to be initiated within the GAP systems quickly in order that existing infrastructure does not deteriorate and jeopardise productivity of the systems.

*Objectives*

The main objectives of this project are:

- to develop and implement a program of asset management that enables IAs to know what infrastructure they currently have responsibility for, assess the current and expected functionality of each asset, and develop a schedule of likely replacement costs so that assets can be maintained in sufficient condition to continue to enable managers to meet their operational objectives;
- to determine the actual cost stream that will be required to replace assets when they reach the end of their useful life, determine what this translates into in terms of a routine irrigation and drainage service fee, and implement a business plan that will enable IAs to generate capital, reinvest in infrastructure when needed, and allow for possible modernisation;
- to determine the extent to which IAs in their current form can effectively be transformed so that they can change their orientation from one that focuses largely on water allocation and distribution to running as a business enterprise capable of dealing with assets management, capitalisation and reinvestment, or whether some alternative approach to the whole issue of asset management is required.

Depending on the nature of conditions faced in GAP, and taking into account the views of water users, it may be necessary to develop separate groups to deal with the management and maintenance of drainage control infrastructure.

*Methodology*

The initial stage of the project should be an assessment of the needs of GAP irrigation systems for a structured approach to asset management. This should include a review of whether IA groups in their current form will be able to transform themselves into businesses capable of proper asset management. In a few locations in other countries such asset management programs have been initiated, and exchange of views and experience would be valuable for IA officers and policy makers in the GAP region. This stage would finish with a policy workshop to determine realistic approaches to asset management, recapitalization and system improvements. Included in the decisions would be the nature of the financing of such organisations, their responsibilities and commitments, and their relationship to GAP, other government agencies and water users.

Depending on the outcome of the first stage, a set of capacity building programs will be initiated that train up the people identified as the potential officers of the new asset management agency. This might be the IA officers but could equally well be an independent commercial group as has been adopted in a number of other countries.

A third stage, but probable as a follow-on project due to the time frame involved, would be the pilot testing of asset management companies, and a subsequent review of their commercial and technical viability.

*Expected outputs*

- Specific maintenance plans for each IA based on a thorough inventory of all assets, their current functionality, and expected life length.
- Determination of full costs of system upkeep costed over a multi-year period to cover replacement or modernisation of all assets.
  - Development of appropriate institutional arrangements that allow management of assets on a commercial basis, either by IA groups themselves or, more likely, by involvement of private sector service providers.

*Implementing Agency*
GAP, GAP MOM, DSİ, Irrigation Associations, Private Sector Service Providers

*Potential donors*
EU (MEDA GAP component on SME's), UNDP (Projects 10 and 14)

***Topic 3 Environmental Impact Assessment and Monitoring***

**Project 3.1 Development of a sustainable salinity and waterlogging management system for Harran Plain**

*Rationale*
The Harran Plain is a semi-closed basin with a very limited flow of drainage water towards Syria at its southern limit. Furthermore, the railway dike following the Syrian border constitutes an artificial barrier to groundwater flow towards the south. Therefore waterlogging associated with some soil salinisation seems to have existed in the lower parts of the plain since irrigation started in the area in the 70's. The recent extension of irrigated surfaces under the Şanli Urfa – Harran irrigation scheme without subsurface drainage has increased waterlogging which is now not only limited to southern irrigation districts but is mentioned as a constraint for farmers in other districts located in the central part of the plain (Çabirensar, Bereket). Soil salinity is sometimes mentioned due to the appearance of salt efflorescences on soil surface, as well as soil sodicity, but do not seem to be yet quantified.

According to the system design, a network of open drains converge towards the southern part of the plain, and due to its low level, drainage water then needs to be pumped in a main drain which conveys a limited flow across the Syrian border. Very recently GDRS has been implementing subsurface drainage on 2 pilot areas of a total of 6650 ha, and gypsum has been applied locally on 500 ha to 'reduce soil sodicity'. Local variations of soil permeability support the hypothesis of local sodicity though unquantified.

Overirrigation and the lack of subsurface drainage are recognised by technical agencies as the causes for waterlogging, but farmers' awareness of these reasons is poor if not absent, as well as a quantified evaluation of salinity/sodicity extent and intensity.

*Objectives*

- Analyse the basin-wide waterlogging mechanisms and salinity / sodicity budgets in Harran Plain
- Develop a sustainable salinity management system for Harran Plain

*Methodology*

- Inventory of existing data related to waterlogging (DSI piezometric network, existing tubewells) and salinity/sodicity (Çukurova Univ. ?).
- Use of historical remote sensing data to evaluate the recent evolution of the extent of waterlogging.
- Adaptation and implementation of a basin-wide salt budget model and integration of the model in a management support system to be used by the most relevant technical agency in close relation with irrigation unions.

*Expected outputs*

- Better understanding of waterlogging and salinity repartition and evolution in the plain.
- Increase awareness of technical agencies on the necessity of subsurface drainage and salt monitoring.
- Reduction of overirrigation by increased farmers' awareness of its negative impact on the crop yields and soil fertility.

*Implementing agency*

GAP, GDRS, Irrigation Unions.
Investigate possibility of relaunching tripartite agreement through drainage/salinity collaborative investigations : in the present case, possible Syria – Turkey collaboration.

*Potential donors*

France (FASEP), EU (Euromed Water Action Plan)

### Project 3.2 Sustainable management of groundwater

*Rationale*

Outside the Harran Plain there are significant areas where groundwater is already being used for irrigation, and there are plans for intensifying groundwater use in favourable locations. However, in both locations visited in this mission (Nurdağ in the west of the GAP region and Ikicircip near Ceylanpinar) established irrigation associations reported significant drops in the groundwater table that not only increased there pumping costs but in some cases had led to wells drying up or experiencing greatly reduced discharges.

In neither location was there any evidence of proper management of the groundwater resource. While it was reported that DSİ does monitor groundwater, the information was not available to Irrigation Cooperatives or Irrigation Associations, and therefore there was no opportunity for them to plan pumping against information on actual depth to groundwater prior to each irrigation season.

In both locations the formal irrigation groups complained that part of the problem was that in areas adjacent to their systems there had been uncontrolled groundwater development by

private farmers. Legally no well can be drilled without a permit from DSİ, but in practice many wells are drilled first, and a permit sought after the well in functioning. As a result there is no formal census of the number of wells, their capacities or locations, nor of the depth to watertable before and after well installation.

Although groundwater resources along the Syrian border are reported to be very large (possibly 10% of all Turkey's exploitable groundwater resources) it may be that overexploitation will lead to a drop in accessible groundwater to the point where it becomes uneconomical to grow many crops. Farmers would need to grow only very high value crops if groundwater is more than 100 m, a depth reported as being quite common in both areas visited.

The mission team therefore feels there is a need for a project that addresses the sustainability and economics of groundwater exploitation for irrigation.

*Objectives*

- Undertake a review of existing information of groundwater resources, changes in depth to groundwater since the establishment of irrigation groups and the more recent expansion of the irrigation sector, and re-evaluation of likely sustainable levels of groundwater exploitation in each hydrogeological zone, as well as exploration of the potential for artificial groundwater recharge.
- Undertake a detailed evaluation of actual pumping costs for groundwater-based irrigation groups so that cropping patterns can be matched to the economic conditions faced by water users.
- Develop management strategies for groundwater-based irrigation groups that allows them full access to data to groundwater levels, develops community-wide rules for pumping rates in relation to recorded groundwater depths, and enables groundwater to be kept at depths which are both sustainable and economic.

*Methodology*

- Inventory of existing data related to hydrogeological conditions in each sub-basin of the GAP region (DSI groundwater division and other groundwater studies) plus sample field surveys of the extent of private groundwater development (some of this can be done through remote sensing to determine irrigated area and cropping patterns outside canal irrigated areas and can involve universities).
- Detailed survey of energy cost of pumping per hectare and per volume, and of likely replacement costs for wells, pumps and motors, to develop knowledge of real costs of groundwater irrigation (by GAP or GDRS).
- Implementation of pilot activities for community based monitoring of groundwater depths and pumping strategies, both in smaller semi-closed basins and in the open areas along the Syrian border (by GAP, DSİ).

*Expected outputs*

- Model practices for sustainable groundwater management that involves both government agencies and water user groups, including artificial recharge in adequate areas.
- Increased awareness of technical agencies on the need for measurement of data of groundwater conditions, and dissemination of this information to water users.
- Improved information to water users on suitable management strategies of groundwater, and on cropping pattern alternatives best suited to high cost irrigation practices.

*Implementing agency*
GAP, DSİ, GDRS, Irrigation Unions.

*Potential donors*
EU (MEDA GAP component on rural development), France (FASEP)

### *Topic 4 Assessing and monitoring the agro-socio-economic impact of irrigation projects*

Under this topic, two projects have been identified, both located in, and solely concerning, the Sanli Urfa – Harran plain.

### Project 4.1 Evaluation of the socio-economic impact of irrigation

*Rationale*
Eight years after the start of the project, an overall evaluation of the GAP socio-economic impact is necessary. Not only to compare the results with the original design, adjust expectations and objectives, and eventually help to define another phase, but also to try to measure its overall impact on different levels of the economy (national, regional, farm,...) and for different stakeholders (state, DSI, GDRS, GAP, WUAs, farmers, private sector,...).

Judging by the present project 'go-slow', or – to put it less bluntly – declining dynamism, it seems that the different stakeholders have a different interpretation of what has happened so far and a different opinion of their respective roles and responsibilities. In such cases, an external audit bringing up fresh, transparent, and 'objective' data usually gives good results.

What is needed in fact is a mid-project cost-benefit analysis, with a clear identification of all the costs and benefits, a clear way of taking into account secondary and induced costs and benefits (e.g. non traded), and a clear accounting system of economic (shadow) prices.

The major outcome of such an approach will be an answer to these important questions for the future of the project : what are the real overall costs of the project and how have they been so far paid for ? What are the overall costs of irrigation water and how have they been so far paid for ? Can these costs be lowered, how could they be met in the future, and who is going to pay what share ?

*Objectives*

- Provide an 'objective' and transparent mid-term project evaluation
- Point out the inter-sector transfers that were / are being achieved
- Propose a detailed overall cost of irrigation
- Suggest a phased progression toward pricing irrigation water at its 'sustainability cost'

*Methodology*
The methodology will be that of an international standard cost-benefit analysis, collecting past and present data with the help of all the stakeholders : state, GAP, DSI, GDRS, farmers, private sector,... These will be involved through a number of consultation meetings called for at the decisive steps of the analysis : initial presentation, financial analysis results, economic analysis results, final restitution.

*Expected outputs*

- A thorough mid-term project evaluation including a comparison between the initial objectives and the achieved results in terms of costs and benefits.
- A detailed analysis of the distribution of all past costs and benefits between the project stakeholders.
- A revised cost-benefit analysis for the next 20 or 25 years, also indicating a proposed (and agreed) distribution of future costs and benefits between stakeholders

*Implementing agency*

GAP-RDA assisted by University partners, and involving at various crucial stages all the stakeholders listed above (state, GAP, DSİ, GDRS, Irrigation Unions, etc).

*Potential donors*

EU (MEDA GAP component on rural development, Euromed Water Action Plan)

## Project 4.2 Land Tenure, Social Organisations and Farming

*Rationale*

Beside the overall feeling of a significant local development pace, the two most striking aspects of a field visit in the Harran Plain are the quasi monoculture of cotton and the sub-optimal use of water : excess water here (erosion, salinity), lack of water there (as per farmers).

In all irrigation projects, farmers are expected to behave in an optimal way both in applying irrigation water and selecting their cropping pattern. However, in the Harran Plain as in most irrigation projects, farmers lack training both individually (as decision makers on their own farm) and collectively (as members of Irrigation Unions). But these complaints usually hide a more profound factor which could be called the "sociological infrastructure" at work : the rational management brought about in an irrigation project often proves to be just a thin layer of modernity over a thick coat of social habits and values on which decisions are made and empowerment is based.

*Objectives*

- Provide an overall picture of the agricultural population of the Harran plain , a detailed analysis of land tenure and land farming and a typology of the various production systems at work.
- Realise a comparative performance analysis of the 23 Irrigation Unions and recommend capacity building actions for farmers and Irrigation Unions.

*Methodology*

The methodology used will be a combination of :

- documentation (project documents, existing studies,...)
- field surveys (representative samples, in-depth interviews,...)
- sociological and legal expertise (for land tenure)
- and frequent consultation (at the crucial stages of the R&D project)

*Expected outputs*

- An overall picture of the agricultural population.
- A detailed analysis of land tenure and land farming.
- A typology of the various production systems at work.
- A comparative performance analysis of the 23 irrigation unions.
- Capacity building recommendations for farmers and irrigation unions.

*Implementing agency*

GAP-RDA closely working with national and international sociologists and socio-economists.

*Potential donors*

EU (MEDA GAP component on rural development )

# 4. Contacts with donors

## *4.1 French Embassy – Economic, Trade and Finance Commission*

Since 1998, there is no more economic cooperation protocol between Turkey and France : therefore no funding can be expected from it. However, applied R&D actions and projects would be funded under the mechanism called FASEP, which is presently used to co-finance the project n°26 of the GAP UNDP Sustainable Development Programme on « Reuse of municipal waste water in small communities ». Requirements of this mechanism are that the project be focused on studies in a cooperative framework involving GAP, local institutions and French institutions and private companies.

## *4.2 European Union*

European funding seems to be the most appropriate for most of the proposed priorities. They can be classified in two categories :

- the MEDA GAP Regional Development Program
- the Euromediterranean Water Action Plan

***The MEDA GAP Regional Development Program***

Following the Helsinki Summit of 2000, the EU has been considering a grant of € 550 Million for Turkey under the MEDA Programme. More recently, the MED Committee met on 14 November 2001 in Brussels. They gave a favourable opinion on six national MEDA Annual Financing Plans for a total of € 476 million including Turkey at a level of € 167 million. The MEDA Annual Financing Plan 2001 for Turkey now comprises 14 projects covering fields as diverse as Regional Development, Promoting SMEs, and Judicial and Administrative Reform. The GAP Regional Development Programme would be support at the level € 45 million and consists of 3 components :

- Promotion of SME's, Small and Medium Enterprises (GAP-GIDEM), whose terms of reference are being finalised by UNDP (€ 6 million) ;
- Rural Development and Micro-Credit, a component to be operated with GAP by TKV (Development Foundation of Turkey), a Turkish important NGO (30000 employees) who is presently preparing the terms of reference of this component (€ 25 million) ;
- Protection and promotion of cultural heritage.

The mission recommends that the 2 first components be further explored by GAP for possible integration of R&D components. This particularly concerns project 2.2 (under component 1 on SME's) and projects 1.2, 2.1, 3.2, 4.1 and 4.2 (under component 2 on rural development). It would be appropriate for GAP to approach TKV as soon as possible to discuss the possibilities of including R&D projects on irrigation and drainage which require a strong involvement of farmers through Irrigation Unions.

***The Euromediterranean Water Action Plan***

The Euro-Mediterranean Action Plan decided by the Ministerial Conference of Turin, October 1999 on Local Water Management includes 6 priorities, namely: (1) integrated management of services in domestic water distribution and wastewater treatment; (2) local management of

water resources and demand at river basins and islands scale; (3) drought mitigation and resource management under water scarcity conditions; (4) water management for irrigation; (5) use of non conventional water resources; and (6) preparation of national and local scenarios for 2025. The following actions are proposed to implement the above priorities: (i) institutional strengthening and capacity building; (ii) information and knowledge exchange; (iii) know-how and technology transfer; and (iv) sensibilisation of the public.

This Action Plan is expected to be supported by the European Community in the order of ε 30 million, which would be split as follows: ε 3 million for the implementation of national water focal points in the South and East Mediterranean countries; ε 3 million for support actions and accompanying measures; ε 3 million for each of the 6 priorities; and ε 3 million for each of the 2 priorities in which there will be an important number of good proposals. Proposals should involve at least 3 countries and include at least 1 country from the EU, and the funds will be administered by (one of) the EU partners of the consortium. Plans are to select around 20 proposals and to fund them at a level of ε 1 to 3 million.

In June 2000, the European Commission (EC) proposed to set up a Euromediterranean Water Forum including EC, Water Directors from Euromediterranean countries, the European Investment Bank, the World Bank, and some NGOs as observers. This Forum was to prepare a call for proposals based on the Action Plan issued in Turin, with a calendar planning the funding and start-up of projects by the end of 2001. Important delays in setting up this Forum has not yet made possible the release of the call for proposals. However evolution of this Action Plan should be carefully monitored as a possible support for the priorities proposed by the mission.

### *4.3 UNDP*

Although it has not been possible to meet with UNDP officers at the end of the mission, the documents made available to the mission show the possibility of including R&D components within the following projects of the GAP – UNDP Sustainable Development Programme, which are detailed in Annex 4, p. 40:

- GAP-UNDP Project 4 : Establishment of GAP Regional Research and Development Center
- GAP-UNDP Project 10 : Pilot Implementation for Organizational Development and Training Farmers in GAP
- GAP-UNDP Project 11 : Agricultural Research and Development Project (2nd Phase)
- GAP-UNDP Project 14 : Establishment Farm to Integration Crop Management Service and Training in Harran Plain

## 5. Conclusions and follow-up

The mission provided a good overview of the prevailing issues and priorities for research and development (R&D) in the GAP region of Turkey. While acknowledging the relative dynamism of irrigated agriculture in the GAP region, the mission as well as people and institutions visited identified a substantial potential for improving agricultural and water productivities. Such an improvement would require R&D activities focused on a better assessment of the present agricultural, technical, environmental.

The mission identified four R&D priority topics, each including two projects:

- **Topic 1 Planning, monitoring and evaluating Şanlı Urfa – Harran irrigation project**
  - Project 1.1 Revisiting and acquiring technical and economical data on irrigated agriculture
  - Project 1.2 Development of decision support tools
- **Topic 2 Introducing Performance Oriented Management in GAP Irrigation Systems**
  - Project 2.1 Strengthening Participatory Operation of Irrigation Systems
  - Project 2.2 Strengthening Maintenance by Irrigation Associations
- **Topic 3 Environmental Impact Assessment and Monitoring**
  - Project 3.1 Development of a sustainable salinity and waterlogging management system for Harran Plain
  - Project 3.2 Sustainable management of groundwater
- **Topic 4 Assessing and monitoring the agro-socio-economic impact of irrigation projects**
  - Project 4.1 Evaluation of the socio-economic impact of irrigation
  - Project 4.2 Land Tenure, Social Organisations and Farming

The present draft report will be submitted to GAP-RDA for comments, modifications then approval. After approval and publication of the report by IPTRID, identified R&D project will be prioritised by GAP-RDA in relation with national institutions, and contacts will be taken with donors, already identified by the mission and others, to check for their interest in the prioritised projects and topics. An IPTRID formulation mission could then take place upon request of GAP-RDA to formulate full proposals of the prioritised projects for which an expression of interest from donors will have been identified.

## 6. Agenda

| | |
|---|---|
| Monday 15 October | Arrival to Ankara |
| Tuesday 16 October | Documents review (past and on-going R&D activities, policies and institutional issues)<br>Meeting with Dr. Unver, President GAP & Briefing<br>Mission Technical committee meeting |
| Wednesday 17 October | Meetings with DSİ, GDRS and METU<br>Travel to Sanliurfa via Gaziantep |
| Thursday 18 October | Visit to GAP Regional Directorate<br>Visit to XV Regional Directorate of State Hydraulic Works (DSI) : water distribution systems in Sanliurfa-Harran Plains (canalets and GERSAR project site)<br>Visit to GDRS Sanliurfa Research Institute: researches conducted on irrigation and crop production and economical benefits of irrigation<br>Visit to Göktepe Company Regional Directorate: regional demand on irrigation equipment<br>Visit to Governorate Ag. Dept. of Sanliurfa : agricultural extension and irrigation problems |
| Friday 19 October | Visit to Harran University Agric. Faculty : irrigated agriculture and economic and environmental aspects of irrigation<br>Visit to GAP-MOM (Maintenance Operation and Management of Irrigation Systems): project implementations and farmer meetings<br>Visit to Koruklu Research Station- GAP-RDA researches<br>Visit to GDRS Bolatlar Project Directorate: investigation on underground drainage site and environmental problems |
| Saturday 20 October | Meeting with the Harran plain Irrigation Unions : economic and institutional aspect of water management, understanding of institutional aspects such as, legal, accounting, and auditing<br>Debriefing of 1st mission week |
| Sunday 21 October | Debriefing of 1st mission week (continued)<br>Preparation of mission report |
| Monday 22 October | Visit to Sanliurfa-G.Antep Nurdağı<br>Visit to -G.Antep Nurdağ Gedikli Water Users' Coop : economic and institutional aspect of water management<br>Visit to G.Antep Museum<br>Visit to Bireçik dam<br>G.Antep-Sanliurfa |
| Tuesday 23 October | Visit to Sanliurfa -Ceylanpinar<br>Visit to Ceylanpinar- State Farm TIGEM<br>Visit to Ceylanpinar-Cırcıp Groundwater User Association<br>Debriefing meeting with GAP Regional Directorate |
| Wednesday 24 October | Travel to Ankara via Gaziantep<br>Preparation of mission report<br>Meeting with French Embassy in Ankara |
| Thursday 25 October | Preparation of mission report<br>Meeting with EU representation<br>Debriefing meeting with GAP-RDA, donors, DSI and GDRS |
| Friday 26 October | Return travel |

## 7. Contact persons met

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# 8. Annexes

## *8.1 Annex 1: Approval letter*

To be completed after approval of the revised report by GAP-RDA

## 8.2 Annex 2: Various technical and economic performance indicators collected by the mission

Draft table to be completed by the mission

| Project | Sanli Urfa - Harran Project | | | TIGEM Farm, Ceylanpinar | | | Ikicircip GW Project |
|---|---|---|---|---|---|---|---|
| Crop | Cotton | Irrigated Wheat | All | Cotton | Wheat (irrigated) | Wheat (dry) | Cotton |
| Information Source (Year 2000) | GDRS | GDRS | GAP | | TIGEM Farm, Ceylanpinar | | |
| Planned cropped area (ha) | 20600 | 36050 | 103000 | 900 | 50000 | 100000 | 3600 |
| Actual cropped area (ha) | 92700 | 8240 | 103000 | 900 | 50000 | 100000 | 3600 |
| Volume derived or pumped (m3/ha) | 10500 | *3000* | 10000 | 9000 | 3000 | | *10500* |
| Yield T/ha | 3.2 | | n/a | 3.5 | 6 | 3 | 3.5 |
| Gross income US$/ha | *1550* | | | 1700 | | | 1570 |
| Subsidies US$/ha | 320 | | | 350 | | | 350 |
| Subsidised gross income US$/ha | 1870 | | 1932 | 2050 | | | 1920 |
| Gross water productivity US$/m3 | 0.178 | | 0.193 | 0.228 | | | 0.183 |
| Production costs US$/ha (without pumping) | 690 | | 378 | 1620 | | | 1100 |
| Pumping costs US$/ha | 0 | | 0 | 100 | | | 300 |
| Total production costs US$/ha | 690 | | 378 | 1720 | | | 1400 |
| Net income US$/ha | 1180 | 520 | 1554 | 330 | 160 | 80 | 520 |
| Net water productivity US$/m3 | 0.112 | 0.173 | 0.155 | 0.037 | 0.053 | n/a | 0.050 |

*Figures in italics are estimations*

## *8.3 Annex 3: Şanli Urfa – Harran irrigation unions main characteristics and budget*

To be replaced by the table prepared by the mission (Bernard and Hammond)

**Table 5.1 : Existing Water Users' Associations**

| Item No | Name of Association | Date of Establishment | Number of Founding Villages | Irrigation Area (Hectares) |
|---|---|---|---|---|
| 1 | Şanliurfa Merkez | 1995 | 10 | 5 688 |
| 2 | Fırat | 1995 | 12 | 7784 |
| 3 | Kısas | 1995 | 6 | 4 182 |
| 4 | Koruklu | 1995 | 12 | 5 291 |
| 5 | Tahılalan | 1995 | 12 | 6 538 |
| 6 | Onüçüncü Yedak | 1995 | 12 | 3 645 |
| 7 | Haktanır | 1995 | 11 | 5 698 |
| 8 | Yalımlı - Onortak | 1995 | 5 | 3 900 |
| 9 | Topçu - Gündaş | 1995 | 3 | 2 915 |
| 10 | Sevimli-Elveren-Bolatlar | 1995 | 13 | 3 710 |
| 11 | Temsettin - Güneren | 1995 | 7 | 4 475 |
| 12 | Tektek | 1997 | 28 | 15 087 |
| 13 | Tuayb | 1997 | 17 | 8 744 |
| 14 | Kurtuluş | 1998 | 22 | 6 633 |
| 15 | Cabirensar | 1998 | 30 | 11 719 |
| | Total | | | 96009 |

## *8.4 Annex 4 : Description of the components of the GAP – UNDP Sustainable Development Programme in which R&D actions could be included*

***GAP-UNDP Project 4 : Establishment of GAP Regional Research and Development Center***

Executing Agency : GAP Administration

Implementing Agency : GAP Administration, other related institutions

Duration : 5 years

Implementation Area : Şanlıurfa province is a candidate for the headquarter of "GAP regional Research and Development Center". Other provinces of the Project Region may be considered as the places for branches or field divisions of the Center.

Project Description : Research and development efforts must continue in the Region to increase the Region's export earnings in a competitive environment with the use of most recent technology and management techniques with well developed and highly productive human resources, and thus to achieve the expected multi-sectorial development. GAP Regional Research and Development Center will serve to develop wars and tools to adopt competitive technology in the Region.

Objectives : To lead and conduct scientific, innovative and practical research and development of technology and organisational structures which will enhance the quality of human resources, the Region's economic growth, the ability to conserve natural resources, and which will provide a smooth and healthy transformation of society on a sustainable basis.

Outputs:

- Identification of new strategic opportunities for the development;
- Enhancement of GAP's basic development sectors for sustainable, productive and competitive features;
- Development of Research collaborations and consultancies for the Region's socio-economic enhancement;
- Promotion, protection and development of Region's human and natural resources.

Project Scope:

- Agricultural research and development,
- Livestock development and animal health,
- Water resources and irrigation systems,
- Waterborne diseases and human health,
- Regional resources development,
- Environmental monitoring and impact assessment,
- Industrial technology, productivity and management,
- Social policy development.

Project Cost : US $ 350.000

***GAP-UNDP Project 10 : Pilot Implementation for Organizational Development and Training Farmers in GAP***

Executing Agency : GAP Administration

Implementing Agency : GAP Administration, State Hydraulic Works (DSI) GeneralDirectorate, Rural Services (KHGM) and NGOs

Implementation Area: Selected pilot areas in the GAP Region

Project Description: The planning, design and construction of the storage, conveyance and distribution works, as well as detailed investigations on water saving methods and technologies for efficient use of water for vastirrigation development programmes, such as the GAP, are extremely important. The achievement of period at a maximum level requires not only a sound design and a good implementation of the engineering structures, but also a suitable policy (strategies, procedures and organisational structures) for the MOM of such system. The management of an irrigation system and the design of this structural components are intimately interrelated, i.e., there are important tradeoffs between the structural and management components of an irrigation system for given levels of performance. The choice of an appropriate management-structural combination, therefore, depends on administrative feasibility, economic efficiency, national interest, acceptance by farmers, applicability etc.

Objectives:

- To identify the conveyance, distribution and application methods that maximise the production value of the water:
- To minimise the environmental impact of the irrigation and drainage activities;
- To establish the most convenient method for the use of the physical infrastructure which constitutes the irrigation system, according to three factors varying in course of time, water availability, climatic conditions, cropping pattern:
- To assure continuous and perfect efficiency of the physical infrastructure to a llow the regular performance of the operation.

Activities :

1. Identification of appropriate alternative model for implementation scope.
2. Implementation

   a) The proposed models will cover the general structure of the organisation and the relation between the irrigation districts and the government. The organisation proposed in the model will act as an "information clearing house" and inform the farmers, of the studies of public and private sector. Besides, it will develop recommendations related with the co-ordination integration and reorganisation of the work carried out by different agencies.

   b) The existing laws and regulations, during the designing of the MOM model will be evaluated and new regulations and changes it the existing system will be proposed,

   c) The selected model/models will be applied to selected sample irrigation areas both in Euphrates and Tigris basins and the required personnel will be trained.
3. Monitoring

   a) The model application will cover the studies of the irrigation district and its higher level organisation and the interaction.

   b) The irrigation district will be responsible from the management of water at the field level.

c) An M and E system will be established, which will carry out a mid-term survey and an ex-post evaluation within the project period. The system will be able to make the necessary modifications.

Project Cost: US $ 250.000

***GAP-UNDP Project 11 : Agricultural Research and Development Project (2nd Phase)***

Executing Agency : GAP Administration

Implementing Agency : GAP Administration, Çukurova University, Harran University,

Duration : 2 years

Starting Date : June, 1996

Project Sites : Koruklu Research Station-Harran Plain and Agricultural Faculty, Harran University Şanlıurfa-Turkey.

Project Description: Since the irrigated lands in the South-eastern Anatolia Project region correspond to 19% of the national total and area to be opened to irrigation will be 1.7 million hectares, it is very important to grow irrigated crops and to increase the cropping intensity in the irrigated areas. GAP Administration with the awareness of this important issue, have financed a 5 year project for selected field crops, fruits and vegetables in the research station established especially for this purpose. At the end of the project, all the suitable crop kinds and varieties have been identified together with the rotation alternatives. To supplement these findings, the second phase of the project, to carry out production technique trails (soil preparation. needing, sowing, planting, irrigation, harvesting, chemical application procedures and times), has been prepared. All the planning to supply seeds, seedlings, fertilisers, chemicals will depend on the result of the ongoing projects.

Objectives : To carry out the plant production trials on field crops and fruits and vegetables, which are found very well adapted to the conditions of the region, during the 1st Phase of the study carried out by the Çukurova University, Agricultural Faculty and financed by the GAP Administration. Within the study, 20 sub-projects will be carried out by Çukurova University and 25 sub-projects will be carried our by Çukurova University and 25 sub-projects by Harran University.

Project Cost : US $ 595.000

Remark: UNDP-GAP Administration collaboration may be used to convey research findings to farmers (training/workshop component).

***GAP-UNDP Project 14 : Establishment Farm to Integration Crop Management Service and Training in Harran Plain***

Executing Agency : GAP Administration

Implementing Agency : GAP Administration. Ministry of Agricultural and Rural Affairs. DSI General Directorate of Rural Services, Union of Turkish Chamber of Agriculture

Location : Şanlıurfa-Harran Plain

Duration : 3 years

Project Description : Irrigation development in the South-eastern Anatolia is progressing, with the major storage dams constructed and studies for supply strategies, evaluation of on-farm irrigation systems and suitable crop and livestock alternatives proceeding. To maximise this development there is a requirement to ensure the new irrigation farmers have adequate management skills, and to provide a core of trained staff to guide the long-term sustainable management of the region. The proposed Irrigation Demonstration Training Farm Project will achieve this. This project will have as a central focus on development of an irrigated crop management services (ICMS), based on successful examples of some countries. This service matches the requirement of climate, soil properties. water quality, irrigation systems and crop types.

Project Objectives : The project will be of major benefit to the implementing agencies by providing a comprehensive irrigation management facility, with provision for objective planning at both regional and individual property level.

Outputs :

- Training in overseas for a core of specialist Turkish staff responsible for leadership and administration of the ICMS, and assistance with the development of a package of services to be offered.
- Training at the Demonstration Farm at two levels. Turkish technologists responsible for field operations of the ICMS, will receive 12 months training in specific subject areas. To compliment these staff from the Implementing Agencies and key farmers will be given basic training in irrigation management and introduced to the range of services to be provided, during a short course of 4-6 weeks duration.
- Central demonstration areas for intensive high value horticulture and vegetable crops and fadder production.
- Local village demonstrations for key crops (cotton, maize, etc.) and irrigation, techniques: These demonstrations will be used as part of the training during the project, but will also form the basis of future work at the conclusion of the project.

Inputs : A Design Mission, involving foreign and Turkish irrigation specialists and economists, will be required to develop detailed plans of the, ICMS, including demonstration areas and training courses. Foreign company has to expertise in irrigation technology and extension experience to provide appropriate training courses and set up the demonstration areas. Resources required for the project include:

- 2-4 ha irrigated land, possible adjoining the Koruklu station of GAP Administration, intensive, high value crops;
- 20 ha irrigable land, for extensive irrigated production, possible at the Akçakale Research Institute:
- Provision of tractor, tillage and harvesting equipment to sow crop and fodder trials. Additional specialist irrigation equipment will need to be procured either in Turkey or from overseas;

- Accommodation, classroom, equipment, storage and administration facilities will be provided by the implementing agencies.

Project Cost: US $ 1.200.000

Remark : UNDP-GAP Administration collaboration is possible (expected) in "Overseas training for Turkish experts" component when the project is initiated by GAP Administration with funding from elsewhere.

# OUTPUT 2

Contribution to Mission Report to Egypt, January 2002 – Regional Cooperation Potential in the North Mediterranean-Sea Area

Output 2 – Mission to Egypt –
Certification by Mission Leader

6/3/2003

Dear Ian,

I can confirm that your recollection of what happened agrees with what I remember. We did not produce a mission report in the end (well not a report like previous IPTRID country missions). The reasons for this are various but it became clear during the mission that the TOR did not address the problems that we are a team saw. I reported this in a joint Back-to-Office report (Brabben & Vidal). Jacob Burke of AGLW, FAO was also on the mission and prepared his own BTOR.

Zhongping made useful contributions to the team's work and discussions and I think I reported favourably on this to you at the time. I can't find a relevant email though.

What we produced as a Team in Egypt was a PowerPoint briefing for Mona El Kady. Zhongping contributed to this to a great extent.

I have looked through what I still have and have found an email report to Mona explaining why IPTRID had to put this mission report and follow up on the "back-burner". Alain Vidal also followed up from the Mediterranean side and prepared a fiche for Olivier Cogels in June 2002.

I can certify that Zhongping Zhu was an important and effective team member in the IPTRID mission to Egypt in Jan/Feb 2002. His experience of Egypt and his recent professional contacts in the country were extremely useful to me as Team Leader and for the team as a whole. He was energetic and hard working and I would have no hesitation in wanting him to join a similar mission.

Regards,
Tom Brabben
Wallingford

| AGL Back to Office Report | | |
|---|---|---|
| | **Country visited** | **Egypt** |
| | **Date** | **27 January - 8 February 2002** |
| | **Traveller** | **T. E. Brabben, A. Vidal, Regional Theme Managers, IPTRID** |
| | **Purpose** | To identify and consider the feasibility of the establishment of a regional Programme on research and technology transfer for agricultural water management in the RNE region. |
| | **Follow up** | Mission report and outline proposal preparation by end-March 2002 (Action IPTRID RTMs).<br>Develop TORs & retain suitable consultants to develop thematic needs papers and priorities by end-June 2002 (Action: IPTRID RTMs).<br>Organize workshop to launch initiative in September 2002, in Egypt. (Action: IPTRID & NWRC).<br>In parallel hold discussions with potential donors; with EU Brussels on Euro-Med Programme, French Embassy/BLAFE and with CIDA for support for Workshop. (Action: IPTRID RTMs).<br>Provide advice and assistance to NWRC by including documents in WCA infoNET and further strengthen the existing IPTRID network node in NWRC to take on a role in the Southern & Eastern Mediterranean region. Plan possible visits to Cairo, 2nd quarter 2002. (Action: IPTRID Information Officer & Network Coordinator). |
| | **Project Symbol** | **IPTRID GCP/INT/705/MUL-Child** |
| **Distribution** | **Cc** | **A.Y. Bukhari, ADG/RR, RNE**<br>**Z. Abdalla, FAOR Egypt a.i.**<br>**M. Bazza, RNEG**<br>**Rodney Standring, EC, EuropeAid**<br>**Ghislaine Rimmen-Mohl, French Embassy**<br>**Philippe Amé, BLAFE**<br>**Michelle Grosset, MAP/DPEI**<br>**Bruno Molle, Cemagref**<br>**AGL-list**<br>**Brabben chrono**<br>**Vidal chrono**<br>**AGL Reg. 1** |
| | **Registry Code** | **LA 6/1 Brabben & Vidal** |

*This report has been authorized by Chief, AGLW, for distribution bas indicated above. Date: 26/2/02*

**DUTY TRAVEL REPORT**
**Mission to Cairo, Egypt**
**27 January to 8 February 2002**
**by**
**T.E. Brabben, Acting Officer-in-Charge - IPTRID**
**A. Vidal, Regional Theme Manager - IPTRID**
**Water Resources, Development and Management Service**
**Land and Water Development Division**

## I. Introduction and justification of the mission

The purpose of the mission, which took place from 27 January to 8 February 2002, was to identify and consider the feasibility of the establishment of a regional programme on research and technology transfer for agricultural water management in the RNE region. The mission was a follow up to a mission undertaken by the Programme Manager of IPTRID in August 2001. The present mission was undertaken in collaboration with the National Water Research Center (NWRC) in Cairo.

The Reporter was the Team Leader of the mission, which comprised four international members and five Egyptian members[1], and the IPTRID Regional Theme Manager. The mission was hosted by the National Water Research Center (NWRC) under the guidance of their Chairperson, Dr Mona El-Kady. The mission concentrated upon identifying needs for a regional initiative through several brainstorming and programme formulation sessions. Meetings were also arranged with the Water Resources Adviser at the FAO Regional Office, a selection of NWRC and Agricultural Research Center (ARC) research bodies and with training institutes in and around Cairo, (see Annex 2 for the programme).

## II. Findings

The process

The programme formulation process was lengthy taking as a starting point the mission TORs (originally developed in August 2001, see Annex 3). The Team agreed that there was little to be gained in repeating a review of water resources research needs in the region. The original concept was a region comprising all countries making up FAO's Regional office for the Near East (RNE). This was too large a region to provide any meaningful direction to the determination of research, technology transfer and ultimately technology up-take for agricultural water management. The region, for the purpose of this initiative is therefore restricted to the Southern and Eastern Mediterranean[2]. This has the added advantage of closely coinciding with the Euro-Med definition and with IPTRID's priorities on the water conservation theme.

The choice of thematic directions took longer than expected. There was a wide ranging discussion among the team members on what technology and research issues related to drainage and irrigation could be developed into concrete research/transfer modules along with the appropriate training and dissemination elements. It proved difficult to focus on particular agricultural water management (irrigation and drainage) issues that could be realistically implemented in a modest IPTRID regional programme. This formulation took as a starting point the outputs of the roundtable meeting held by IPTRID in Rome in November 1999.

| Regional projects |
|---|
| Improvement of on-farm surface irrigation |
| Adoption of improved irrigation technologies by farmers |
| Wastewater irrigation practices and impacts |
| Technology transfer in conditions of irrigation management transfer |
| Institutional, technical and economic aspects of water demand management |

[1] Mission members listed in Annex 1
[2] Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Syria, Tunisia, Turkey

After considerable brainstorming and debate, the mission revised and agreed upon the following principal themes.

| Principal Theme | Detail | Suggested possible countries – organizations[3] |
|---|---|---|
| Enhancing water productivity | increasing per unit water productivity, i.e. "more crop per drop" (sprinklers, drip, scheduling, etc.) | **Tunisia – INRGREF**<br>**Egypt – SWERI**, AEnRI, NWRC<br>Jordan – JVA (IAS)<br>Algeria<br>Lebanon |
| Irrigation modernization | including both institutional and physical strengthening | **Turkey – GAP**<br>Egypt – NWRC<br>Jordan – JVA<br>Morocco – ORMVAS |
| Groundwater | sustainable use for agriculture recognising high dependency on groundwater for irrigation in region | **Egypt – NWRC**<br>Libya<br>Syria<br>Jordan – WAJ |
| Water reuse | a) wastewater reuse for irrigation<br><br>b) sustainable reuse of drainage water | *Wastewater*<br>**Tunisia – INRGREF**<br>Egypt – SWERI<br>Jordan – UoJ<br>Morocco – IAV H2<br>*Drainage water*<br>**Egypt – NWRC**<br>Morocco – ORMVAG<br>Algeria |
| Salinity and water management | salt balance & disposal | **Jordan – JVA**<br>Egypt – SWERI, NWRC<br>Morocco – ORMVAG/T<br>Tunisia – INRGREF |
| Communication and networking | developing specific regional initiatives to enhance information exchange & capacity building | **Egypt – NWRC**<br>Morocco – AGR<br>Turkey – GAP |

| | |
|---|---|
| AEnRI | Agricultural Engineering Research Institute, Egypt |
| AGR | Administration du Génie Rural, Morocco |
| GAP | Güneudoğu Anadolu Projesi = Southeastern Anatolia Project |
| IAV H2 | Institut Agronomique et Vétérinaire Hassan II, Morocco |
| INRGREF | Institut National de Recherche en Génie Rural, Eaux et Forêts, Tunisia |
| JVA | Jordan Valley Authority |
| ORMVAG | Office Régional de Mise en Valeur Agricole du Gharb, Morocco |
| ORMVAS | Office Régional de Mise en Valeur Agricole du Souss-Massa, Morocco |
| ORMVAT | Office Régional de Mise en Valeur Agricole du Tadla, Morocco |
| NWRC | National Water Research Center, Egypt |
| SWERI | Soil, Water and Environment Research Institute, Egypt |
| UoJ | University of Jordan |
| WAJ | Water Authority of Jordan |

[3] Suggested coordinating institutions in **bold**

Thematic outputs

The idea that one or two countries should collaborate on specific research and technology transfer packages was suggested and endorsed. This will permit solid country ownership and drive. To make these themes attractive to national research organisations for regional collaboration and dissemination it is proposed that IPTRID develop and check the feasibility of this approach by picking certain of the principal themes which consultants can work up and discuss with specific national institutions. The idea is to obtain commitment of the countries and organizations that could be involved and to define where there are clear gaps in technology and research that could be successfully addressed by regional collaboration. These results would then be presented to a regional workshop to be convened by IPTRID and NWRC in September 2002.

The institutional arrangements

There is no regional body within which such a regional initative could reside and through which it could be co-ordinated. The proposal, made in August 2001, for NWRC to provide an institutional home for the initiative was considered and revised. This proposal (including a full-time secretariat, advisory committee and the financial burden that this implies) was left "on-the-table" as an institutional arrangement that may be the ultimate result. An alternative and/or complementary arrangement would consist of the different thematic components being co-ordinated by institutions around the Mediterranean as listed in the previous table. The need to move quickly but in small steps was agreed and an initial phase of about one year, when IPTRID could co-ordinate a "light" programme, was thought to make more sense.

Donor support

The main donor potential discussed was that of the EU's Euro-Med programme (Euro-Mediterranean Regional Water Programme for Local Water Management), for which requests for proposals were issued in early 2002. Given that this programme has specific windows for irrigation research/technology transfer as well as for wastewater reuse, it was agreed that the submission of a proposal addressing at least one of the principal themes by May 2002 should be a priority. The IPTRID Regional Theme Manager will hold further discussions in Brussels on 18 February.

Due to Government of Egypt meetings with donor organizations during the latter part of the mission, the team did not meet donor representatives in Cairo. The Water Conservation RTM did however meet with the French Embassy officials, who indicated their interest for a co-funding of actions primarily based in Egypt and involving research institutions of the Ministry of Agriculture and Land Reclamation (SWERI, AEnRI).

Further discussions will be held with CIDA (Canada) to follow up an offer made during the IPTRID Donor meeting in Paris, in November 2001, on likely CIDA support for this regional initiative and the launch workshop.

## III. Conclusions

The mission agreed that it would be feasible to establish a regional programme on agricultural water management but that care should be taken to focus upon issues of true regional importance and relevance and which could be resolved by concerted regional cooperation though technology transfer. The goal and purpose of the proposed initiative is as follows.

*Goal*

To improve and sustain the agricultural productivity of available water in the region.

*Purpose of programme*

To promote targeted research and technology transfer in agricultural water management across Southern & Eastern Mediterranean countries to meet shifting agricultural priorities.

The overall goal of the proposed initiative would be to improve agricultural productivity in the region through enhanced water management. Programmatic links to agriculture (as the end-user) need to be clearly maintained so as to achieve sustainable development impacts. An early measure of the success of this regional initiative will be the cooperation and professional links between water resources (irrigation and drainage engineers) and agricultural extension services throughout the region as defined.

Further action and follow up by IPTRID is summarized below. IPTRID Secretariat and Partner Institution activities are dependent upon financial and staff resources being available.

## IV. Follow-up

- Mission report and outline proposal preparation by end-March 2002 (Action IPTRID RTMs).
- Develop TORs and retain suitable consultants to develop thematic needs papers and priorities by end-June 2002 (Action: IPTRID RTMs).
- Organize workshop to launch initiative in September 2002, in Egypt. (Action: IPTRID and NWRC).
- In parallel, hold discussions with potential donors: with EU Brussels on Euro-Med Programme, French Embassy/BLAFE and with CIDA for support for Workshop. (Action: IPTRID RTMs).
- Provide advice and assistance to NWRC by including documents in WCA infoNET and further strengthen the existing IPTRID network node in NWRC to take on a role in the Southern and Eastern Mediterranean region. Plan possible visits to Cairo during the second quarter 2002. (Action: IPTRID Information Officer and Network Coordinator).

## V. Itinerary

| | |
|---|---|
| 26/01/02 | T.E. Brabben - departure Rome |
| 27/01/02 | T.E. Brabben - arrival Cairo |
| 03/02/02 | A. Vidal - arrival Cairo |
| 08/02/02 | Departure Cairo, arrival Rome and Paris |

**Annex 1**

## Mission Team Members

*International*
Tom Brabben, Regional Theme Manager – IPTRID (Team Leader 27/1–8/2)
Jacob Burke, Senior Officer AGLW, FAO (30/1–5/2)
Bruno Molle, Cemagref (31/1)
Laurie Tollefson, PFRA-Canada (6/2)
Alain Vidal, Regional Theme Manager – IPTRID (3/2–8/2)
Zhongping Zhu, IWMI (27/1–8/2)

*National*
Gamal Ibrahim Youssef Allam, NWRC
Mohamed Hassan Amer, Consultant
Abdallah Sadik Bazaraa, American University in Cairo
Abd El-Kawy A. M. Khalifa, Khalifa Consulting Engineers
Mahmoud Mohamed Moustafa, NWRC

**Annex 2**

## Mission Activities

| Date | Activities | Visited Person(s) |
|---|---|---|
| 27 Jan<br>Sunday | • **Connected NWRC for meeting schedules**<br>• **Met with NWRC representatives**<br>• **Internal preparation**<br><br>IPTRID: Tom Brabben, Zhongping Zhu | Dr Gamal Allam, NWRC General Secretary<br>Dr Mahmoud Moustafa, Irrigation and drainage specialist, NWRC Technical Office |
| 28 Jan<br>Monday | • **Briefed Dr Mona El Kady, NWRC Chairperson**<br>• **Met with local consultants (listed below)**<br><br>IPTRID: Tom Brabben, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | |
| 29 Jan<br>Tuesday | • **Visited FAO/RNE office**<br>• **Started discussion with local consultants**<br><br>IPTRID: Tom Brabben, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | Dr Mohamed Bazza, Senior Official, FAO/RNE |
| 30 Jan<br>Wednesday | • **Visited 6 NWRC institutes at the Delta Barrage**<br><br>IPTRID: Tom Brabben, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | Dr Abdel-Gawad Shaden, Director, NWRC/DRI<br>Dr Hasan Wahby, Director, NWRC/WMRI<br>Dr Moustafa Gaweesh, Director, NWRC/HRI<br>Dr Ahmed R. Khater, Director, NWRC/RIGW<br>Dr Mohamed Abd El-Fadil, Director, NWRC/CM<br>Dr Tarek Tawfik, Director, NWRC Central Lab |
| 31 Jan<br>Thursday | • **Dr Amer presentation on Arab Countries Water Vision**<br><br>IPTRID: Tom Brabben, Zhongping Zhu, Bruno Molle<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | |
| 1 Feb<br>Friday | Weekend break | |
| 2 Feb<br>Saturday | • **Visited ARC**<br>• **Visited MWRI Training Center, 6th October City**<br><br>IPTRID: Tom Brabben, Jacob Burke, Zhongping Zhu, Bruno Molle<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | Dr S. N. Shaalan, Director, ARC/SWERI<br>Dr Dalal Alnaggar, Director, MWRI Training Center |

| | | |
|---|---|---|
| 3 Feb<br>Sunday | • **Discussions on program framework and details**<br><br>IPTRID: Tom Brabben, Jacob Burke, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | |
| 4 Feb<br>Monday | • **Discussions on program framework and details**<br>• **Preparation of mission presentation**<br>• **Alain Vidal visited French Embassy**<br><br>IPTRID: Tom Brabben, Alain Vidal, Jacob Burke, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | Ms Ghislaine Rimmen-Mohl, Attachée Commerciale, French Embassy to Egypt<br>Mr Philippe Amé, Co-director, Bureau de Liaison Agricole Franco-Egyptien |
| 5 Feb<br>Tuesday | • **Tom Brabben presented draft mission findings**<br><br>IPTRID: Tom Brabben, Alain Vidal, Jacob Burke, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | |
| 6 Feb<br>Wednesday | • **Visited Laurie Tollefson, Coordinator of Agriculture and Agri-Food Canada**<br>• **Revised mission findings**<br><br>IPTRID: Tom Brabben, Alain Vidal, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | Mr Laurie Tollefson, Headquarters coordinator, Agriculture and Agri-Food Canada |
| 7 Feb<br>Thursday | • **Discussion with Dr Mona El Kady, NWRC representatives, and local consultants**<br>• **Mission wrap-up**<br><br>IPTRID: Tom Brabben, Alain Vidal, Zhongping Zhu<br>NWRC: Gamal Allam, Mahmoud Moustafa<br>Local Consultants: Hassan Amer, Abdallah Bazaraa, Abd El-Kawy Khalifa | Dr Mona El Kady, Chairperson, NWRC<br>Dr S. N. Shaalan, Director, ARC/SWERI |

**Annex 3**

## Terms of Reference of the Identification Mission

The objective of the identification mission is to identify and prepare a feasibility report on the establishment of a Near East and North African Regional (RNE) Programme on Research and Technology Transfer on Agricultural Water Management. The identification mission is a joint activity of NWRC and IPTRID. The mission will undertake the following duties under the general guidance of the Chairperson of NWRC and Programme Manager of IPTRID.

1. The Mission will review the status of water resources, agricultural development, agricultural water use in the context of food security, sustainable water development and environmental protection within the RNE.

2. It will identify major problems faced by the water and agriculture sectors in the region and their impacts in short, medium and long terms.

3. The mission will identify research and technology transfer needs in the context of the identified problems.

4. The mission will develop a framework proposal for a Near East and North African Regional (RNE) Programme on Research and Technology Transfer on Agricultural Water Management. This proposal should deal with the following aspects:

   - Objective of the regional programme
   - Outputs
   - Activities
   - Operational mechanisms and arrangements
   - Funding requirements and resource mobilisation

5. The proposal for a Near East and North African Regional (RNE) Programme on Research and Technology Transfer on Agricultural Water Management should also contain a logical framework analysis.

6. The report of the mission should contain appropriate annexes and supplementary information.

### Composition of the Mission

Four international consultants drawn from IPTRID Secretariat and IPTRID Partner Institutions.
Five national consultants appointed by NWRC.

### Dates of the Mission

27 January to 8 February 2002

# OUTPUT 3

Final Report – Survey on Modernization of Irrigation Schemes. Selected Case of Tao-Yuan Irrigation Association, Taiwan. June 2002 by Agricultural Engineering Research Centre, Taiwan

FAO: International Program for Technology and Research in Irrigation and Drainage (IPTRID)-

# Final Report
# Survey on Modernization of Irrigation Systems
# Selected Case of
# The Scheme of Tao-Yuan Irrigation Association, Taiwan

Submitted to

International Water Management Institutes (IWMI)

Prepared by
Agricultural Engineering Research Center (AERC), Taiwan
In Association with Tao-Yuan Irrigation Association, Taiwan

June 26 2002
Agricultural Engineering Research Center
No.196-1 Chung-Yuan Road, Chung-Li
Taiwan, Republic of China

FAO: International Program for Technology and Research in Irrigation and Drainage (IPTRID)-

Final Report
Survey on the Modernization of Irrigation Systems
Selected Case of
The Scheme of Tao-Yuan Irrigation Association, Taiwan

**BREIF BACKGROUND**

On behalf of International Program for Technology and Research in Irrigation and Drainage (IPTRID) under FAO in Rome, International Water Management Institute (IWMI) sent a signed contract together with the Terms of Reference (TOR) and relevant background information for the captioned survey, dated 28th May 2002, to Agricultural Engineering Research Center (AERC) of Taiwan to seek his acceptance of undertaking the captioned survey. The contract was received by AERC on 3rd June 2002 and was co-signed by the Director of AERC, Dr. Chen. W. Liu on 6th June 2002. The TOR of survey is attached in Appendix 1. In this connection, the survey committed by AERC has designated Mr. Ko Hai-Sheng, the Research Scientist, AERC and his assistants to carry out officially after signing the contract. The survey was completed within 10 working days as scheduled in TOR. The report submitted hereunder is the result of survey in accordance with the signed contact for fulfilling its requirement.

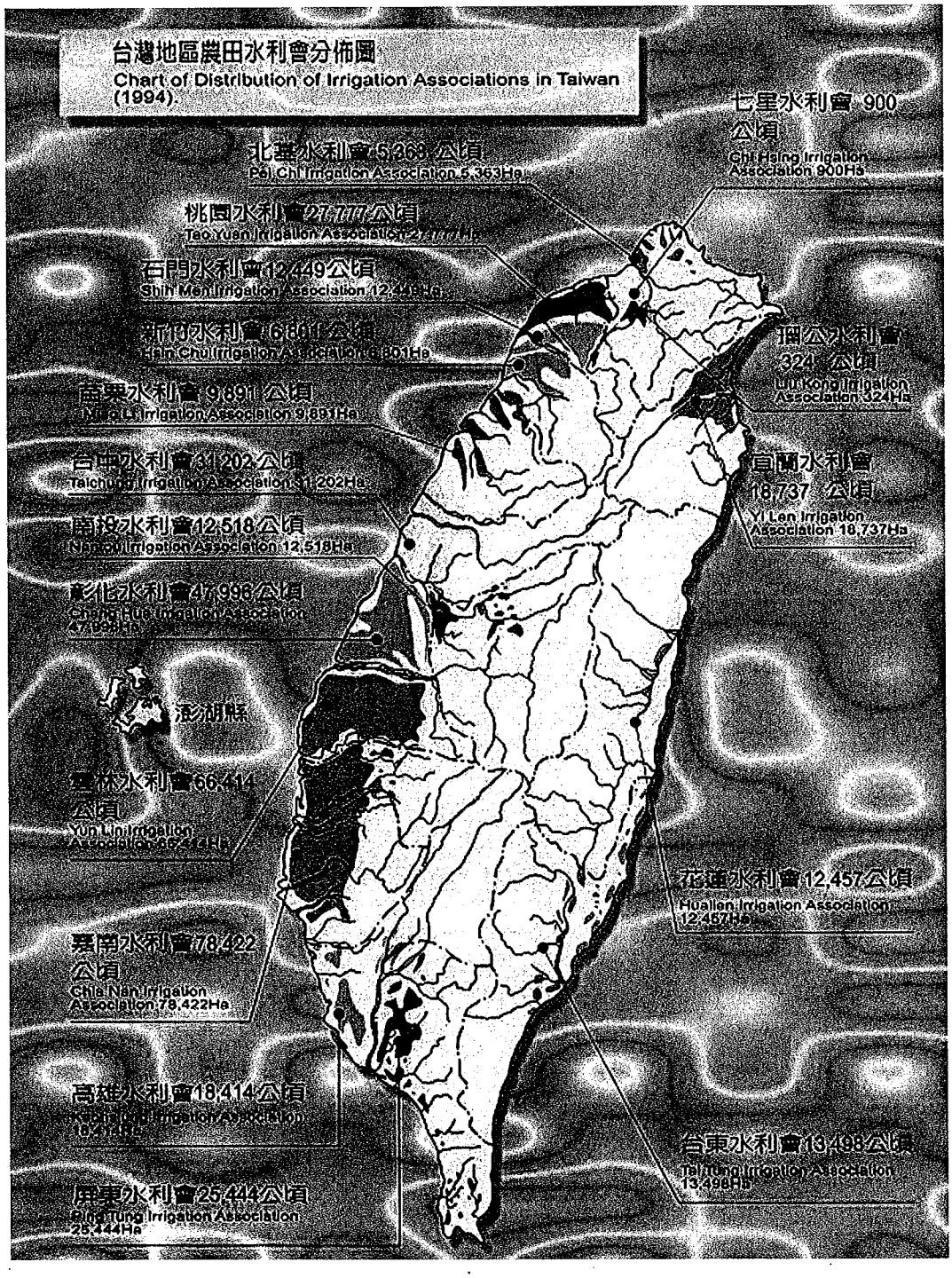
**Main Report of Survey**

**Part A:**

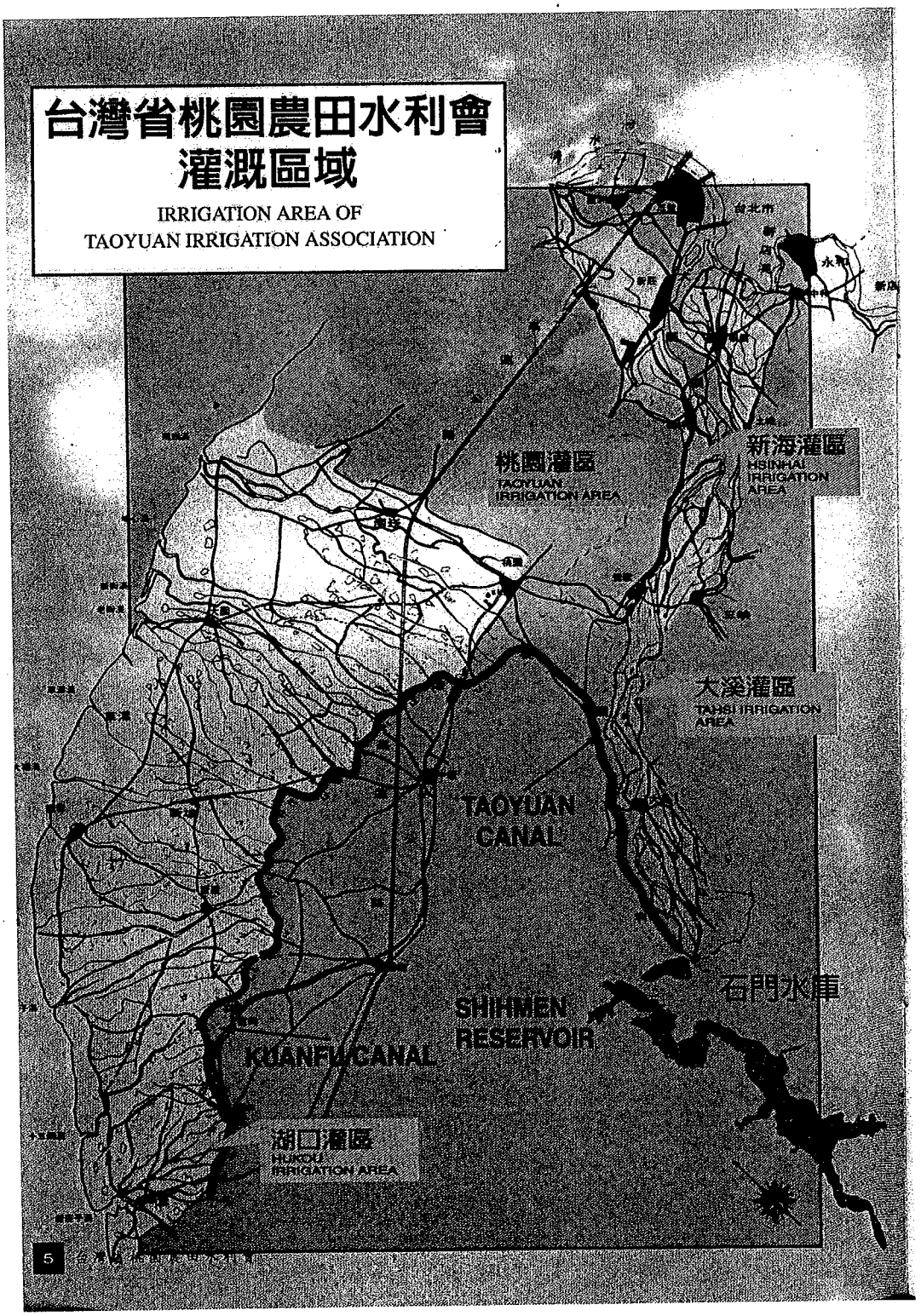
**Brief description of the modernized irrigation system- the scheme of Tao-yuan Irrigation Association**

I. Location

1. The location of Tao-yuan Irrigation Association on the island of Taiwan is shown in Map 1.
2. The irrigation system of Tao-yuan Irrigation Association is illustrated in Map 2.
3. The range of Tao-yuan Irrigation Association, in geographic coordinate, is shown below:
   UL (upper left corner): 25° 08' N, 120 50' E
   LL (lower right corner): 24° 41' N, 120 25' E




Map 1: Relative Location of Tao-yuan Irrigation to the other irrigation schemes in Taiwan




Map2. The Map of the Irrigation System of Tao-yuan Irrigation Association

II. Command and Irrigated Areas

| Year | Command Area (ha) | Irrigated Area (ha) |
|---|---|---|
| 1999 | 25,967 | 51,934 |
| 1998 | 25,985 | 51,970 |
| 1997 | 25,983 | 51,966 |
| 1996 | 25,983 | 26,023 |
| 1995 | 25,983 | 51,966 |
| 1994 | 26,004 | 43,361 |
| 1993 | 27,777 | 52,008 |
| 1992 | 26,001 | 52,002 |
| 1991 | 26,007 | 52,014 |
| 1990 | 26,083 | 45,560 |

Remark: 1. The cropping pattern of this scheme is double paddy rice crop pattern, i.e. growing two crops of paddy rice a year, thus the irrigated area was usually about twice of the command area.

2. In the year of 1995, the irrigated area was almost the same as command area, because a serious drought spelled out in the dry season from the December of 1994 to May 1995, and thus one crop of paddy rice was fallowed without undertaking any irrigation activity.

III. Land Tenure Structure

1. Prior to the Land Reform Period (1949):
   (1). Land Lords (land owner): 60 per cent of total estimated land annual production at fixed term regardless of actual production as the land rent for land lord to receive. Land lord also needed to pay land tax but not production costs.
   (2). Tillers or renters (Farmers): the renters kept the remaining 40 per cent of production, and had to pay all production costs and took risks of drought, flooding, insect and pet diseases.
   (3). It was estimated that about 60 per cent of land was rented out by non-farmer land lord, and remaining 40 per cent of land owned by farmers, i.e. they were land lords and also the tillers.
2. After Land Reform (after 1949 to now): the "**37.5 per cent Rent Reduction Acts**" was mandated in 1949, the details of ACTS are:
   (1). The rent of land was reduced from original 60 per cent of production to 37.5 per cent based on the actual production only counted on main crops (rice); and land lord also had to pay land tax;

(2). Land rental contract could not be expired without the agreement of renter; and renter had to bear all production costs and 37.5 per cent of water fees;

(3). Renter has the first priority to purchase the land when land was going to be sold; the Government would provide lower interest soft loan to farmers to purchase the land when the land lard was going to sell their land;

(4). The land-ownership structure had been greatly changed from the result of the implementation of these Acts. Nowadays, only about 5 per cent of land in this scheme is still owned by non-farmer land lord, and the remaining 95 per cent of lands is owned by farmers themselves.

IV. Date of Built: 1916 to 1924

V. Date of Modernization:

1. The first modernization: 1916 to 1924
2. The second modernization: 1957 to 1964
3. The third modernization: 1995 to now

VI. Water Resources:

Unit: 10,000 $m^3$/year

| Year | Shihmen Reservoir | Diversion weirs of creeks & Water Ponds | Total |
|---|---|---|---|
| 1999 | 37,223.71 | 24,055.68 | 61,279.39 |
| 1998 | 35,263.81 | 18,942.22 | 54,206.04 |
| 1997 | 35,354.19 | 19,184.15 | 54,538.34 |
| 1996 | 21,700.66 | 15,245.16 | 36,945.82 |
| 1995 | 36,221.56 | 18,346.64 | 54,568.20 |

VII. Energy Source:

About 99 per cent of energy source for the operation of irrigation system is from the electricity power provided by Taiwan Power Company. Energy has never been a problem for the operation of irrigation system.

VIII. System Type:

The system type of this scheme either on-farm or off-farm is gravity and open channel type. Only one sub-scheme with an area of about 50 ha

has built pipeline system to substitute on-farm open channel ditches. The initial investment cost of pipeline system was still too expensive unable to compensate the saving of maintenance cost of open channel ditches.

IX. Water Rights:

1. According to the "Water Law" of Taiwan, any water user is entitled to register water rights based on the actual need in the water rights registration office under the Department of Water Conservancy, the Ministry of Economic Affairs.
2. The registration of water rights would be permitted on first-come-first service basis until the availability of water at certain location in certain period is being registered exhausted. It is therefore, the registration of water rights is usually has to notice to the public for at least one month to wait until no complain from any third party on his registered water rights would be offended has been received by the registration office.
3. The registration of water rights has submitted with justifiable every 10-day water use program.
   (1). When drought was spelled out, the availability of water resources could not meet the need of all water users registered water rights, the order of priority for sharing the limited water resources is given to: domestic water; agricultural water; then industrial water, and others.
   (2). Annual availability of water resources in Taiwan is characterized by wih very high fluctuation. In the minimal year, the annual availability water can be only 30 per cent of long-term average, while in the maximal year at 210 per cent.
   (3). Water registration was usually not precisely counted its actual availability. In this connection, the amount of registered water rights was usual much higher than the actual amount that the register can obtain. Tao-yuan scheme had the same situation. The comparison of the amount of registered water and actually diverted water is shown below:

Unit: 10,000 $m^3$

| Year | Amount of registered water rights | Actual amount of water diverted |
|---|---|---|
| 1999 | 104,529.40 | 61,279.39 |
| 1998 | 177,705.96 | 54,206.04 |

X. Main Crops: Paddy rice

XI. Main Soils

| Type of Soils | Clay loam | Sandy loam | Light clay | Sandy Clay | Total |
|---|---|---|---|---|---|
| Percentage to the total area (%) | 39.0 | 26.0 | 18.6 | 16.4 | 100.0 |

XII. Type of Infrastructure

| Infrastructure | Quantity and Type |
|---|---|
| Main Reservoir (Shiemen Reservoir) | Rock-filled earth dam, with gate-controlled Ogee type concrete spillway and one power plant |
| Off-farm irrigation canals | 549,980 m. in length, 100%with concrete lining |
| On-farm irrigation ditches | 2,206,268 m. in length, 51% with concrete lining |
| Diversion weir with Head Works | 377 in number, and 100 % in concrete structure |
| Canal related structures | 19,736 in number, and 100% in concrete structure |

XIII. Q design: 18.0 $m^3$/sec at the intake of Shiemen Reservoir

XIV. O&M Costs:

Unit: US$1,000 (Constant price at 2000)

| Year | Total O&M Costs | | | | |
|---|---|---|---|---|---|
| | Maintenance of infrastructure | Personnel costs | Operation Costs | Rehabilitation of Flood Damages | Total |
| 1991 | 3,415 | 4,205 | 10,307 | 1,799 | 19,726 |
| 1992 | 3,284 | 3,840 | 10,853 | 88 | 18,059 |
| 1993 | 3,769 | 4,165 | 9,354 | 118 | 17,408 |
| 1994 | 3,225 | 4,594 | 4,2,52 | 496 | 12,539 |
| 1995 | 4,589 | 4,930 | 20,920 | 666 | 31,104 |
| 1996 | 3,723 | 5,134 | 4,313 | 27 | 13,197 |
| 1997 | 2,987 | 5,650 | 6,156 | 403 | 15,196 |
| 1998 | 2,085 | 6,129 | 6,114 | 214 | 15,261 |
| 1999 | 2,723 | 6,360 | 9,331 | 269 | 18,683 |
| 2000 | 4,230 | 8,876 | 12,910 | 263 | 26,290 |

Remark: Foreign exchange rate in 2000: US$1.0=NT$31.23 (local currency)

XV. Other:

There are about ten (10) industrial zones situated inside the command area of this scheme. Most of wasted water from those industrial zones was not treated appropriately and directly drained into the all creeks of the scheme. Water pollution of the water resources from creeks is becoming more and more serious. Water quality monitoring and control is now the newly emerged issue for the operation of this scheme.

**Part B:**

**Modernization Process**

I. Causes that led to system modernization

1. The first modernization (1916 to 1924)
   (1). The policy of colonial Japanese Government needed Taiwan to produce more rice and sugar to meet their food sufficiency; and
   (2). Exporting rice and sugar was the potential for foreign exchange earnings.
2. The second modernization (1957 to 1964)
   (1). Concerning the possible war between two sides of Taiwan Straight, the Government's policy led to produce more rice and to enhance the level of food security. The modernization of irrigation scheme included: construction of big size of reservoir, undertaking concrete lining projects for canal system, land consolidation program and improvement of canal related structures etc., so as to increase the availability of water as well as to enhance the irrigation efficiency and to expand the irrigable areas; and
   (2). Foreign exchange earning by exporting rice and sugar was the one of the viable methods before Taiwan's industrialization has started.
3. The third modernization (1995 to now):

   Irrigation Associations (IAs) in Taiwan are the autonomous farmers' cooperative bodies, which have ever been characterized by high water uses' participations, including payment for operation and maintenance and for substantial portion of system improvement. Presently, users' participation in terms of financial self-sufficiency has declined totally, and water users are no longer required to pay any water fee, while the Government has become obligated to provide

reasonable funds every year to IAs for keeping the system operable since 1995. However, provision of such funds to IAs is a heavy burden of the Government. Therefore, Government usually requested all IAs to take appropriate austerity measures to reduce the operation cost. As a result, the status of O&M for all IAs in Taiwan since 1995 have been in the following status:

(1). O&M costs for the operation of all irrigation systems in Taiwan have been becoming sky-high together with issue of rice surplus, thus rice production with irrigation is no longer economically viable. The function of irrigation has changed from the enhancement of rice productivity to: maintaining the food security; preventing further widening the income gap between rural and urban; control of rice surplus, and preserving ecosystem, biodiversity and multi-functionality of paddy field; and

(2). In order to realize the above-mentioned needs, the latest modernization has emphasized on the enhancement of operation efficiency to reduce the O&M costs for irrigation system; and preserving soil and water for the long-run sustainable utilization.

II. Steps of the modernization process: Who, what, how?

1. The first modernization (1916 to 1924)

(1). Who:

The colonial Japanese Government initiated and implemented the modernization, and the farmer's organization, i.e. irrigation association, was just followed the Government's order and rendered their assistant role in completing the modernization.

(2). What:

Undertaking the irrigation modernization including:

- Construction of an main intake on the upstream of Ta-ku-kang River;
- Construction of new water convey system consists of leading canal 20,467 meters, main canal 25,376 meters; lateral canal 258,872 meters; and all required canal related structures;
- Construction of 231 on-farm water storage ponds;
- Construction of 132 diversion weirs on the small creeks;
- Construction of on-farm irrigation ditches for 846,486 meters;
- The irrigable area increased from about 6,000 hectares to

23,000 hectares with more stable water resources.

(3). How:

- Detailed environment, geographic and soil surveys and investigations on the command area;
- Social-economic, and agronomy related surveys;
- Status investigation on existing irrigation schemes;
- Drafted and legislated required laws and regulations to legitimate the modernization;
- Modernization study on engineering planning and design;
- Drafting modernization program and submitting it to the Government for review, and the public hearing was taken place, the agreement of beneficiaries was signed to commit to participation in irrigation modernization including: following the planned cropping pattern and payment of cost recovery fees and O&M costs;
- Government approved the modernization Program;
- Government allotted budget for the modernization program;
- Project implementation, completion, operation and maintenance.

2. The second modernization (1957 to 1964)

(1). Who:

Taiwan was restored the Republic of China in 1945,. Government's policy at that time was to prioritize the increase in rice production so as to assure national food security, and to earn foreign exchange from rice exportation. Thus the Government was the initiator and the financial supporter for the second modernization.

(2). What:

- The large size of multi-purpose of water storage facility at original intake site, Shiemen Reservoir, was constructed to replace the old intake and further constructed the following related structures:
- One 133 meter high, 369 meter long earth rock filled dam;
- With 310 million $m^3$ maximum gate controlled storage capacity; or 210 million $m^3$ without gate controlled effective storage capacity;
- One 45,000 KW hydraulic power plant;
- An additional 36 kilometers long main canals; 136 kilometer

long lateral canals and 163 kilometer long sub-lateral canals to increase the irrigated area by 20,600 hectares mainly in the higher land were constructed in irrigated area. This scheme was organized as a new irrigation association, namely Shiehmen Irrigation Association, not belonging to the Tao-yuan Irrigation Association;

- The irrigated area of Tao-yuan Irrigation Association was not increased, but the water resources became much more stable and the productivity of the irrigated area increased by about 15 per cent to 20 per cent;
- In addition to provision of water resources to the irrigation and power sectors, this new multi-purpose reservoir also provided 30,000 $m^3$ of water daily to the domestic and industrial sector;
- Land consolidation for on-farm systems were about 85 per cent completed during that period; and
- Canal related structures including water measurement devices and water controlling structures were 90 per cent improved enabling to carry out a higher efficient rotation irrigation,

(3). How:

The procedures and step to undertake this second modernization were mostly followed the way of above-mentioned first modernization except the relevant laws were revised to the Chinese way with more democratic manner and rather higher beneficiaries' participation.

3. The third modernization (1995 to now)

(1). Who:

In order to reduce the operation cost, modernization of irrigation system this time was initiated by irrigation associations themselves. However, technically and financially, the Government still provided about 20 per cent of financial assistance for the modernization.

(2). What:

- Computerizing all operations in a maximal ways, including internal documentations, bookkeeping, statistics, irrigation planning and field data recording, computerizing the engineering survey, design, and billing documentation, GIS

for land ledgers, and irrigation and drainage systems;

- Automation and remote control of main irrigation facilities, including check, intake and off gates;
- Remote sensing the records of weather, hydrology and water measures devices, and the automation of recording, transmission, and centralized display;
- Set up about 30 sites of water quality monitoring stations, regularly sampling irrigation water to the water quality laboratory located in the Head quarters of irrigation association for testing; and
- Soil pollution monitoring and the establishment of related laboratory are under planning; and it would be implemented within next three years.

(3). How:

- Most modernizations this time were initiated and carried out by irrigation association himself; it did not like the last two times of modernizations which were planning, designed, financed and carried out by the Government;
- The modernization activities were not well planned and scheduled; they might be carried out just depending upon the availability of funding and techniques;
- Many modernizations were carried out by cut-and-try basis, so some of them were not very successful or even failed and given up;
- Among irrigation associations, they learned and help each other with less Government assistance; and
- It is therefore, modernization is still going on, and will be continually carried out for the coming few years.

Ⅲ. Organizational/Institutions involved, including users participation

1. The first modernization (1916 to 1924)

(1). Central Government:

- Japan Cabinet: approved budget for modernization;
- Taiwan Governor Office of Japan Colonial Government: Executing agency of modernization project.

(2). Tsou (County) Office: Implementing agency of the modernization;

(3). Tao-yuan Irrigation Association: one of main implementing

agency;

(4). Agricultural Experimentation Stations inside the project area:

Conducting experiments on optimal cropping pattern and most efficient irrigation methods during the construction period.

2. The second modernization (1957 to 1964)

(1). Central Government:

- Executive Yuan of the Republic of China: approved budget;
- USAID Office in Taiwan: provide soft loan and grant for technical assistance;
- JCRR (Joint Commission on Rural Reconstruction): US assistant office specialized in agriculture and rural development sectors; provision of technical assistance and financial supports

(2). Provincial Government:

- Water Conservancy Bureau of Taiwan Provincial Government: Executing agency of modernization;
- Shiehmen Reservoir Construction Committee: the implementing agency ( on a job oriented temporary basis)
- Tao-yuan Irrigation Association: support the implementation of the modernization; and
- Local relevant agricultural experiment stations in charge of the arrangement of optimal farming schedule, irrigation method, and selection and recommendation of the most suitable varieties of rice and other upland crops, and
- More than 60 per cent of beneficiary farmers had signed individual agreement to accept the Government's arrangements of new cropping pattern and to pay the project cost recovery (60 per cent of project cost) within 15 to 20 years)

3. The third modernization (1995 to now)

The third modernization has not been implemented on a project basis. There were no a firmed target and schedule and no special executing and implementing agencies has been set-up. Therefore the agencies and institutions involved are only limited below:

(1). Central Government

- The Commission of Agriculture (COA): provision of partial financial supports;
- Relevant agricultural experiment stations; and

- Relevant engineering academic and research agencies;

(2). Tao-yuan Irrigation Association: implementing agency;

IV. Implementation of the modernization process

The details of implementation of modernization process have already been shown in Part B, II. Steps of the modernization process: Who, what, how? It would not be repeated here.

V. Actual modernization that took place:

All modernizations indicated in this report had all actually taken place.

VI. Was any Training done prior, during or after modernization? What, how and for whom?

1. Planers and designers of modernization

   Most of planers and designers for modernization were the Government's employee. They had their regular training program. And special training program particularly for modernization was generally on a self- education basis.

2. System operators:

   All irrigation operators to be in charge of the operation and maintenance of modernized irrigation system were provided on-job training programs to assure that they would understand and familiarize with the rules of the operation for modernized system. Most of trainers and trainees were usually the system designers, planners and operators.

3. Farmers:

   Demonstrations in the relevant experimental stations were the commonly adopted as training program for the benefited farmers.

VII. Financing of the process

4. Except the third modernization, the Government' budget provided 100 per cent of financial supports to the implementation of modernizations including the costs of planning, design, and construction. The cost recovery from the beneficiary was limited to about 60 per cent of the construction costs. Repayment period usually included two years longer than construction period as the grace period; and repayment period was generally 15 to 20 years

5. Third modernization is implementing on a regular O& M basis. Government is generally finance 40 per cent to 100 per cent of annual required costs. No cost recovery mechanism has ever been collected.

VIII. Estimated cost of the process; Total, per unit area

6. The first modernization (1916 to 1924): No data available
7. The second modernization (1957 to 1964):

| Total Costs in billion NT$ (Prices of current year) | Total Costs in billion NT$ (at constant price of year 2000) | Total Costs in billion US$ (at constant price of 2000 | Unit area cost NT$ per hectare at constant price of 2000) | Unit area cost in US$ per hectare (at constant price of 2000) |
|---|---|---|---|---|
| 5.914 | 8.043 | 0.2495 | 309,359 | 9,598 |

(1) The total cost mainly modernization of irrigation system including about 30 per cent of the total costs of dam, and total costs of land consolidation and drainage improvement and other major improvement of infrastructure undertaken until 1990s; but excluding the costs of power plants, domestic water supply facilities;

(2). The average price escalation factor in engineering construction cost is estimated at 1.0 per cent per a year;

(3). Foreign exchange rate in the year 2000 was estimated in average at: US$1.0=NT$32.23

8. The third modernization (1995 to now):

(1). The modernization is not being carried out on a project basis; the progress of modernization depends on: availability of funding inclusive of Government's subsidy and the counter funds of irrigation association.

(2). The average annual cost of the last 6 years is estimated at NT$9.0 million at the constant price of 2000 (US$ 280,000), or NT$346 per hectare per annum (US$11.0 per hectare per annum).

IX. Was system performance evaluation done PRIOR to modernization? Elaborate

System performance evaluation had been evaluated prior to the modernization was carried out. The evaluations were carried out differently in the three modernizations shown below:

1. The first modernization (1916 to 1924):

- Prior to the modernization, the Colonial Government needed very

badly the sufficient food for Taiwan as well as for Japan. The Government had found that, the Tao-yuan area would be the most appropriate place to increase significant mount of rice production through modernization of existing irrigation system;

- The history of rice cultivation have already prevailed for more than 300 years, farmers were familiar with rice production; population density was one of the highest area among various agriculture areas in Taiwan; labor shortage would not be worried for rice production after modernization;
- Soil is rather heavy and irrigation efficiency could be high;
- The average annual rainfalls recorded at that time was about 1,500 mm and its distribution was comparatively even; it had the advantage of utilizing the effective rainfalls;
- Major river water resources were about 75 per cent to 80 per cent adequate to meet the needs of irrigation requirements for two crops of paddy rice;
- Social orders was becoming stable;
- Overall evaluation was concluded that, there was very high possibility to realize the target of irrigation modernization.

2. The second modernization (1957 to 1964)
   - A larger scale of water storage reservoir was found imperatively important for a need of significant increase in the rice production;
   - Technique on the enhancement of irrigation efficiency by adoption of rotation irrigation on various level was found to be mature obtained from the experiment stations or demonstration farms;
   - Technique of design and construction of earth dam by local engineers became possible with a minimal foreign technical assistance;
   - Effective use of fertilizers and pesticides to increase rice production by 5 to 10 per cent was ensured;
   - From macro economic point of view, either food security (worried about war), larger scale increase in rice production was a national consensus at time;
   - The industrialization around the irrigation area started, competition in the use of water resources among various sectors might occur anytime in the future, and thus additional water resources were required to develop by construction of larger

reservoir and modernization of irrigation scheme was deemed to be justifiable.

3. The third modernization (1995 to now).
   - Serious rice surplus has started since mid 1980s[1], and the rice production costs in Taiwan at that was about 300 per cent higher than the international trade price, thus the surplus rice not only could not be consumed in the local market but also was unable to be exported. Consequently, the Government had to start to carry out " *the Rice Fallowing Program*", of which a reasonable amount of cash was provided to the farmer whoever was entitled to grow rice but was willing to fallow his land". This Rice Fallowing Program is still one of the important agricultural activities every year as of now;
   - Flowing the industrialization, the labor wage rate in Taiwan was increasing every year, correspondingly, the operation cost of irrigation schemes became higher every year, irrigation associations could not operate the irrigation scheme just depending upon the water fees collected from the farmer, and thus the Government begun to subside the O&M costs for all irrigation associations. The rate of subsidy to the O&M started from 40 per cent of the total at mid 1980s to 100 per cent in 1995;
   - After rice surplus has occurred since 1995, increasing the yield of rice production and enhancing the irrigation efficiency was no longer the Government's agricultural policy. The emphasis of rice production cost since then has been placed on the food security, avoiding widening the income differentials between the urban and the rural;
   - Correspondingly, it is no longer justifiable to increase the subsidy for the O&M costs for all irrigation associations; and thus the Government had frozen the subsidy level at 300 kg paddy rice equivalent cash since 1995;
   - Regardless of freezing the Government's subsidy O&M costs to irrigation associations, the actual cost for labor wages and staff salary kept increasing every year. It meant that all irrigation associations had no choice to take both austerity measure and

[1] As mater of fact, rice surplus occurred by the decrease in per capita rice consumption from 120 kg per capita per year in 1960s to 60 kg per capita per year in 1990s, simultaneously non-rice foods such as wheat products, meat, milk, wine, liquor were imported and consumed as the substitution of rice.

increase the operation efficiency to meet the need of decreasing the available funds for O&M costs; and

- The third modernization was one of action program aiming at the enhancement of operation efficiency so as to reduce the O&M costs.

**Part C:**

**Impact of modernization: Describe CHANGES, if any, in the following aspects of the system as result of the modernization activity**

I. Governance:

Governance has never been a serious issue for the operation of irrigation scheme in Taiwan; and the above-mentioned three times of modernization have never set "governance" as the main target for modernizations. No significant impact of modernization in the aspect of the governance of irrigation association has ever found.

II. Water rights, water allocation

1. The first modernization (1916 to 1924)
   - When industrialization did not yet start, about 80 to 85 per cent of developed water rights had preserved to the irrigation sector; and water uses in domestic water supply and industrial sectors were still very minor.
   - Whenever drought spelled out, irrigation sector was usually able to allocate almost adequate water 100 per cent satisfying the need of domestic uses and industrial purposes, because the need of additional water from both sectors was so minor compared to the need of agriculture regardless of shortage of agriculture sector still were still existing.
2. The second modernization (1957 to 1964):
   - Competition on the use of water between agriculture and non-agriculture sectors including domestic and industrial uses started in the early 1980s. When the water shortage of non-agriculture sectors occurred, the irrigation sector was always being asked to transfer part of his water to other sectors;
   - Water transfer from agriculture to non-agriculture sectors usually happened when it was drought before mid 1980s; after that time, the inter-sector water transfer begun on a regular basis; and the agriculture sector was usually compensated by cash from the

non-agricultural sectors with the average rate of US$0.08 to US$ 0.12;

- The non-agricultural sectors shared only 5 per cent of the total water rights of Sheimen Reservoir when it was completed in 1964; and now about 25 per cent of total water resources are consumed by domestic and industrial sectors. The trend of increasing appears more rapidly than before.

3. The third modernization (1995 to now):
   - The competition over the use of limited water resources after 2000s is becoming more acute, demand of the amount of water to be transferred from agriculture is always larger than the decrease in the area of agriculture;
   - The irrigation sector is not satisfied with the compensated prices of water being transferred; negations and argument over the amount compensation for water transfer have never stopped;
   - Regardless of water rights registered is in favor of irrigation sector, whenever drought occurs, the Government always exercises his administration power to allocate more adequate of water for non-agriculture sector, because the production value of per unit of water in industrial sector is about 75 to 250 times of agriculture sector.

Ⅲ. Water service fee structure:

1. The first modernization (1916 to 1924):
   (1). Cost Recovery Fee for Construction:

   About 40 to 60 per cent of the total cost recovery fees were collected within 30 years from the beneficiaries; but the information of precise percentage of cost recovery had been collected is not available.

   (2). Water Service Fees for O&M:

   The amount of water service fees were collected sufficient to provide 60 per cent of total O&M costs; but during the World War II, the collection was intermitted.

2. The second modernization (1957 to 1964)
   (1). Cost Recovery Fee for Construction Costs:

   60 per cent cost recovery for the total construction costs was agreed by the beneficiary, but after completing 85 per cent of total amount for collection, the Government had paid on behalf of the

farmer, because the Government had found that the farmer repayment capability had become very low.

(2). Water Service Fees for O&M Cost:

In principle, the beneficiaries had to pay 100 per cent of O&M costs; but there set a legal floor and ceiling for this kind of water fee collection, i.e. 30 kg of paddy rice equivalent cash was the floor for the water fee; and 300 kg for the ceiling. Most cases, only ceiling was sufficient to maintain the system operable.

3. The third modernization (1995 to now)

Both the cost recovery and O&M fees were exempted since 1995, and thus farmer are free to use water and the Government pays for the farmer.

IV. Water service provider:

The irrigation association has been the water service provider since the first modernization until now.

V. Water distribution method:

1. Gravity method is unique method being adopted for water distribution all the times for this scheme.
2. Rotation irrigation method has been prevailing either on-farm and off-farm system.

VI. System performance: agricultural water productivity, equity of water distribution, economic indicators, impact on environment, administrative and financial, farmers' satisfaction, etc.

1. The first and second modernizations were deemed to be fairly successful. The goals or target of modernizations were about 85 to 90 per cent realized.
2. Rice production had not only provided adequate food domestically, but also had surplus for export. The society of the scheme area apparently appeared prosperous after completion of modernization.
3. The increase of rice production was not only from the enlarging the cultivation area due to the availability of water, but also from enhancing the yield of unit area by adopting the technique of pest and insect control, better use of fertilizers and efficient irrigation as well. The yield of paddy production had increase from average of 1.0 to 1.5 ton of paddy per hectare per crop to about 2.0 ton in the first modernization. For the second modernization, the average increase in

per unit area of rice production about by 10 to 15 per cent or 4.5 ton per hectare per crop and the highest yield of 6.0 ton per hectare per crop was often found.

4. After adoption and practice of rotation irrigation, the equity of water distribution was considered to be one of the best schemes in the World.
5. The percentage of national agriculture GDP contribution was estimated at 5 to 8 per cent.
6. The most import environment impact was that, because of the availability of water resources, population is increasing and recently more than 10 industrial zones were established inside the area of irrigation schemes, because of which the problem of water resources pollution has been increasingly serious.
7. The administration of this irrigation scheme is considered to be satisfactory to the farmer and the Government. The financial status of this irrigation association is one of the four best in Taiwan. The association is not only capable of properly maintaining the irrigation system, but also is able to support irrigation relevant research domestically and internationally.
8. Farmers were generally satisfactory with modernizations, their farming incomes had generally increased by 5 to 15 per cent; however they still complained that, the water fees including cost recovery and O&M costs were too high to them. Sometimes, when drought spelled out, their net incomes of farming had been almost negative.
9. As for the third modernization, the program is undertaking and final evaluation cannot be done immediately. The only thing we can mention is that, although the objectives of this modernization are mainly for the reduction of operation costs, but it did not appear more cost saving in terms of personnel cost. Computerizing the operation system and remote control or GIS etc. have actually improved the operation efficiency and quality, but for handling those modernizations, the association needs to hire more well educated staff and the old staff are not justifiable to be laid off now. It therefore, the total operation costs of third modernization as of today does not appear significantly more cost saving. However, in the long run, it may be more cost saving in the operation when the old staff is retired.

VII. Have others systems in the country followed the same process?

Yes! Existing other 16 irrigation schemes followed the same process. Actually, the process was formulated by the Government and could be considered to be the Government's policy.

**Part D:**

**Consultant's own conclusions and/or comments/suggestions/recommendations**

I. What is YOUR appreciation of modernization that took place?

One of most important factors for the success of modernization is that the Government led the modernization, and they had sufficient manpower to undertake the planning and design. They had never been in hurry to implement the modernization until:

1. Technically, the modernization was very sure feasible;
2. Modernization never started until the whole financial sources had been found available;
3. Beneficiary's participation was at maximum manner;
4. About 99 per cent of technique was originated locally; therefore they are more suitable and practical..

II. Do you perceive any MAJOR gaps in the process that took place?

The economical and financial benefits of modernizations did not 100 per cent realized was found the major gaps in the process of modernization. In particular, farmers were usually unable to pay 100 per cent of cost recovery for construction toward the end of payment schedule.

III. Can the process be replicated elsewhere?

Yes, provided the Government has sufficient desire, financial capability and manpower to undertake the planning, implementation, and maintain and operate of modernized schemes.

IV. What lesson can be learned from the modernization process that took place?

The international trade price of paddy rice is so low that very few countries could implement the irrigation modernization with a economically viable manner. Even previous two times of modernizations in Taiwan had been carried out mainly based on the political decision rather than economical justification. As cost for modernization of irrigation schemes is so high now that, the modernization of irrigation can be carried out only based on the social welfare or for political gaining; otherwise the

modernization of irrigation scheme as the manner of Taiwan should be very cautiously planned.

V. Do you feel there is enough information in order to undertake a more IN-DEPTH study on the process some comments

Definitely yes!

**APPENDIX 1**

FAO: International Program for Technology and Research in Irrigation and Drainage (IPTRID)-

Terms of Reference (TOR) for
Survey on Modernization of Irrigation Systems on
The Schemes of Tao-Yuan Irrigation Association, Taiwan

Part A. Brief description of the Modernized irrigation system, including, at least:

- Location
- Irrigated Area
- Date Built
- Water Resources
- System Type
- Main Crops
- Type of infrastructure
- O&M
- Command Area
- Land tenure structure
- Date Modernized
- Energy Source
- Water Rights
- Main Soils
- Q design
- Others

(The consultant is encouraged to present MOST of this information in table form)

Part B. Modernization Process

- Cause that led to system modernization
- Steps of the modernization process: Who, what, how?
- Organizational/Institutions involved, including users participation
- Implementation of the modernization process
- Actual modernization that took place
- Was any Training done prior, during or after modernization? What, how and for whom?
- Financing of the process
- Estimated cost of the process; Total, per unit area
- Was system performance evaluation done PRIOR to modernization? Elaborate

Part C. Impact of modernization: Describe CHANGES, if any, in the following aspects of the system as result of the modernization activity

- Governance
- Water rights, water allocation
- Water service provider
- Water distribution method

- Water service fee structure
- System performance: agricultural water productivity, equity of water distribution, economic indicators, impact on environment, administrative and financial, farmers satisfaction, etc..
- Have others systems in the country followed the same process?

Part D. Consultant's own conclusions and/or comments/suggestions/recommendations

- What is YOUR appreciation of modernization that took place?
- Do you perceive any MAJOR gaps in the process that took place?
- Can the process be replicated elsewhere?
- What lesson can be learned from the modernization process that took place?
- Do you feel there is enough information in order to undertake a more IN-DEPTH study on the process some comments

# OUTPUT 4

Background Paper – Agricultural Water Use and Improving Rural Livelihoods in Sub-Saharan Africa: Current Status, Future Directions, and the Role of IPTRID. A Contribution to the IPTRID Session at ICID, Montreal, July 2002

# AGRICULTURAL WATER USE AND IMPROVING RURAL LIVELIHOODS IN SUB-SAHARAN AFRICA: CURRENT STATUS, FUTURE DIRECTIONS, AND THE ROLE OF THE INTERNATIONAL PROGRAMME FOR TECHNOLOGY AND RESEARCH IN IRRIGATION AND DRAINAGE (IPTRID)[F1]

Keynote Paper prepared for the IPTRID Event [F2]at the International Congress for Irrigation and Drainage (ICID), Montreal, Canada, 23 July 2002

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Preparation of this paper was an office-wide team effort. With support from Douglas Merrey, Marna de Lange coordinated the various inputs and chaired the meetings where drafts were discussed. Sections were written by Charles Crosby, Francis Gichuki, Arlene Inocencio, Abdul Kamara, Hervé Levite, Douglas Merrey, Hilmy Sally, and Barbara van Koppen. Douglas Merrey then integrated and finalized the paper for presentation. Correct author citation would be in the following order: Merrey, de Lange, Gichuki, van Koppen, Inocencio, Kamara, Crosby, Levite, and Sally. The views expressed are those of the authors.

# [F3]AGRICULTURAL WATER USE AND IMPROVING RURAL LIVELIHOODS IN SUB-SAHARAN AFRICA: CURRENT STATUS, FUTURE DIRECTIONS, AND THE ROLE OF IPTRID

## I. Issues Facing SSA in Relation to the Role of Irrigation in Rural Livelihoods

### 1.1 Overview

This paper was commissioned by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID). Its focus is on small-scale agricultural water use technologies (irrigation in its widest sense) in sub-Saharan Africa. Section 1 provides an overview of the current status of natural resources, rural development and poverty, irrigation investment trends, and emerging new irrigation technology options. Section 2 discusses IPTRID's contribution to these emerging options. Section 3 proposes some ideas for consideration in terms of the future directions of IPTRID's work on small-scale irrigation in sub-Saharan Africa.

### I.2 Water and Other Natural Resources[1]

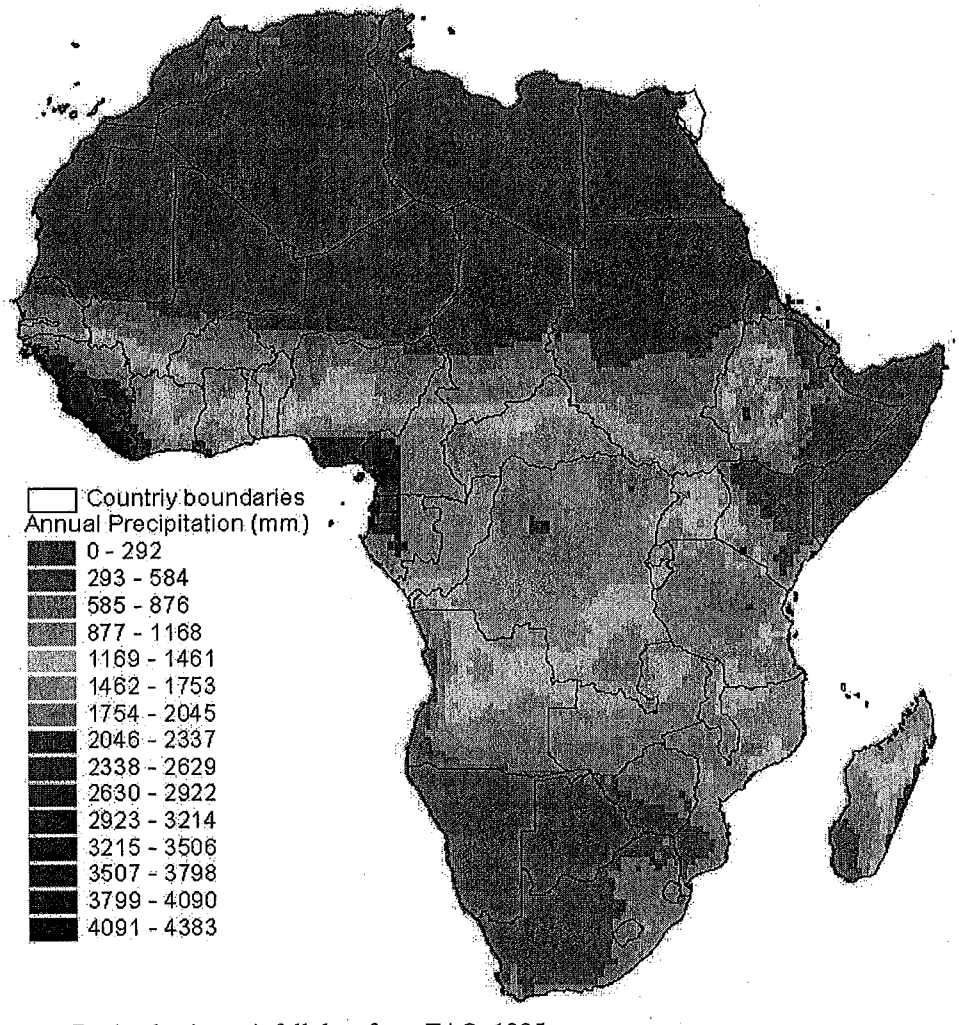
#### *1.2.1 Limited and unreliable rainfall*

The mean annual rainfall over the African continent is 724mm and the standard deviation is 664. The rainfall is poorly distributed with approximately 67 percent of the area receiving less than 1 000 mm per annum (Figure 1). Twenty five percent, 50 percent and 75 percent of the land area receives less than 134, 564 and 1,178 mm per annum respectively. Approximately 10 percent of the area receives more that 1,650 mm. Hence the internally renewable water resources in semi-arid areas of Africa is low and the potential contribution of the more humid areas to water resources in the semi-arid areas is limited due to the low percentage of the areas receiving more than 1,000 mm of rainfall and their spatial distribution.

Other characteristics of rainfall in the semi-arid portions of sub-Saharan Africa (SSA) that create additional management challenges are its high intensity, short duration, temporal variability, and unpredictability. High rainfall intensities lead to high runoff and soil loss potential. The short duration limits the length of the growing season, while temporal variability and unpredictability of rainfall is an important reason for smallholder farmers' reluctance to invest in high input crop production. There is also a high variability in the rainfall onset date (30–50 days onset window) and the seasonal rainfall decreases with the delay in the onset of the rains. For example, trends analysis of seasonal rainfall for Dwa-Kibwezi rainfall station in the semi-arid areas of Kenya, which has a bimodal rainfall shows that seasonal rainfall (120 days) has a range from 0–850 mm. A chronology of bad, fair and good rainfall seasons (defined in terms of a seasonal rainfall threshold value of 250 mm needed to produce a Makueni Composite Maize crop)

[1] Much of the material in this section is adapted from a recent paper by Gichuki and Merrey (2002).

shows that bad seasons occur characteristically in runs of 2–5 seasons rather than singly (Gichuki, 2000).




Source: Derived using rainfall data from FAO, 1995.

**Figure 1: Spatial variability of annual precipitation.**

### *1.2.2 Irrigation in sub-Saharan Africa*

An estimated 88 percent of water diverted for human use in SSA goes to agriculture. Arid regions, where irrigation plays an important role, have the highest level of water withdrawal for agriculture. In contrast, the humid regions show the lowest agricultural withdrawals: 62 percent for the Gulf of Guinea and 43 percent for the central region, where agricultural water use is of the same order of magnitude as domestic use. Out of a total area of 212 million ha under cultivation in sub-Saharan Africa, an estimated 5.1 million ha (2.4%) is under irrigation, supplying 10 percent of the agricultural production. Regional distribution of areas under irrigation, however, is very uneven. Three countries (Madagascar, South Africa and Sudan), which cover 18 percent of Africa, account for

almost 70 percent of the irrigated area. In contrast, 28 countries, covering more than 30 percent of Africa, share a mere 5 percent of irrigated lands.

An FAO study (FAO, 1995) estimates the irrigation potential in Africa, based on land suitability, water availability and irrigation requirement, to be about 42.5 million ha for the entire continent. Of this potential area, an estimated 60 percent is concentrated in only seven countries (Angola, Sudan, Egypt, Zaïre, Ethiopia, Mozambique and Nigeria). If the area under irrigation in SSA were increased by 5 percent per year to over 17 million hectares (a high investment scenario as compared to the present expansion rate of less than 1 per cent), this would still represent a minor contribution to the required threefold food production increase needed by 2025 (FAO, 1995).[F4]

### 1.2.3 Overuse of water in upper reaches of river basins

Overuse of water by upstream users is significantly reducing dry season river flows in many rivers in Africa. In the Ewaso Ngiro in Kenya for example, dry season flows have been reported to decrease from 10 to 1 $m^3/s$ between 1960 and 2000 (Gichuki et al., 1998). Similar experiences are reported for the Great Ruaha river in Tanzania where dry season flows have been reported to have declined since the early 1970s, with the complete cessation of flow during drought years (SMUC, 2001). The situation is predicted to get worse in the future. For example in the Lower Limpopo Basin one study predicts there will be a decrease of 20 percent in the present inflows of the Limpopo at Pafuri (Mozambique) in the medium term; and a decrease of 20 percent in the inflows in the Olifants and 40 percent in the Limpopo at Pafuri in the long term (UNEP, 2000a). Over-use of water in the upper more humid watersheds results in reductions in surface water flows into the semi-arid areas. This has major implications for future surface and groundwater availability, cost of development, and management responses in the semi-arid areas.

### 1.2.4 Periodic droughts

Climatic droughts occur when rainfall is below normally expected amounts. Droughts of different intensities have been reported for different parts of semi-arid areas. Gichuki (2000) reports that in the semi-arid areas of Makueni District, Kenya, the probability of light, moderate and severe droughts ranges from 43-55, 32-43, and 13-30 percent respectively. The chronology of drought indices show that droughts come in runs of 2-5 seasons.

Semi-arid regions experience periodic droughts with adverse and sometimes crippling food security impacts. High risks for crop failure are a reality every 5th year and risk of yield reductions associated with water constraints every 2nd year (Rockström et al., 2001). The impact of drought is illustrated by recent Southern Africa experiences. In the 1994-95 cropping season in Southern Africa, cereal harvests declined by 35 percent compared to the previous year. The maize harvest fell by 42 percent due to drought (UNEP 2000b). Drought was equally devastating during the 1991-92 cropping season in the SADC region, where cereal production was nearly halved, with more than 20 million out of 85 million people affected by food shortages (UNEP 2000b). The current (2002-2003) drought is said to threaten the lives of nearly 30 million people.

Agricultural droughts occur when water supply is insufficient to cover crop or livestock water requirements. They are influenced by weather factors, investments in water conservation and water management strategies adopted to cope with drought conditions. A long series of droughts result in severe hardship, loss of planting material, desiccation of the land, loss of animals, and a high dependency on external assistance (food aid, remittances from relatives, etc.). The poor are the most disadvantaged by drought and its associated water shortages as they (a) pay very high prices per unit volume of water, (b) expend more calories carrying water for long distances, (c) suffer more in impaired health from contaminated or insufficient water, and (d) lose more in diminished livelihoods and in extreme cases loss of life.

### *1.2.5 Waterlogging and salinization*

Continental level analysis shows that approximately 40-60 percent of irrigation water is lost through seepage and evaporation. This seepage loss contributes to serious soil salinization and waterlogging problems. For example, in Mozambique, the lower Limpopo basin is experiencing serious salt problems partly due to the salinity brought down stream from the poorly drained Chokwé Irrigation scheme and also by salt coming from the Changane river tributary which passes through saline soils of the Changane Basin (UNEP, 2000a).

In the Nile Delta, waterlogging and salinity problems are very extensive partly due to the hot-arid climate, the high level of irrigation water use and the fine-grained alluvial soils with poor internal drainage (Murakami, 1995). Murakami (1995) reports that in 1982 almost all the irrigated area in Egypt was potentially affected by salt and about 400 $km^2$ of irrigated area were being equipped with drainage systems each year at a cost of US$200 per hectare to partially address the salinization problem. Solutions to waterlogging and salinization were being constrained by farmers' inability to make the required level of investment and the irrigation authorities' inability to effectively operate the drainage system.

### *1.2.6 Water pollution and soil loss*

Poor agricultural water management practices are the major source of water pollution and soil losses. Gichuki et al. (1998) report that the Upper Ewaso Ngiro North basin in Kenya experiences a high soil loss with suspended sediment load of the 15,200 $km^2$ basin area ranging from 350-1538 ppm. Kihara (1998) reports that sediment discharge for different sub-catchments of the Ewaso Ngiro North basin vary from 12 - 281 t $km^{-2}$ $yr^{-1}$. Thomas (1995) reports the sediment discharge of an ephemeral catchment (2.21 $km^2$) and reports suspended sediment discharge as high as 200 kg $s^{-1}$ during peak flow period. Soil loss at plot level for a single storm as found to range from 1-5.6 t $ha^{-1}$ (Mutunga, 1994) and the average seasonal soil loss for a gently sloping (5%) catchment in the semi-arid, Laikipia Plateau of the Ewaso Ngiro North basin is 24.8 t $ha^{-1}$ and 19.7 t $ha^{-1}$ for crop land and grazing land respectively (Liniger, 1995). Okwach (2000) investigated the effect of tillage and crop cover on runoff and soil loss on Chromic Luvisols on 8-10 percent slopes in Katumani, Kenya and reports that the control plot ploughed and left bare had the highest runoff and soil loss, 26 percent and 32 t $ha^{-1}$. The plot that was

conventionally ploughed, mulched with 50 percent of previous season maize stover and planted with a maize plant population of 22,000 plants per hectare had runoff loss of 15 percent and soil loss of 10 t $ha^{-1}$. A conventionally ploughed plot, mulched with 100 percent stover from the previous season and a maize plant population of 53,000 plants per hectare had runoff loss of 7 percent and soil loss of 2 t $ha^{-1}$. Doubling the maize plant population doubled the maize yield and reduces soil and runoff loss.

Compounding this soil loss is the loss of soil fertility. Soils deficient in major nutrients like nitrogen and phosphorus have been identified as a major problem affecting crop productivity in much of SSA. This is especially the case in densely populated countries like Ethiopia, Kenya, Malawi and Rwanda. There is a clear synergy, in a negative sense, between poor water management degradation of soil fertility.

Poor agricultural land use and management is blamed for eutrophication[2] that is taking place in some places at an alarming rate (Bugenyi and Balirwa, 1998). The increased deposition rates of nitrogen and phosphorous into water bodies is associated with agricultural activities and modification of the riverine ecosystem, particularly wetlands which perform some natural purification function. Degradation of these aquatic ecosystems is threatening the sustainability of fishery resources.

### *1.2.7 Groundwater*

Groundwater resources management challenges include groundwater recharge, development, pollution and over- or under-exploitation. In the semi-arid areas evaporation is higher than rainfall and hence the potential contribution of rainwater to groundwater recharge is low and mainly takes place in areas with sandy soils and/or where runoff accumulates. Hence most of the groundwater resources in semi-arid areas originate from the surrounding semi-humid and humid areas. Development of groundwater in semi-arid areas is constrained by the limited aquifer capacity and water yield, lack of data on water availability and quality, and the high cost of exploring, developing and lifting groundwater resources. Pollution and over-exploitation of groundwater is a serious problem in some localized areas. In other areas the groundwater resources are relatively under-utilized and can serve as a buffer against seasonal shortfalls in rainfall and surface water resources.

### *1.2.8 Projections of physical and economic water scarcity*

IWMI's global research on water scarcity and its relationship to food security shows that some countries in Africa (South Africa and Northern Africa) are facing "absolute water scarcity" – a divergence between future demand and available supply that is already leading to major changes in how water is managed (Seckler et al., 1998). The same study finds that all other sub-Saharan African countries are facing serious "economic water scarcity" – the cost of developing the necessary water supplies required by 2025 will seriously strain the country's finances (Figure 2).

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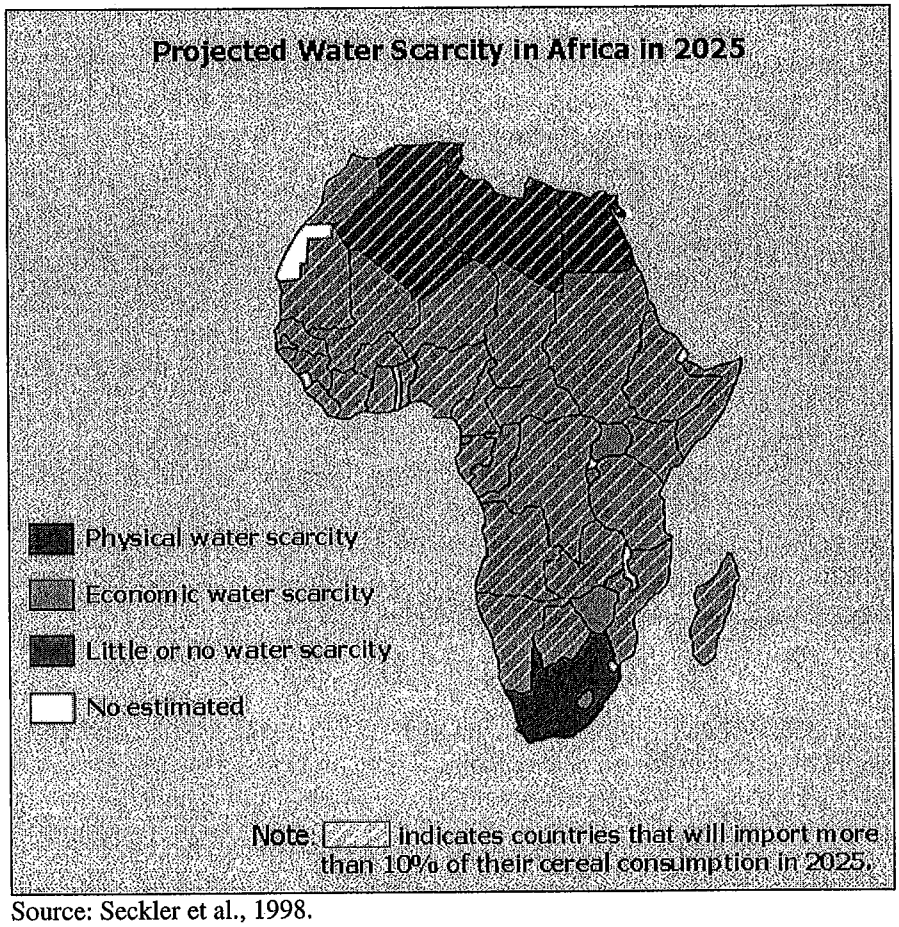
[2] Eutrophication is an aquatic environmental degradation process whereby water bodies become progressively enriched with nutrients (mainly nitrogen and phosphorous), with a resulting excess production of plant (usually algae) biomass which grossly disturbs the ecological functioning and floral and faunal balances of the water body.

Competition for water is thus on the increase. By 2025 an estimated 300 million of the region's expected population will be living in a water-scarce environment. When water quality is taken into consideration, the rate becomes even more alarming. As a consequence of this imbalance of demand and supply of water with an acceptable quality, as many as nine SSA countries will be in a situation of water stress by 2025, forcing them to make hard choices in development and water resource allocation between agriculture, domestic water use, power generation, environment and other uses.




Source: Seckler et al., 1998.

**Figure 2: A water scarcity scenario for Africa in 2025.**

Even if potential for expanding irrigation exists, agriculture will compete with the rapidly growing urban sector. If agricultural allocations are reduced and partially shifted to more lucrative urban markets, the rate of food production, which presently is not keeping up with population growth, may be further undermined.

### *1.2.9 Inappropriate land use and management*

The main natural ecosystems undergoing major land use changes in Africa are forests, grassland and wetlands. Intensification is taking place in most land uses particularly where high population pressure and market forces drive intensification. Inappropriate land use and management in both semi-arid areas and the more humid upland watersheds

have been identified as a major threat to water availability for domestic, livestock and wildlife use (Gichuki et. al., 1998).

Deforestation of upper watersheds has been identified as a major threat. Africa lost 55 million hectares to deforestation in the period 1980-1995 with Cameroon accounting for nearly 2 million hectares (FAO 1997). The Democratic Republic of Congo was ranked 3rd most deforesting country in the world with an annual loss of 740,000 hectares; Sudan is ranked 9th with an annual deforestation rate of 350,000 hectares. In just 100 years, Ethiopia's forests have declined from 40 percent to only 3 percent of the land cover. Cote d'Ivoire has been losing 15 percent of its tree cover every year and according to Irvine . (1996) only 2.5 percent of its original tree-cover remains. These land use changes have adversely affected ground and surface water availability and seasonality of surface water in the semi-arid areas as the upper watersheds are the main sources of water in semi-arid areas.

Wetlands form buffers that provide water quality regulation in receiving waters and represent a habitat of great ecological importance. The ecological functions of wetlands (e.g., as habitats for water fowl, fish, and other wildlife, as regulators of water quantity and quality in receiving waters, areas of high biodiversity, etc.) have for generations been the basis of sustainable socioeconomic returns as sources of food-fish, drinking water, building materials, medicines, protection from floods, and areas of seasonal grazing. Conversion of swamps and marshlands to cropland and urban-industrial establishments is threatening the integrity of these aquatic ecosystems and their ability to perform ecological functions (Day, 1998; Bugenyi and Balirwa, 1998). Also increased water use mainly for agriculture in the upper reaches of the rivers is in some cases resulting in drying up of the wetlands in semi-arid areas with extensive negative social, economic and environmental impacts.

Water yield and quality from grassland landscapes in semi-arid areas are also influenced by land use and management. Land uses that maintain good ground cover conditions contribute to reducing soil erosion and direct runoff. Where grasslands have been converted to croplands without adequate conservation measures or are over-grazed the water quality is negatively impacted. As a consequence of inappropriate land use and management, wildlife ecosystems and habitats are threatened by the decline in dry season flows, destruction of habitats created by seasonal flooding, and encroachment and conversion of savannahs, wetlands and forest land (Gichuki et al, 1998; SMUC, 2001).

## I.3 Poverty in sub-Saharan Africa

### *1.3.1 Poverty incidence and trends*

While sub-Saharan Africa with 620 million inhabitants constitutes only one tenth of the world's population, it is home to a quarter of the 1.2 billion people in the world who live on one US dollar or less per day. On average, the income-poor, who are deprived of an income needed to reach adequate standards of nutrition, shelter, and personal amenities, is close to half of the population. This varies from 42 percent in Cote d'Ivoire, to 68 percent in Zambia and Sierra Leone (ADB, 2002). Most of SSA, except Ethiopia, Ghana, and Uganda, has seen little poverty reduction in terms of relative proportion of people

below the poverty line since the late 1970s. With an annual population growth of 3 percent in the past decades, the absolute number of the poor has grown considerably.

Poverty in SSA is primarily a rural phenomenon. Seventy percent of the poor live in rural areas, where agriculture is their mainstay. Estimates of the relative importance of the agricultural sub-sectors in Eastern and Southern Africa show that crops constitute 61 percent of the total agricultural production, livestock 36 percent, and fisheries about 2.5 percent (IFAD, 2001b: 16). Low productivity of agriculture and strong dependence upon limited and highly variable rainfall in arid and semi-arid areas render poor people extremely vulnerable to risk. Sub-Saharan Africa is the only region in the world where per capita food production has declined over the past two decades. Food production has been growing less than 2 percent annually, compared to population growth at 3 percent (Benneh, 1996).

Although the rural population still constitutes a large majority, the rate of urbanization in SSA is faster than in any other continent. Around 2030 the majority of Africans will have left the rural areas (Benneh, 1996: 16; World Bank, 1996). Urban poverty is less prevalent and less severe than rural poverty (IFAD, 2001a: 42).

Scores on other poverty indicators in SSA are also high. Child malnutrition is severe: a quarter of the under-fives are underweight (ADB, 2002). The adult illiteracy rate is 30 percent for men, but 47 percent for women. In the early 1990s, only 23 percent of the population had access to safe water and 16 percent to sanitation (Jazairy et al., 1992)—the figures have not changed much since. Life expectancy is 47 years. Human deprivation in SSA is seriously aggravated by civil strife, which is estimated to affect one out of every five Africans (Short & Weisman, 2002). With less than one tenth of the world's population, the African continent has more than a quarter of the world's more than 10 million refuges (Benneh, 1996: 25).

Two thirds of the 34 million people in the world that are affected by HIV/AIDS are Africans. The highest incidence is in Southern Africa, where selective male rural to urban migration and prostitution have been massive. In Botswana, the life expectancy would have risen to 70 years in the next decade without HIV/AIDS. Now, with the disease it has already declined to 40 years (ADB, 2002: 38). Women between 15 and 30 years old are twice as likely as men to contract HIV/AIDS. This already led to large falls in female/male ratios (IFAD, 2001a: 32). While poverty contributes to the spread of HIV/AIDS, it results in deeper poverty—forming a vicious circle and affecting the availability of labour, which is already precarious in smallholder agriculture. It also demands huge financial and human resources for the care of the sick and the orphaned. Malaria and tuberculosis are other examples of poverty-related diseases that prevail particularly in sub-Saharan Africa. Malaria results in a death toll of 1.5 million persons per year in SSA, which is 90 percent of total casualties in the world.

In addition to these manifestations of absolute poverty, the level of income inequality in Africa is among the highest in the world. A comparison among 49 African, Asian, and Latin American countries for which Gini coefficients for income distribution were

available show the high value of 0.50 or more for 41 percent of the African countries, but only 26 percent of the Latin American and 8 percent of the Asia countries (Jazairy et al., 1992: 402). In Africa, the inequities in income distribution are about the same for urban and rural areas (ADB, 2002).

Other features of poverty in sub-Saharan Africa are the lack of human, capital, and social assets; risk of being caught in a vicious downward circle after shocks of disease, death, loss of employment, or natural disaster; socio-political exclusion and lack of organization; active or passive denial of information; and lack of voice in decision-making bodies from local to national level. As poor people themselves emphasize, they also suffer from violence and crime, discrimination, insecurity and political repression, biased or brutal policing, and victimization by rude, neglectful or corrupt public agencies (Narayan et al., 2000, cited in IFAD, 2001a).

As poverty is multi-faceted, poverty reduction strategies must also be multi-faceted. Small improvements in the range of dimensions of wellbeing tend to be more effective than big changes in one dimension only. In the last five to ten years, smallholder agriculture is increasingly being identified in mainstream development debates as a major cause of, and potential solution for, poverty reduction *and* economic growth (Jazairy et al., 1992; DFID, 2002). This is most relevant in the context of this paper. So without denying the importance of other aspects of poverty and poverty processes in SSA, the remainder of this section focuses on smallholder agriculture, poverty, and growth.

### *1.3.2 Increasing land scarcity*

Land resources are a key asset for production, asset building, and buffer against shocks such as famine in an agrarian society. Land is becoming increasingly scarce in sub-Saharan Africa. Per capita availability of land has decreased from 0.5 ha in 1965, to 0.4 ha in 1980, to less than 0.3 ha in 1990 (Cleaver and Schrieber, 1994, cited in Benneh, 1996: 15). In Rwanda average land availability is as low as 0.14 ha per capita – an often forgotten factor in the 'ethnic' wars devastating this region. Shifting cultivation has halted virtually everywhere in SSA. Tensions between pastoralists and sedentary agriculturists are increasing, for example in the Sahelian zones. Lower land availability is also leading to significant numbers of landless people. The average percentage of landless people is estimated at 11 percent. In countries like Ethiopia and Kenya landlessness has become an acute problem (Jazairy et al., 1992).

Some scope to expand the land frontiers still exists in parts of Tanzania, Angola, DRC, and Zambia. The extinction of the tse-tse fly and trypanosomiasis that prevails in about a quarter of the region, particularly in humid areas, would also add important tracts of land for livestock and human settlement (Benneh, 1996: 10).

In parts of Southern and Eastern Africa distributive land reform for both poverty reduction and improved productivity figures on the policy agendas. In these areas colonial regimes either appropriated a minor but highly productive and well-watered portion of agricultural land (as in Kenya, Malawi, Uganda, Tanzania, and Zambia) or appropriated large shares of the land and confined the original inhabitants to reserves (as

in South Africa, Zimbabwe, Namibia, and Botswana). In Zimbabwe, for example, 4,500 largely white farmers own 11 million ha of mainly high-quality agricultural land, while more than 1.2 million poor black households live on 16 million ha of low-quality communal areas (IFAD, 2001b: 19).

In large parts of SSA male-biased land inheritance and communal tenure arrangements compound patriarchal marriage arrangements that enable men to appropriate part of the fruits of women's labour. These inequities negatively affect women farmers' productivity and the wellbeing of women and their dependents. Women's productivity is at least as high as men's provided women have similar access to inputs and markets, and control the produce themselves (Zwarteveen, 1997; Quisumbing, 1996; Adesina and Djato, 1997: 52). Stronger independent access to land, for example by protecting widows' land rights and enforcing gender-equal inheritance rules, stimulates women farmers to increase productivity and investments. Their better access to training, markets, credits, and inputs is equally important. Many African women are farm decision-makers. In West Africa, women often cultivate their own plots. In Imo and Abia States in Nigeria, for example, women cultivate 2.4 ha out of the total household area of 9.8 ha (IFAD, 2001a: 86). Elsewhere, male migration to off-farm employment has led to a massive feminization of agriculture. In some districts in South Africa, Zimbabwe, Lesotho, and Kenya, the proportion of women farm decision-makers is as high as 50 or 90 percent (Safiliou, 1994; FAO, 1998b).

The implication of the increasing pressure on land resources is that agricultural productivity and profitability must be enhanced and stabilized by intensification, greater gender equity, and in some areas, distributive land reform.

### *1.3.3 Smallholder agriculture: Engine of pro-poor growth?*

Intensification of smallholder agriculture in sub-Saharan Africa is increasingly seen as an important solution for both poverty reduction *and* agricultural growth. Although the role of agriculture for economic growth has been highlighted for decades (cf. Johnston and Mellor, 1961, cited in Koning: 2002), the discussion is being taken up again. However, the focus is now explicitly on poor farmers (Jazairy et al., 1992; IFAD, 2001a; IFAD, 2001b+c; DFID, 2002). Moreover, the need for strengthening national markets and the potential role of import tariffs in overcoming the current agrarian malaise are increasingly highlighted (Koning, 2002).

The main argument is as follows. The assumed viability of poverty reduction through agricultural growth is based on evidence from the past decades in the Green Revolution areas of Asia, as well as from evidence in Kenya, Malawi, and Ghana, that smaller farms can be at least twice as productive as the larger farms, allowing for land quality and land productivity. Small farmers' advantages are due less to higher yields of the same crop, than to a higher-value crop-mix, more double cropping and intercropping, and less fallowing. Moreover, smaller farmers raise production of staples by putting more of their land in them. The cultivation of staples is important because rapid growth in yields of staples has contributed substantially to the reduction of poverty in recent decades,

releasing land and labour for further poverty reduction based on cash crops, livestock, and non-farm activity.

Smallholder agriculture could be an engine of pro-poor 'trickle up' growth because of the four types of synergistic effects of agricultural growth. First, increased productivity augments incomes in kind, often staple foods, but with increasing wealth, also augments cash incomes of the direct producers and their dependents. Second, intensification in small farms raises the demand for wage labour even more than intensification by larger farmers, because smallholders tend to employ more labour per unit of land than larger farmers. Third, intensification of agriculture drives rural non-farm enterprise and employment. Off-farm employment is not 'more important' than agricultural growth, but rural off-farm dynamism is driven by and *reflects* agricultural development. The linkages concern backward linkages (e.g., input provision, technology manufacturing), forward linkages (e.g., road construction, transport, trade, processing, raw material for agro-business), and 'consumer linkages' of new demands for goods and services by farmers and their employees. Small farmers and their employees tend to spend more of their incomes on employment-intensive rural non-farm products than larger farmers. The importance of the rural non-farm sector as a contributor to household income is confirmed in 25 case studies in Africa. It was found that 45 percent of rural incomes are derived from non-farm employment (IFAD, 2001a: 102). The fourth effect of agricultural growth is that rural poverty reduction is more likely to decrease urban poverty than the other way around.

The last argument in favour of the viability of this path of economic growth based on agriculture refers to virtually all current cases of successful development. Ghana, Uganda and parts of Ethiopia show some poverty reduction in the past decade because of developing smallholder agriculture. The Green Revolution in Asia makes the same case. Last but not least, today's developed countries also went through such a development path. A strong local and national agricultural market typically preceded successful entrance on the world agricultural market. There are no empirical examples that the demand impetus for development came from any other sector than agriculture (Koning, 2002).

This win-win scenario that starts where the majority of the poor improve their livelihoods by seeking to increase productivity of staple foods in the poorest areas and cash crops in more developed areas represents a major break with past development theory and action in SSA, for at least three reasons.

First, agriculture in SSA has largely been neglected. Colonial governments before 1955-1965 and most independent governments thereafter were biased towards non-farm sectors such as mining and large-scale forestry. In sparsely populated Africa, smallholder farmers were and still are primarily seen as the labour force for these 'more important sectors'. However, little wealth has 'trickled down' through these labour arrangements. The remittances of wages and minimal welfare grants only partly compensated for gaps in the labour requirements for cultivation largely based on hand tools. The share of public expenditures for agriculture has always been way below agriculture's contribution to

GDP and even more below the relative volume of employment created through agriculture. Budget cuts under the structural adjustments programs in the 1980s further reduced public expenditures for agriculture, eroding most of the agricultural research and extension services. Limited attention, land alienation, and other restrictions directly damaged smallholder agriculture. It was 'underdevelopment by design' (IFAD, 2001b).

Second, while support for agriculture was limited, the services that did exist were biased towards large-scale farming and export crops. Agricultural intervention exploited the agricultural sector as the 'cash cow' for the urban elites (IFAD, 2001b: 30). In 1955 there was hardly a single country in Southern and Eastern Africa in which internal marketing and pricing of food crops, and the collection and marketing of export crops, were not the legal monopoly of the state, a parastatal or private organization. When the governments of newly independent countries came to power, these structures were often left in place. The monopsonistic boards bought export products at artificially low prices, while selling at higher world market prices. For example, in 1983, Ghana's cocoa farmers obtained only one seventh of the world market prices (Leechor, 1994; cited in Koning, 2002). Overvaluation of the currency to make imports cheap but exports expensive further depressed the terms of trade, over and above the generally negative 'secular' downward trends of primary commodity prices on the world markets (IFAD, 2001b: 22).

However, the abolition of these boards, reliance on privatization, and corresponding reduction in the public services in the 1980s may still appear 'better at rural deconstruction than rural reconstruction' (IFAD, 2001b: 24). Abolishment took the bit of support, especially in the form of subsidized fertilizers and other inputs and research, extension and training away without offering anything in place. New dependence upon private monopsony large-scale buyers may be just as extractive as the abolished boards.

Most importantly, sub-Saharan Africa's position on the world market has considerably weakened in the past decades. The situation is gloomy indeed. Shares in exports declined in general and agricultural exports, which had always been the core of overall exports, also decreased. Today they are only a third of what they were 30 years ago (DFID, 2002). The shares in the world markets of even traditional export commodities, such as coffee and cotton, have declined. Decreasing export shares are compounded by the general down-sloping trends in agricultural commodity prices on the world market.

On the other hand, national food deficits and food imports are increasing. Almost 50 percent of national rice consumption in rice-growing countries such as Ghana and Cote d'Ivoire is imported. About half of the aggregate food gap is currently met by food aid, which constitutes a considerable gap compared to 1970, when only 15 percent of cereal imports was met by aid. The situation is likely to worsen: the World Bank estimates that Africa could have a food shortage of 250 million tons by 2020, more the 20 times the current food gap, if present trends continue. With weak economies and astronomically rising foreign debts, there will be insufficient foreign exchange to pay for these massive imports (Benneh, 1996: 16).

It is feared that without protection, African producers will be the losers to massive imports (IFAD, 2001b: 180). African delegations at the WTO are beginning to plead for more flexibility to protect their agriculture against cheap imports. An increasing number of SSA countries have started negotiating protection of their markets. Mozambique has successfully fought against the demand of the IMF to do away with a protective import duty on sugar (Koning, 2002). Many African countries seek to be allowed to do the same as developed countries continue to do, and for the same, if not better, reasons.

## I.4 Investment Environment in SSA

### *1.4.1 Trends and constraints to increased investments*

World Bank lending worldwide for projects with irrigation components over four decades reached a total of US$31 billion, peaking in the late 1970s at US$2.5 to 3 billion annually (World Bank, 1994). However, these high levels of investments started to decline in the early 1980s with the World Bank investing less than US$1 billion per year in irrigation projects. Total spending by all donors and financial institutions has averaged around US$2 billion annually during the same period (World Food Summit, 1996).

In the 1950s and 1960s, funding for irrigation primarily went to development of new irrigation schemes. But from the 1970s onwards, more funds have been spent on rehabilitation, modernization and expansion. In fact, in the mid-1990s more than half of all irrigation investment was devoted to these purposes (World Food Summit, 1996). New construction projects are easily more costly than rehabilitation projects (World Bank, 1994; Aviron Violet et al., 1991; FAO, 1986; van Steekelenberg and Zijlstra, 1985). The cost of developing new systems is said to be rising mainly because the most economically attractive ones have already been developed (World Bank, 1994). The same report however, does not endorse simple rehabilitation to the old standard, but rather one that takes into account the changing environment and therefore the need for "constantly re-designing." Thus, rehabilitation or upgrading will not be as cheap as often assumed because it is proposed to include "intensive application of engineering and social solutions" aimed to reduce unit costs, conserve water, and provide better service.

In terms of size of area served, the World Bank-financed projects irrigated an average of 132,000 ha ranging from 282,000 ha in India to 26,000 ha in sub-Saharan Africa and 17,000 ha in North Africa. The large schemes presumably irrigated bigger areas than small schemes but required more capital for large reservoirs or major canals. Large-scale projects with full water control have been strongly criticized for causing environmental damage, social inequities and violating the rights of traditional land users (World Food Summit 1996). There are also growing public health concerns related to large-scale irrigation schemes.

Of total World Bank lending for irrigation, Africa has received only about 12 percent while the bulk (69 percent) went to Asia. Investments in Africa have largely gone to the arid and semi-arid regions of North Africa, the Sahel and Madagascar. Average irrigation projects in Africa are characterized as small, accounting for 30 percent of World Bank-financed projects in terms of number (World Bank, 1994). With the decline

in Bank investments in global irrigation development, the investment share of SSA has declined proportionately. Investments from other agencies show a similar decline.

Various reasons have been put forward to explain this decline in investments in agriculture and irrigation investments: low average performance, the complexity and cost of lending, crowding out by lending for structural adjustment in the 1980s, the reduction of specialized agricultural staff in external assistance agencies, and falling international agricultural commodity prices (World Food Summit, 1996). The decline can also be seen as phasing out of programs that performed poorly.

In SSA, the poor performance of investments in irrigation development has been seen in the failure to deliver expected yields and incomes, the lack of sustainability and stakeholder ownership, and adverse environmental impact. Poor planning and quality of design were often cited as largely contributing to the low performance.

The cost of irrigation investment per ha in SSA is considerably higher than in other regions. Some of the identified causes of high irrigation costs include: (1) construction and transport costs are generally higher than in Asia; (2) overvaluation of most African currencies; (3) input taxes which are seldom waived; (4) lack of local manufacture of equipment and spares as well as supply limitations making high inventories necessary; (5) lack of local equipment service agents; (6) lack of local skilled personnel and small contractors and therefore the need for external manpower and management; and (7) the need to set up substantial infrastructure especially in large African schemes, in addition to physical/hydrological constraints (FAO, 1986). While the nature of this cost problem is only partially understood, with declining world market food prices it is clear that high investment cost is a problem as it reduces rate of returns.

The lack of basic infrastructure in most of Africa makes investments in formal large scale irrigation generally very capital intensive. Inadequate rural roads and transportation network contribute to higher cost of transporting materials and labour to project sites. These constraints affect cost of marketing outputs also which may influence decisions to invest or not in the first place. For example, the agricultural marketing margins in five major African countries studied by Ahmed and Rustagi (1985, cited in Benneh, 1996) were shown to be twice as high as in four major Asian countries, with transportation costs accounting for 40 percent of the difference.

Also contributing to higher cost of investment is the lack of systematic planning and administration which includes poor surveys and inadequate preparation contribute to construction delays and costs overruns (Barghouti and Le Moigne, 1990). The lack of sufficient preliminary studies has also been cited as contributing to the high costs. For example, in a scheme in Chad, the construction of unlined canals in very sandy soils resulted in the need for frequent maintenance (Aviron Violet et al., 1991).

Planning for irrigation development "tended to focus on achieving the most technically efficient system of water distribution on the project perimeter without taking into account the managerial and social factors which will determine whether this later leads to

efficient agricultural production" (FAO, 1986). For example there is a tendency to construct "larger-than-necessary" dams and pumping stations, intended to provide a wide safety margin. This tendency may reflect a lack of knowledge of local conditions by consulting firms carrying out the projects (Aviron Violet et al., 1991).

Olivares (1990, citing FAO, 1986) shows that large-scale irrigation schemes require more investment per ha than small-scale. Specifically, costs of large-scale, government-developed irrigation projects in Mali, Burkina Faso, Madagascar and Mauritania ranged from US$5,000 to $10,000 per ha while in Ghana, Niger, and Nigeria the range is higher at US$10,000 to $20,000 per ha. On the other hand, small-scale schemes in Ethiopia cost from US$1,500 to $2,000 per ha while in Mali, the costs per hectare were less than US$1,000.

### *1.4.2 Returns to investments*

Returns to irrigation investments globally are said to be comparable to alternative investments in agriculture and non-agricultural projects (World Bank, 1994). An evaluation of 192 World Bank-financed irrigation projects from 1950 to 1993 shows that about two-thirds got an overall satisfactory rating with an average economic rate of return (IRR) of 15 percent at evaluation (compared to 22 percent anticipated at appraisal) (World Bank, 1994). When irrigation projects were weighted by area actually served, the average IRR increased to 29 percent (World Bank, 1994). However, the World Bank (1994) also reports that in Africa, the 11gravity irrigation projects evaluated had an average rate of return of 9 percent, the 7 pump projects 13 percent, and the 5 mixed projects 14 percent. An earlier review of 15 Bank funded projects in sub-Saharan Africa by Barghouti and Le Moigne (1990) showed that five had rates of return above 10 percent while four had positive and six had negative returns. Brown and Nooter (1992) cited an FAO review of investment performance showing greater success, with 50 percent of African irrigation projects achieving re-estimated rates of return higher than the appraised rates.

Some researchers have suggested that just as large investments in formal irrigation were important in the Asian Green Revolution, so too such investments could make a major contribution to solving SSA's food security problems (e.g., Lipton and Litchfield, 2002). However, the environment for such investments has changed dramatically since the 1960s to 1980s -- in large part because of the success of Asian irrigation investments. Whereas previously food grain prices were high, reflecting global shortages, today they are too low to justify expensive formal irrigation investments -- and the trend is for stable or lower grain prices in future (Rosegrant & Perez, 1995). The relatively high cost of irrigation development in Africa compounds this problem (World Bank, 1994). Further, recall the point of Figure 2, the African water scarcity map: it is precisely those sub-Saharan African countries facing the severest food security problems that can least afford such expensive investments -- they face "economic water scarcity" which is really a scarcity of financial (and human) resources. Further, the lack of infrastructure, especially roads, in SSA is so great that it has been suggested food security cannot be attained through "another green revolution" patterned on the Asian example "but must be based

on establishing self-contained agricultural production and consumption zones which can operate with a minimum or outside purchased inputs" (World Food Summit, 1996).

In essence, we argue the Green Revolution experience of Asia, with its massive investments in large-scale irrigation combined with support for new crop varieties and crop management practices is not replicable 40 years later in Africa. Such large-scale formal irrigation investments will have a role, but this role will be limited to conditions where costs are reasonable, the potential productivity is high, and because of severe aridity other alternatives are not available. It is therefore imperative that Africa identifies more innovative cost effective interventions to improve water and land management as bases of achieving food security and economic development. We believe that such innovative approaches to water (and land) management for agriculture is essential for promoting rural development through smallholder agriculture. With Africa's dispersed populations, resource-poor farming systems require investments in technologies that can be sustained and can support intensification of African traditional agriculture. This approach will include the promotion of low-cost small-scale water lifting and application technologies, combined with rainwater harvesting, tapping shallow groundwater aquifers, recycling urban waste water in peri-urban agriculture, and exploitation of wetlands where this can be done without harming the entire ecosystem.

Overall, there is also a need to develop innovative ways to finance irrigation and for donors, governments and external support agencies to reverse the trend of declining investment in irrigation. To promote innovative approaches in water in agriculture, an enabling environment is very important. Brown and Nooter's (1992) review of successful small-scale farmer-controlled irrigation is applicable: (1) simple and low cost technology; (2) private and individual operation of the system; (3) sufficient infrastructure support to permit access to inputs and to markets for the sale of surplus production; (4) high and timely cash returns to farmers; (5) the farmer is committed and actively participated in the design and implementation of the project.

Small-scale farmer group-managed irrigation projects are another potential means to intensify smallholder agriculture. While small-scale projects may not be necessarily cheaper to build, in principle they represent smaller financial commitments, managerial requirements are not as challenging as in large-scale schemes, the technology can be better adapted to farmers' needs, and there is the theoretical possibility that farmers will be more involved and consequently more committed (Moris and Thom, 1987; see also Moris, 1991). Small-scale projects tend to benefit more small farmers and returns to investment can be more immediate relative to large-scale projects having long gestation periods. The added advantage of small-scale irrigation development is that it can take advantage of easily accessible water sources such as rainfall, runoff, and natural storage in the dry season close to the fields. On the other hand the number of such schemes that are truly profitable and self-sustaining in SSA is very small: they require effective institutional support systems for profitable agriculture that provide opportunities for farmers to earn substantial incomes which make it worthwhile for farmers to invest their human and financial resources to make the schemes work. These conditions are rarely met (Shah et al., 2002).

## 1.5 Technology Options for Enhancing Productivity of Agricultural Water

Getting more crop output from the amount of water that is beneficially consumed can significantly reduce the need for additional irrigation water and contribute to easing the strains of water scarcity. This can be achieved through alternative agronomic practices (improved crop varieties, crop substitution, better cultural practices), and improved approaches to water management such as precision irrigation whereby the required quantity of water is provided to the crop in the right amount and at the right time. Precision irrigation does not necessarily imply expensive 'high technology' irrigation. Instead it refers to a broad range of technologies and water management practices that enable farmers with limited access to water to apply that water to their crops in the time and amount that increases the productivity of water. Examples include bucket or drum and drip irrigation, pot irrigation, small sprinkler systems, level basins, as well as conventional drip and sprinkler systems. Precision irrigation has the added advantages of keeping non-beneficial evaporation to a minimum and reducing water diversion requirements from the source. It can even be practiced with existing conventional technologies if proper timing of irrigation deliveries can be ensured.

In addition inexpensive and effective techniques for capturing, storing, and distributing water for crop production have considerable potential for improving water resource use in water-scarce areas. The techniques range from water-harvesting techniques to water-lifting devices, such as small diesel, electric or muscle-powered pumps, for abstracting water from storage structures and wells.

Innovative water management systems, combining precision irrigation technologies with water harvesting or groundwater use, can be particularly useful for supplemental irrigation in situations where rainfall is limited and uncertain, and where one or two timely irrigation applications can have a big impact on crop production.

## I.6 Policy and Institutional Support Mechanisms

### *1.6.1 Support systems for smallholder irrigators*

Advances in agricultural water use technology and changes to traditional ways of production and marketing undoubtedly offer potentially huge benefits for improving the standards of living and nutrition of the poor and food-insecure. But changes to policies and institutions must also be made to fully exploit these opportunities; otherwise, the more disadvantaged segments of society run the risk of being left behind by the expected technological 'revolution'.

In African smallholder irrigation, policy and institutional questions essentially concern the relationship between the farmers who are users of these systems, the government bureaucracies tasked with assisting or stimulating the performance of such systems, and the private sector and NGOs who provide various support services to smallholder farmers. The large number of institutional interventions that have taken place whereby governments seek to change their relationships with irrigation systems in some positive way amply illustrates this.

Often, governments have been responsible for the initial investments to create irrigation schemes. After creating them, they find themselves faced with a dilemma. On one hand, there is the need (if not the responsibility) to ensure that the returns from irrigated agriculture are commensurate with the investments made; hence, governments may feel that they should continue to be directly involved in irrigation system management. On the other hand, they would not like their financial responsibility to continue indefinitely, especially when there are competing claims and pressures on national budgets from other sectors. Hence the trend favouring government disengagement from irrigation scheme management, whereby responsibility for certain functions and bearing the related expenditure is transferred to the users.

Abernethy et al. (2000) and Sally (2001) discuss the prospects for self-management of irrigation in West Africa, and highlight the financial and institutional challenges of transfer arrangements related to the specific circumstances in Niger and Burkina Faso. These findings are confirmed by Shah et al. (2002), who review global and African experiences in irrigation management transfer and observe that, hitherto, there have been few successful examples of management transfer in Africa.

On the other hand, Gadelle (2002), while recognizing that government-sponsored irrigation schemes in West Africa, be they large or small-scale, have largely failed, suggests that the development of individual irrigation shows greater promise, especially for vegetable and fruit production. Similarly, Abubakar (2002) shows that individual ownership of pumps and greater access to credit have been the major factors of success that have led to improved profitability of *fadama* farming in Northern Nigeria.

These results are in line with the conclusions of Shah et al. (2002) that enhancing the income-creation potential of smallholder irrigated farming, improving access to credits and markets, and providing effective extension and support services hold the key to viable smallholder irrigation.

The development and application of innovative poverty-focused approaches to irrigation and water management are taking place all over the world, usually spearheaded by NGOs and similar grassroots organizations. But these innovations are often not known or disseminated beyond a very local domain. There are many reasons for this lack of spread: problems related to the credibility of the message as well as the messenger. On one hand, the information presented in support of the claims to success of an innovation may not be complete or convincing; crucial but inconvenient pieces of information may sometimes be omitted. On the other hand, the promoters, who are often the innovators themselves, may be perceived as exaggerating the merits of their innovations. As a result, even outstanding local innovations with potential for wider application and impact may remain relatively unknown and unutilized nationally and regionally. Uptake, if any, tends to be slow and random.

Hence, there is significant scope for carrying out systematic scientific scrutiny of promising innovations in irrigation and water management, both African-grown and African-adapted, with a view to refining and promoting practical dissemination and application of those that show high potential for adoption and positive impacts among

poor people. The emphasis must be on participatory identification and adaptation of such innovations (IPTRID, 2001).

But a sound policy environment as well as effective institutional arrangements and support systems at different scales also need to be put in place to encourage uptake and upscaling of innovations (Inocencio et al., 2002). Such measures assume even greater importance in light of the increasing contributions of urban and peri-urban agriculture, and the productive use of wetlands towards meeting the food security needs of sub-Saharan Africa. Indeed, these give rise to new considerations and challenges to contend with such as balancing productive potential with protecting the health of producers and consumers, and avoiding ecological catastrophe through unwise exploitation of sensitive environments.

### *1.6.2 Strengthening skills and capacity*

In many countries of sub-Saharan Africa the irrigated agriculture sector is relatively small compared to that of dryland agriculture. Education and training programs oriented towards serving the needs of the latter sector and a rather limited cadre of skilled irrigation professionals are natural corollaries of this situation. These are also possible contributory factors to the under-performance of irrigation schemes.

Just as much as the formulation of sound policies and institutions are vital for good land and water management and improved production and productivity, they must be accompanied by the development of the requisite organizational capacity and skills for making full use of innovations, and for enforcement and regulation.

Not only should the roles, rights and responsibilities of the various actors in the agriculture and water sectors be well demarcated but serious efforts must be deployed to also promote new forms of public and private partnerships for investment, operation and maintenance of irrigation schemes. The emergence of financially self-reliant service delivery organizations that are responsive and accountable to water users must be encouraged and meaningful participation of all stakeholders in the planning, operation, maintenance and management of irrigation schemes ensured.

### *1.6.3 Improving irrigation services: Private sector role*

The level of irrigation services provided to farmers is influenced by the physical design of the system, its operation and maintenance and the underlying institutional environment. When farmers are provided with reliable irrigation services, they are more likely to invest in improved technologies and practices, usually resulting in increased production, higher incomes and improved irrigation performance. But in general, more flexible and sophisticated technology will require levels of management capability that are not always readily available in rural environments. Thus, in seeking to provide a stable and predictable water supply to farmers, it is quite important to find ways and means of doing so that are commensurate with the available skills and resources (Sakthivadivel and Sally, forthcoming).

Ensuring reliable irrigation services also implies the establishment of clear rules and agreements between providers and users. Among the information details that must be provided are: (a) the nature of the services and the compensation arrangements for providing and receiving such services, (b) mechanisms for monitoring and control of obligations, (c) modalities for conflict-resolution, and (d) procedures for modifying and updating agreements.

There are an increasing number of promising pilot cases and initiatives to strengthen the role of the private sector in irrigation development (Abernethy and Sally, 2002). As governments seek to increase the role of the private sector in the provision of agricultural goods and services, Abernethy (2002) lists the following domains of activity that may be of interest to the private sector:

- funding of recurrent costs of operation, maintenance and management, especially by existing users of irrigation systems ;
- providing capital to extend existing irrigation systems ;
- constructing new irrigation facilities ;
- investing in higher technologies, especially water-saving technologies, in existing irrigation systems ;
- supplying support services, such as marketing or contracted maintenance.

But he also cautions that particular attention needs to be given to the long-term security of investments, through measures such as systems of documented land and water rights, laws governing the nature and procedures of organizations of irrigators, and facilitation of market development for higher-value crops.

## I.7 Challenges facing irrigation in sub-Saharan Africa

Everywhere, the temptation is almost irresistible to continue investing in large-scale irrigation schemes. One argument is based on the 'economies of scale' to be derived from collective development. However, the disappointing performance of large irrigation systems puts this in question, as do the social costs associated with large-scale developments. The temptation for continued investment is particularly intense where large prior investments have been made in infrastructure development, and rehabilitation is hoped to improve performance. The challenges associated with making large-scale schemes work are many and well researched.

Therefore, the first new challenge we would like to highlight which is facing irrigation in SSA, is to know when it is wise *not* to continue investment in large-scale irrigation schemes.

As argued above, current trends and arguments are compellingly in favor of individual technologies for the development of farmer-controlled irrigation in sub-Saharan Africa. In summary:

- Individual technologies enable the poorest of the poor to engage in intensified agricultural production[3] and to reduce their vulnerability to drought and flood cycles. Thus, development is encouraged where it is needed most. Also, individual technologies have the potential to reach many more poor households, more quickly and at lower cost[4].

- Irrigation development based on individual technologies enables farmers to collect and use disperse pockets of water resources productively, without the need for expensive collective infrastructure.

- The use of collective infrastructure and its requirements for joint management entail daunting transaction costs. These are avoided by using individual technologies at an early development stage when farmers have enough on their plate trying to master the complex skills of irrigated production.

- Unlike irrigation schemes and other 'project'-type developments which limit participation to the chosen few, the use of individual technologies is in no way exclusive – anyone can decide to collect rainwater and grow produce in their backyard or on any other piece of land they have access to. This avoids the creation of 'islands of prosperity in seas of deprivation', which almost invariably leads to conflict in the broader community.

What challenges can we expect to be the associated with irrigation expansion based on individual technologies? We suggest the following are especially important:

- The need for effective user mobilization through awareness raising, by targeting the right clients/users and by assisting uptake of individual technologies. Irrigation expansion is achieved through individual technologies by:
    - Existing smallholder irrigation farmers expanding their area of operation in circumstances where individual technologies reduce the labor requirement, e.g., by reducing the need to carry water for irrigation.
    - Dryland/rainfed farmers who intensify their production by introducing irrigation through the use of individual technologies.
    - Non-producers who are encouraged and enabled to engage in irrigated production through the introduction of individual technologies.

- Farmers' ready access to these individual technologies, repair services and technical assistance, through mobilization and/or reorientation of goods and services suppliers

[3] For example: 'Treadle pumps self-select the poor', according to Shah et al. (2000).
[4] An analysis of the South African Rural Survey 1997 highlight that 1.7 million households in South Africa's former homelands engaged in 'subsistence agriculture' have the potential to adopt rainwater harvesting and 'individual' irrigation technologies for improved food security. This is in stark contrast to the total of 56,000 households who currently have access to 'formal' irrigation.

- Farmers' improved profitability through access to produce markets, with worthwhile commodity prices.

- The need to convince decision makers to allocate water use for smallholder farmers. This "water right" must be formalized to avoid future conflicts between users.

- Even if we are talking about individual developments, water use must be sustainable. The resource (e.g., groundwater) is often limited and we need to know the limits for this possible expansion.

- For many African countries, this type of irrigation expansion could be a solution to food security problems. However we need to address the vulnerability of such small systems when unexpected difficulties occur (prolonged droughts/ floods / climate change effects /pests). Consequently the farmers must organize themselves and solidarity systems must be envisaged to overcome such problems.

# II. IPTRID Activities in sub-Saharan Africa

## 2.1 Evolution of IPTRID

IPTRID was established in 1990 with a small secretariat at the World Bank. Between 1990 and 1998 IPTRID concentrated on coordinating and promoting research, often by working closely with Bank officials and developing countries to develop research projects for potential support by the Bank or other investors. In 1998, by agreement with its sponsors and partners, IPTRID was moved to a new home in FAO, Rome. This move saw considerable widening of IPTRID's activities, into the following areas:

- Synthesizing knowledge and making it more accessible to researchers and practitioners;
- Contributing to national capacity building, especially for irrigation researchers; and
- Networking including provision of internet-based information services.

Importantly, at the same time IPTRID began paying considerably more attention to small-scale irrigation, parallel to its continuing interest in large public irrigation schemes. As part of this shift, IPTRID began examining the potential applications of modern and low-cost technologies, such as treadle pumps. Most of this work on low-cost small-scale irrigation technologies has been carried out in SSA.

## 2.2 What has IPTRID been doing in sub-Saharan Africa?[F5]

IPTRID's focus and activities in SSA have been to identify and facilitate the uptake of irrigated agriculture by poor smallholders and make it a success. Suitable combinations of water and soil and relatively low population densities favour small-scale, local, production in much of rural SSA. At present, markets are not large enough to sustain the mass production possible from large-scale irrigation even if it was possible or desirable. The aim has been to synthesize knowledge and build capacities that would encourage and enhance the uptake of smallholder irrigation. Its promotion of irrigation technologies

appropriate for African smallholders has led it to emphasize low-cost micro-irrigation technologies.

### 2.2.1 Affordable technologies for South Africa

An IPTRID-led team including representatives of FAO, International Development Enterprises and IWMI visited South Africa in August 2000 to examine how affordable irrigation technology can be introduced and taken-up by emerging farmers and small-plot cultivators in the country (IPTRID, 2000). The international members were joined by national experts in visiting a variety of small-scale irrigation schemes, community gardens and home gardens in Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo provinces.

It was clear that affordable technology, for example treadle pumps, drip kits, and short furrow irrigation, would find ready acceptance in South Africa, particularly if such initiatives increased the options for small farmers to achieve productivity improvements. The affordable irrigation technology envisaged also gives greater opportunity for groups and individuals to be in control. Much can be done to improve water management through the use of short furrow basin irrigation drip and sprinkler systems on small-scale commercial farms. There are also opportunities for water harvesting at the household and farm level.

In summary the team recommended,

- Continued coordination between government agencies especially in the provinces;
- More effective communication of agricultural water use policies to "front-line" staff;
- Practical training, education and awareness building of "front-line" staff, farmers and policy makers;
- Technology demonstrations (farmer days, demonstration farms, radio and TV);
- Modification of treadle pumps and drip kits for South African users (taking advantage of local manufacturing facilities); and
- Greater effort on water harvesting (e.g., for home gardens using low-cost drip).

Implementation of the policy to revitalize and support small farming communities in South Africa is being planned.

### 2.2.2 Treadle pumps for irrigation in Africa

A state-of-the-art review of treadle pumps for irrigation in Africa brings together experiences and knowledge on this simple but effective technology from Kenya, Niger, Zambia, and Zimbabwe (Kay and Brabben, 2000). This report has been widely distributed throughout Africa, stimulating further interest in the treadle pump. One measure of success has been the continuing development of the treadle pump using the best features of several designs.

With IPTRID's encouragement, laboratory tests of six imported and locally made treadle pumps have been completed in South Africa. The South African Agricultural Research

Council's Institute of Agricultural Engineering has with support from IWMI developed a new low cost "kit" pump designed for village production with a minimum of tools and need for quality control. The project has included the establishment of an advanced test facility. A phase of field testing and user acceptability trials are underway to assess how such pumps can be used and how acceptable they will be to the target group.

Private companies are now making improvements and manufacturing a variety of treadle pumps in the region. IPTRID's role is to continue to facilitate contact between manufacturers and testers throughout the region. One idea under consideration is to create an information exchange forum on treadle pumps via a dedicated web site, initially hosted by IPTRID.

In Malawi, IPTRID recently (April 2001) assisted the Department of Irrigation to plan a publicity campaign to promote the use of treadle pump technology in the country in support of the distribution and subsidized sale of 10,000 pumps being imported from India. The Department has also invited IPTRID to work with it to stimulate South-South, public-private partnerships between manufacturers and suppliers of treadle pumps. In additon, with support from the sub-Regional Office of FAO in Harare, tests of treadle-drip systems have been undertaken at the Zimbabwe Irrigation Technology Centre, Harare (the IPTRID country network partner institution).

### *2.2.3 Field guides on irrigated agriculture*

The 1998 program of work proposed the development of a roving irrigation course for several countries. However, on the basis of the identification missions and within the time and resources available, traditional training courses were thought to be inappropriate, as they would reach very few people. The need was well expressed in Malawi where smallholder irrigation is a key policy for the government. IPTRID and other donor-supported program (e.g., Danida and IFAD) had identified that a major constraint to increased smallholder irrigation is the lack of appropriate irrigation knowledge by "front-line" extension workers. IPTRID therefore proposed and facilitated the preparation of a field guide on irrigated agriculture for extension workers so they can have an easy-to-understand reference book. The Field Guide, produced by HR Wallingford and two Malawi experts, is now available in Malawi and is being reprinted in a loose-leaf binder for easier up-dating and field use.

IPTRID is adapting the Field Guide for use in South Africa in response to demand from Eastern Cape. A technical appraisal undertaken in February 2001 felt that the layout was good but that the information was probably too detailed and complex for most provincial extension workers. Follow-up in June and then in September 2002 started the process of adapting the Field Guide to the particular conditions in Eastern Cape, KwaZulu-Natal and Limpopo provinces. Work on this new Field Guide is being done in collaboration with South African experts.

### *2.2.4 Water lifting technologies*

In view of the limited take-up of water lifting devices in West Africa, the International Fund for Agricultural Development (IFAD) asked IPTRID to design and formulate a

research programme on the adaptability of water lifting technologies in this region. This programme will enable IFAD to propose targeted field interventions and improve access of resource poor farmers to affordable water lifting techniques, adapted to their needs and capacities.

In the first phase, the preliminary study examined the availability and use of water lifting technologies from a sample of countries in West Africa. Practical interventions to encourage better use of these technologies in terms of efficient water use, affordable operational costs and acceptable social impact were then designed. Following field investigations and information gathering a "brainstorming" meeting was used to review the different water lifting technologies and identify opportunities and constraints for their up-take. The final stage was the preparation of an IFAD Technical Assistance Grant proposal for further intervention testing and technological adaptations.

The proposed West Africa Small Pumps (WASP) programme aims to improve livelihoods by enabling people to lift water efficiently and cost-effectively for small-scale irrigation and similar applications. This leads to a tentative list of research and up-take interventions or tasks, as shown in Table 1.

The proposed programme could be mounted in its entirety over several years or pursued as individual studies. Early action on the compilation of information to guide technology choice, and the all-important promotion of uptake is a must. Any development of new or improved technology, and also most of the training and capacity-building, would probably occur later or in subsequent phases and might be financed partly by the programme and partly by others.

### *2.2.5 Review of prospects for small holder irrigation technologies in SSA*

At the invitation of the World Bank, IPTRID commissioned a review of irrigation technologies for smallholders in sub-Saharan Africa (Kay, 2001). The role of traditional technologies and modern water distribution technologies, such as sprinkler and trickle irrigation and low-cost irrigation systems, including such innovations as the use of treadle pumps and drip-kits were reviewed. The report proposes ideas how governments, aid donors, NGOs and the private sector could support future development.

Experience in sub-Saharan Africa has shown that successful smallholders generally use simple technologies and have secure water supplies over which they have full control. The most successful technologies are those that improve existing farming systems rather than those that introduce radically new ideas.

Table 1: Proposed West Africa Small Pumps Programme.

| Theme | Task |
|---|---|
| **Knowledge management: collating information on supply of water-lifting devices and demand for them; guiding choice of technologies** | K1: Systematically collect information, by country & area, (water sources & uses, farm sizes, farm-family situations, tax & credit regimes, fuel prices, etc), and on the present state of water-lifting technology, (including history of aid projects, subsidies, supply chains).<br>K2: Prepare & publish a database of device characteristics & test results, (from all continents & covering all kinds of device), & set up periodic updating.<br>K3: Review the present coverage of situations & needed applications, identify & describe any gaps where new, more efficient, more robust or cheaper technology is needed, & publicise these gaps to encourage development of such technology.<br>K4: Produce TECHNOLOGY CHOICE GUIDES to enable people to match appropriate water-lifting devices to particular applications; update them periodically as more information becomes available. |
| **Research to support that knowledge management** | K5: Select suitable standard test methods for water-lifting devices, developing new tests if necessary; to cover fuel or energy consumption over a range of operating conditions.<br>K6: Collect test results for all known relevant devices (world-wide), using standard methods & formats; conduct tests where results are not available.<br>K7: For human-powered water lifting devices: Investigate ways of improving the cost-effectiveness, robustness, longevity & energy-efficiency by collating & disseminating the work already done or in hand, & by undertaking complementary research to fill any gaps.<br>K8: As K7 but for engine-powered water-lifting devices. |
| **Policy guidance and technology uptake promotion** | U1: Examine all potentially valuable institutional and financial methods and approaches for releasing new or improved technologies into communities, studying especially any relationships between subsidies, credit arrangements & the choice between water-lifting technologies. Quantify the consequences of various policies, and deduce tentative guidelines for policy decisions in West African countries, especially on the structuring & application of subsidies.<br>U2: Investigate the global market for relevant technologies, the reasons for limited availability in some places, and potential solutions. Study the relative merits of manufacturing devices in a few large plants or in many small ones dispersed throughout the countries needing the technology, with regard to quality and reliability. Prepare guidelines for quality control.<br>U3: Use the outputs of all other tasks to promote the uptake of appropriate small water-lifting devices in West Africa.<br>U4: Develop training & awareness-building materials to enable stakeholders to understand applications, situations, and the characteristics of available technologies, and to apply this understanding to the matching of technologies to situations and applications; use them to train people in West Africa<br>U5: Develop training materials for mechanics in the repair and maintenance of the principal types of devices; use them to train mechanics in West Africa.<br>U6: Use the insights gained in the whole programme to build the capacity of policy-makers to understand and improve the policy, institutional and financial environments for the efficient release and use of appropriate water-lifting technologies. |

Low-cost, modern technologies can help smallholders move from subsistence farming into growing cash crops. Success will be determined largely by the capacity of smallholders to take risks and adopt new technologies in situations where services are erratic, costs are high and markets are unpredictable. The rate of development has been slow but speeding-up does not necessarily mean building irrigation schemes faster; it means building many more of them. An important lesson learned over the past 20 years is that smallholder schemes develop through a slow incremental process of improvement,

usually in response to farmer demand[5]. Unfortunately this is at odds with the way some donor and government agencies work.

For irrigation to succeed, experienced and knowledgeable staff will be needed. Support will be required to establish appropriate institutional and in-service training programs that properly equip people for the jobs they must do and to address the fundamental issues related to the improvement and adoption of appropriate irrigation technologies in sub-Saharan Africa.

### 2.2.6 Pumps and irrigated agriculture[F6]

Much of the IPTRID current programme stems from the IPTRID / FAO workshop in Harare in April 1997 (published as FAO Water Reports #14), which highlighted irrigation technology transfer actions. Smallholder irrigation in Africa often depends upon pumping water from shallow aquifers or swamps during the dry season. Pumping technology is therefore critical to the development of irrigation. The first stage, to make use of human powered pumps (treadle pumps), is already being addressed through the state-of-the-art report (Kay and Brabben, 2000). The next stage is for individual or groups of farmers to invest in petrol, diesel or electric powered pumps though in many locations development has jumped directly to using such pumps.

Small pumps have had an impact in West Africa (particularly Nigeria) but this impact has still to be observed in East and Southern Africa. Awareness of how to design, operate and maintain irrigation with a pumped water supply is not widespread. Reports of inappropriate pumps (sometimes gifted by donors), lack of spares, poorly matched and inefficient components are common. IPTRID is using its network partners to design a course on pumps and irrigation (how to select, use and maintain pumps, how to use a pumped supply, i.e. surface irrigation, sprinklers or drip, and how to organize farmer cooperation [one pump can irrigate several farmers' plots]). Initial development is planned for mid 2001 in Uganda with the possibility of extension to Ghana.

In November 2000, IPTRID identified a particular need to enhance the skills of technical officers and technicians in Uganda so that the commissioning and deployment of diesel-powered centrifugal pumps (a gift from the Government of India) can be completed. Practical technical training on the operation and maintenance of the Greaves-Peerless pumps should be provided as a matter of some urgency to selected technical officers and technicians as the pump units were being deployed to farmers. A technician from Sri Lanka visited Uganda, in late April 2001, to develop a two-day practical course for the future deployment of the pump units and future training of additional technicians and users in the correct operation and maintenance of the pumps.

With assistance from HR Wallingford, IPTRID then developed a Training of Trainers course on "Pumps for smallholder irrigated agriculture–Training manual" prepared by Melvyn Kay. This was successfully presented in December 2001 to about 25 trainees. All materials were left in Uganda for development of further training initiatives. IPTRID will organize editing and publication of the manual. Contacts with Ghana and Nigeria have

[5] This point applies to large-scale schemes as well—usually with even longer time horizons.

indicated that similar training events specifically aimed at strengthening capacity to support and advise on pumped irrigation schemes would be well received. IPTRID plans to extend this initiative to these countries in 2002/3.

### *2.2.7 Identifying good practices on irrigated rice schemes in West Africa*

From 1998 to 2001, IPTRID conducted a project entitled "Identification and Dissemination of Good Practices on Irrigated Schemes in West Africa." In this project, 12 irrigated rice schemes in West Africa have been compared (Hermiteau et al., forthcoming). The study concluded that irrigation performance can be improved through implementing organizational changes. Basically, if farmers are assisted to take a more "professional" approach to scheme management, and if assistance is available from the private sector, such schemes can be operated successfully. This conclusion is similar to that of Shah et al. (2002), but where the latter paper is pessimistic about the prospects of achieving such success, the IPTRID study is optimistic. This project has led to the formulation of the "APPIA" project, in which the East Africa (Horn of Africa) component is proposed to be driven by IWMI. Its objective is to improve performance of irrigated schemes in sub-Saharan Africa in term of competitiveness, attractiveness for farmers and sustainability by 1) promoting information exchange between irrigation professionals in SSA, and 2) supporting the emergence of new extension methods and service providers for irrigating farmers and their associations.

This project suggests that under certain conditions, more formal irrigation can be an 'engine of growth' if effective organizational arrangements are put in place both by the farmers themselves and by service-providers. For this to occur, we suggest that governments must also play their role, of putting in place policies and support systems that enable such organizational changes.

## 2.3 What have been IPTRID's contributions?

We have not carried out a formal evaluation of IPTRID's contributions to small scale irrigation in sub-Saharan Africa, and the recent external evaluation of IPTRID does not address this question explicitly either (IPTRID Review 2001). It is clear that IPTRID's resources and program devoted to this issue are rather modest, especially in view of the magnitude of the problems. However, within these limitations, we conclude that IPTRID has focused on the most appropriate area –low-cost smallholder technologies—and has made useful contributions. These are, first, helping raise awareness of and knowledge about the current status and future potential for small-scale low-cost technologies in SSA as means to help poor smallholders to improve their food security and incomes even in the face of unfavourable markets and institutional support systems. Second, IPTRID has made important practical contributions in terms of its evaluation of treadle pump performance, development of field guides and training materials for irrigated agriculture, and assessment of the potential of low-cost technologies in West Africa. We believe these achievements form a solid foundation for a more ambitious future program. As should be clear from the preceding sections of this paper, we endorse the emphasis on low-cost technologies for smallholders.

However, we urge IPTRID to further expand its concept of "small-scale irrigation" to include the management of water (and land) in the context of catchments—thereby including rainwater harvesting technologies which are complementary to water lifting and application technologies.

### 2.4 What are IPTRID's Plans in SSA?

IPTRID's program on small-scale irrigation focuses on the transfer of knowledge and experience to promote effective and successful smallholder irrigation. There is an acute need for technical help and support to sustain and expand such irrigation. Where such help has been provided to farmers there has been a rapid increase in irrigation uptake, improved incomes and nutrition. By appropriate application of technology, farming communities should be able to make better use of the available resources. Water resources in Africa are generally under-used and there is plenty of scope for more smallholder irrigation. IPTRID is facilitating initiatives to extend the knowledge and skills of those who plan, design, and operate smallholder irrigation

More applied research in the SSA on low-cost technologies for irrigation would increase the options available for the end-users, either by increasing the range of suitable and affordable technologies available or reducing the manufacturing costs and, hopefully, the selling price. Therefore, over the next two years, IPTRID plans to continue to encourage applied research in smallholder irrigation in sub-Saharan Africa. This will be achieved through R&D promotion, workshops, electronic discussions, development of training materials, and promotion of skills and experience through networks of NGOs and professionals working with smallholder irrigators.

## III. Suggestions for IPTRID's Future Direction

### 3.1 The Changing Context in Africa

Section 1 of this paper has attempted to establish a foundation for the future direction of development efforts related to agricultural water use for smallholder farmers in SSA. We have characterized the nature of the resources, the sources of poverty, and past experiences with irrigation investments. We have argued strongly in favour of a major effort focused on the application of low-cost individualized small-scale technologies to improve water management (including rainwater harvesting technologies), which can be used by resource-poor farmers to stabilize and increase their productivity and profitability.

It is important to note that the context for rural and agricultural development in Africa is changing rapidly. Africans themselves are strongly articulating new programs, making new commitments, and getting increasingly well-organized to promote new investments and programs. The most important evidence of this is the New Partnership for Africa's Development (NEPAD), which in essence constitutes a commitment at the highest political level to make Africa a more attractive place to invest, and to direct such investments towards poverty reduction especially in rural areas.

A supporting initiative is the Forum for Agricultural Research in Africa (FARA), a consortium of sub-regional agricultural research networks who have developed a prioritized agricultural research program to contribute to achieving food security and profitable agriculture. FARA has in turn challenged the 16 Future Harvest Centres (of which IWMI is one) supported by the Consortium for Agricultural Research (CGIAR) to re-focus itself both institutionally and programmatically to support Africa's programs. The Centres have responded by enhancing cooperation among themselves and with the sub-regional agricultural research networks. During 2002 the Centres are collaborating with FARA to prepare an SSA Challenge Program to focus CGIAR and other resources on critical issues facing the region.

A third initiative of interest is the work of the Africa Water Task Force, which consists of senior African technical people working in the water sector, who are seeking to raise the profile of water investments as a means to enhance economic development in Africa. The Task Force organized a successful Conference on Water and Development in Accra, Ghana, in April 2002, attended by over 200 participants. Its output has been explicitly recognized by the African Ministerial Conference on Water (AMCOW), consisting of all of Africa's ministers responsible for water development. The Task Force is likely to continue its efforts to raise the profile of water for development. It is currently promoting the idea of an Africa Water Investment Facility that may be organized at the Waterdome, a parallel event at the World Summit on Sustainable Development.

These developments have stimulated new interest by donors and public investors, and one hopes eventually private investors. If NEPAD and other regional, sub-regional and national initiatives gain credibility there is evidence donor support would be forthcoming. NEPAD was one of the major items on the agenda of the G8 meeting in June 2002, for example.

We believe that these developments provide an opportunity for IPTRID, along with others like the CGIAR Centres, to attract the support needed to expand its programme on smallholder irrigation in SSA, and over the next decade or so make a significant contribution in partnership with others.

## 3.2 IPTRID's Niche

IPTRID cannot do everything, so it must carefully identify its comparative advantage, and then establish partnerships with others whose strengths are complementary. We suggestion IPTRID's niche lies in the areas of networking and information exchange; synthesizing existing knowledge and disseminating it to users through its networks; identifying research gaps and encouraging those with the capacity for research to carry this work out and make the results available; and cooperating with regional and national training institutions to integrate synthesized knowledge, for example on modern low-cost irrigation technologies, into their training curricula and extension materials.

We also suggest that IPTRID consider expanding further and explicitly its definition of "irrigation technologies." These include but are not limited to treadle pumps; they also include the range of other water-lifting devises (manual, solar-driven, diesel, etc.) and

water application technologies; and as noted in section 2.3, we argue it should also include the range of small-scale rainwater harvesting technologies.

Strengthening and expanding its partnerships is a key ingredient. We are aware that IPTRID already has some strong partners, especially at the national level, and can use FAO's considerable network for approaching others. We suggest that the three sub-regional agricultural research networks (ASARECA, CORAF/WECARD, SACCAR) who are the constituent members of FARA, should also be key partners. All three to varying degrees have networks and programs on water and land management that would be natural partners for IPTRID. IPTRID, like IWMI, can help bridge the current gap between the formal irrigation and large scale water development sector represented by ICID for example, and the agricultural research and extension sectors represented by FARA, the CGIAR and the three sub-regional organizations mentioned above.

## 3.3 Outline of a Way Forward

To conclude this paper, first, we reiterate the critical importance of improving smallholder agriculture in SSA as a key 'engine of growth' and means to reduce poverty and improve livelihoods. We also reiterate that small-scale low-cost modern technologies of the type on which IPTRID has been working in recent years are one of the key means available to help African smallholders to escape their trap of low productivity, vulnerability to drought and other disasters, low incomes, poor health, each feeding the other in a vicious downward cycle. While we recognize large-scale irrigation has a niche in some countries, for many countries, we do not believe that investments in this sector will generate the rapid improvements in smallholder agricultural production at local and household levels that are required.

However, this latter point may not be applicable in all cases: IPTRID's project on 'good practices' in West Africa suggests that there are conditions under which more formal irrigation can make an important difference for people's livelihoods, if characterized by effective internal organization and effective support services from the private sector. While we favour seeking ways to improve the performance of formal irrigation schemes where the conditions make this possible, we nevertheless argue that far more attention needs to be paid to small-scale low-cost modern technologies than has been the case in the past.

IWMI has established a strong presence in Africa over the past two years, with a large regional office in Pretoria, and smaller sub-regional offices in West and East Africa. We are in the process of building a long term research and capacity building program, and establishing the necessary partnerships to be successful. One of the key areas we have identified is that of intensifying rainfed agriculture and scaling up known small-scale technologies for water and land management. We are also implementing programs in peri-urban agriculture and sustainable use of wetlands within which there is an important niche for small-scale technologies.

We therefore make a modest proposal. We propose that IWMI and IPTRID provide the leadership for an African Initiative on Modern Small-Scale Irrigation Technologies

(AIMSIT). IWMI's focus would be on promoting the research required, not only technological, but institutional and policy research, building research capacity, and dialogue with policy makers. IPTRID's role would be synthesizing and disseminating knowledge, identifying research gaps, and building capacity among African institutions for training extension workers, NGOs, technicians and other service providers as well as farmers. IPTRID and IWMI would bring in other international, regional and local partners, for example FAO, other CGIAR Centres, FARA and its constituent sub-regional research network, NGOs active in promoting small-scale irrigation technologies, and various national research, training and extension institutions. It would be important to structure the initiative in a way that supports African overall leadership and initiative.

In addition to this initiative (AIMSIT), we look forward to working with IPTRID and other partners to identify how the performance of formal irrigation schemes in SSA can be improved in a sustainable manner. The proposed extension of the 'APPIA' project, with French government support, will provide an opportunity for IWMI and IPTRID to do this.

The time is ripe to work through NEPAD, FARA, the African Water Task Force, and other African-led initiatives, to make a significant difference in rural African peoples' lives. We hope that IPTRID can grasp this opportunity.

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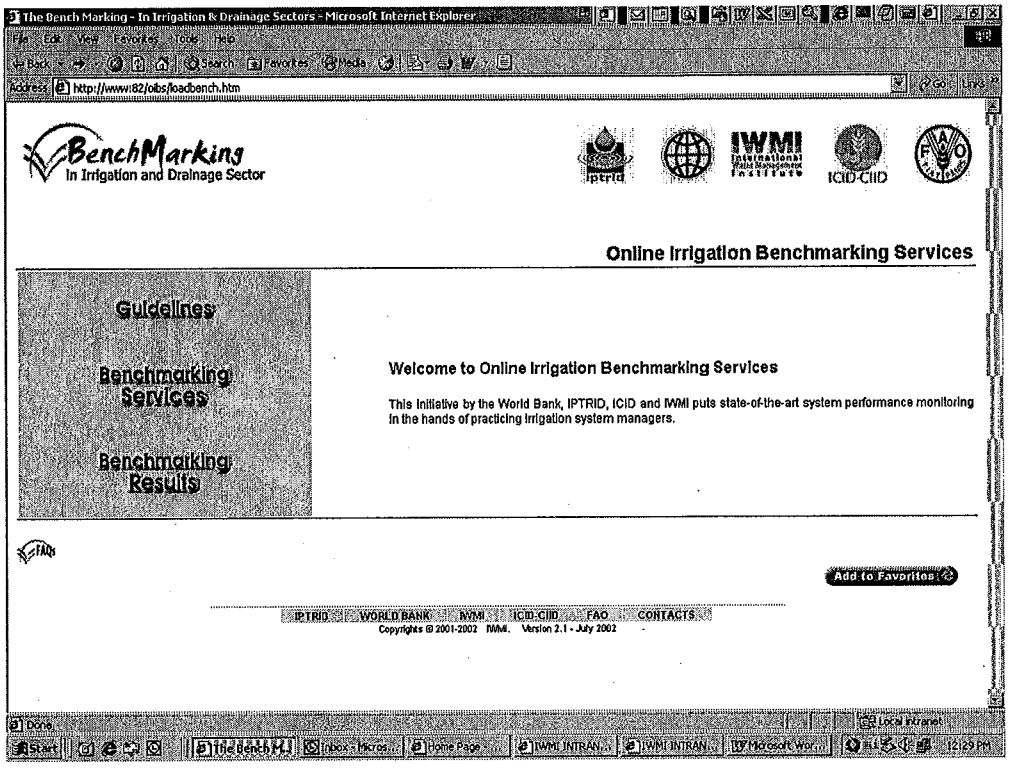
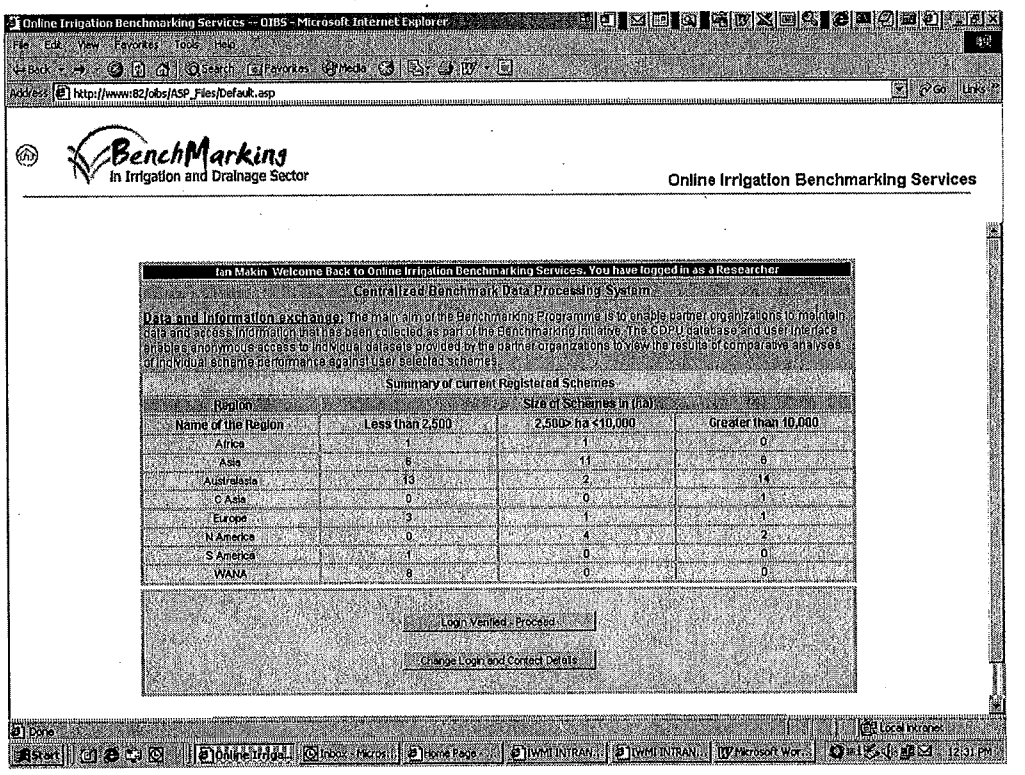
# OUTPUT 5

## On-line Irrigation Benchmarking System (OBIS)

Output 5 – Screen shots of Benchmarking web site OIBS



# OUTPUT 6

Water Supply and Demand of India: Future Scenarios – Upali Amarasinghe, Noel Aloysius, David Molden Draft Report – December 2002

# Water supply and demand of India: Future scenarios

Upali Amarasinghe, Noel Aloysius and David Molden
International Water Management Institute, Colombo

## *Introduction*

Projections show India will become the most populace country by the middle of next century. India's population, 1 billion at present, is estimated to reach 1.3 billion in 2025 and 1.6 billion in 2050 (UN 1998). Three quarters of the present population live in rural areas. Projections indicate that rural population is still expected to be the majority, 57 percent by 2025. Feeding the increasing population adequately is an enormous challenge.

Thanks to increased agricultural development activities, the food production of India has increased significantly in the past decades. India is self sufficient in most of today's food needs. The food grain production has increased at 2.9 percent annually between 1960's and 1990s. The annual growth of the population at the same period was 2.3 percent. India has transformed from a net food grain deficits' of more than 10 percent its domestic consumption in mid 1960's to a net grain surpluses (2 percent of its consumption) in the mid 1980's (FAO 2000). Since 1980's India has managed to be more or less self sufficient in grains even under adverse climatic conditions.

Continued irrigation expansion combined with better seed varieties in India have played a vital role in meeting national food security (CWC 1998, ). The contribution of irrigation to future food production is projected to continue to grow. The irrigation food grain production is projected to increase from 71 percent of the total production in 1995 to 82 percent of the total production in 2025 (IWMI 2000). The irrigation water played a crucial role in agriculture development and also improvements in food security and livelihood in rural India. The estimates of water diversions to agriculture are more than 80 percent of the total diversions (IWMI 2000, Glieck 2000, WRI 2000, FAO 2000).

Several global studies in the recent literature projecting future water supply and demand for different countries show both optimistic as well as pessimistic future scenarios for India. The projections of water demand in 2025 under different scenarios (World Water Vision's and International Food Policy Research Institute's (IFPRI) business as usual scenarios, International Water management's Base scenario, Food and Agriculture organization's (FAO) base scenario) ranges from xx to 24 percent (Rijisberman 2000).

Most global studies consider India as one homogenous analytical unit. Yet, water availability in India is subjected to substantial spatial and temporal variations. For example, the rainfall can vary from as high as 2500 mm to 3000 mm in the Andaman, Nicobar, Lakshadeep islands to less than 500 mm in Rajasthan, West Saurastra and Kutch region. India's bread basket-Punjab and Haryana- receive only about 600 mm of annual rainfall, while Bihar and Uttara Pradesh regions receive 1100 mm of annual rainfall (Thatte xxxx). Most of the rainfall in India receives in 3 to 4 months of monsoon rain. In fact, some estimates that almost all the rainfall in India is received in 100 hours (Agrawal 1999).

The annual per capita mean runoff of India at present is little over 2000 $m^3$ per person. However, this varies from as low as 360 $m^3$ in the Sabramati basin to as high as

16589 $m^3$ in the Bramhaputra and Barak basin. These variations need to be taken into account in projecting future water and food supply and demand. The main objective of this paper is to analyze the spatial variation of water for food supply and demand across river basins in India. The Specific objectives of the paper are

- to estimate the past trends and present status spatial variations of supply and demand food and water across river basins and
- to assess different scenarios of future food and water demand by taking into account the spatial variations across river basins.

A river basin is the ideal analytical unit for water supply and demand studies. The water availability of the Indian River basins are already comprehensively studied (CWC 1998). However, most of the data required for water demand estimation is collected and most of the related policy decisions are taken at the administrative boundary level. Thus demand projection studies, even at sub national level uses administrative boundaries as analytical units (GOI, Indian planning commission 1999). Therefore, the effort in this paper to analyze supply and demand at river basin level is an important step forward. This is even more important in today's context of increasing focus of Integrated Water Resources Management in river basins (IWRM).

Recent studies attempted analyzing spatial water demand in India (CWC 2000, IFPRI 2002). The focus of the spatial variation of these studies is also at river basin level. However, this paper presents a more comprehensive analysis of variations of food and water supply and demand for 19 drainage areas of India. The revised PODIUM model, PODIUMSim India is the source of analysis for the present paper.

The PODIUM, the Policy Dialogue Model, which was developed in 1999 by the International Water Management Institute (IWMI) addresses water supply and demand issues at country level (IWMI 2000, www.cgiar.iwmi.org). The model has been used for generating the World Water Vision scenarios presented at the Second World Water Forum (Rijisberman 2000) and also for generating various other scenarios (IWMI 2000, Molden, Amarasinghe, Huzzain 2000, Molden et al 2002, xxxx and Diner 2002. Since then, in collaboration with the Central Water Commission (CWC) of India, and International Commission for Irrigation and Drainage (ICID), the PODIUM model is modified to handle issues at Indian River basin level. The modified model is, PODIUMSim being applied to 19 river basins in India.

The modified model as in the previous version has three major components: the crop consumption projection at national level, the crop production projections in irrigated and rainfed areas at basin level, and the water supply and demand projections at basin level. The food and water demand estimation in the previous versions was based only on cereals and also at national level. However, the modified versions have a detailed analysis of consumption, production and water demand estimation for 8 crop categories: cereals including rice, wheat, maize and other cereals, pulses, oil crops, vegetables, roots and tubers, sugarcane, fruits and cotton at river basin level.

As in the previous version, the past trends and present status are the information base future projections in the PODIUMSim mode. The magnitudes of future growth of key determinants are exogenous in the structure of the model. The paper presents details of the past trends and present spatial variation of key determinants of food and water

supply and demand of Indian river basins. The future scenarios of water supply and demand are generated using PODIUMSim at River basin level. The results generated at river basins are aggregated to show the national picture for India.The assumptions of the Business as usual (BAU) scenario of the World Water Vision (Gallopin and Rijisberman) form the assumptions for the baseline scenario in the present paper. In brief, the BAU scenario essentially assumes that the current policies on water resources management and development are continued and unsustainable water use may lead to regional water crisis and possibly a world water crisis (Gallopin and Rijsberman, 2000).

These assumptions in the baseline scenario in this paper are exactly the same assumptions of the scenarios that were developed at country level for the BAU scenario. The difference here is that it gives a good picture of the spatial distribution of the water supply and demand and opportunities of addressing critical issues at different spatial locations. In addition to the BAU scenario, we generate few alternate scenarios which address

- Additional growth in productivity required for food self sufficiency
- Food supply and demand under different water withdrawal allocation scenarios between grain and non-grain crops
- Additional growth in productivity and efficiency required for meeting future demands at the present level of water withdrawals

The alternate scenarios would explore the opportunities of averting the crisis at national level.

The format of the paper to follow is described below. The paper consists of two parts. The first part shows the temporal and spatial variations of food and water supply and demand. The second part presents the water supply and demand projections of future scenarios.

The first part begins with a detail description of the analytical units, i.e., river basins. The past trends of the key variables that influence the future projections of different components of the PODIUMSim model are discussed next. Firstly we discussed the past trends at national level of the drivers in the consumption component. Secondly the past trends at national level and the present status at river basin level of the drivers in the production component are discussed. The present status of the water supply and demand of the river basins is presented next. This is followed by a discussion of the water stress conditions of the river basins, and their implications on future water demand and supply. In this we discuss some scenarios to show the impact of water transfers for different cropping patterns on the total crop production.

In the second part, the future projections of food and water supply and demand at basin level with respect to the BAU scenario and some alternative scenarios are presented. First we discuss the BAU scenario with detail description of the key drivers. This is followed by a description of water supply and demand projections to the year 2025.

We conclude the paper discussing the importance of accounting for spatial variations water supply and demand in countries like India, and their implications for future water supply and demand assessments.

# Part I

## River Basins in India

The PODIUMSIM India considers river basins as the basin analytical unit. India's total water resource is considered to drain from 19 major river basins (Annex Table 1 and Figure 1). These basins cover xx percent of the total water resources. The largest basin, Ganga-Brahmaputra-Megna covers 34 percent of total drainage area (column xx, Annex Table 1). This basin has three rivers, Ganga, Brahmaputra, and Megna that confluence before draining to Bay of Bengal. These three rivers are considered as three sub basins in the PODIUMSim model. The four other single largest basins, Indus (draining to sea from the east) and Godavari, Krishna and Mahanadi (draining to sea from the west) cover 32 percent of the drainage area. Eight other small individual basins cover 15 per cent of the area. The rest of the drainage area is divided into four basins, namely rivers which are flowing west Kutch & Saurastra and Luni (WFR 1), rivers south of Tapi basin which are flowing west (WFR 2), rivers flowing east between Mahandai and Pennar basins (EFR1) and rivers flowing east between Pennar and Kanyakumari (EFR 2). The WFR2 basin also covers substantial part of the total drainage area (12 percent).

### *Population*

India's population in 1995 was 933 million (UN 1998) The 19 basins in the study have 96 percent of the total population (column xx, Annex Table 1). The Ganga basin alone, with 27 percent of the total drainage area, has 46 percent of the total population. The four other largest single basins: Indus, Mahanadi, Godavari and Krishna, with 32 percent of the drainage area has 21 percent of the total population. The drainage area combining rivers draining west, WFR2 has another 7 percent of the total population.

The population density (Figure 1, column xx in Annex Table 1) is highest in Sabarmati - the smallest river basin. On the average more than 500 people live in a square kilometer in Sabarmati compare to overall Indian population of density of 282 people per square kilometer, which it self is much higher than the world's average (reference xxx). The Ganga, WFR1 and EFR1 also have high population density with an average of more than 400 people living in one square kilometer area. The Suberanerakha, Cauvery and Mahi river basins follow next with more than 300 people per square kilometer.

Majority of the people in all river basins still lives in rural areas. More than 70 percent of the 1995 Indian population is rural (column xx, Annex table 1). Some basins, have even higher rural population percentage. The Godavari, Brahmani-Baitarni and Brahmaputra basins have even more than 85 percent rural population.

### *Water Resources*

India's total renewable water resources[1] (RWR) is 1869 $km^3$(CWC 1998). Most of these water resources are generated in four monsoon months (CWC 1998) and there

[1] Renewable water resource (RWR) is the surface runoff and the groundwater recharges from the rainfall. The total RWR of India reported by Glieck (2000), Shiklomonave (1999), WRI (2000) and used in IWMI's work on the World Water Vision Studies were higher than the value reported by the Central Water Commission of India.

are claims that even most of this falls within 100 hours (Agrawal 1998). Of the total RWR, only 38 percent, i.e., about 690 $km^3$ is estimated to be potentially utilizable surface water resources (PUSWR) (CWC 1998).

The Brahmaputra river with only 6 percent of the drainage area and with only 3 percent of the total population has 29 percent of the total RWR (about 537 $km^3$) (column xx, Annex table 1). The Brahmaputra is a very narrow river and has very limited potential storage locations within the basin (CWC 2000). Therefore, only 4 percent of the RWR is estimated to be actually utilizable surface water resources (column xx, Annex Table 1). Similarly, only 4 percent of the RWR of the Barak & Others (or also called Megna) is potentially utilizable surface water resources. The low PUSWR ratio of India is primarily due to low PUSWR ratios in the Brahmaputra and Barak basins. The combined PUSWR of other 17 basins is estimated to be 67 percent of their total renewable water resources.

The next highest RWR is in the Ganga river basin (525 $km^3$). This amounts to 28 percent of the total RWR in India. Only 48 percent the RWR in the Ganga basin is estimated to be potentially utilizable surface water resources. The Godavari and the WFR2 also drains substantial amount of the total RWR (17 percent).

It is estimated that another 18 percent of the total RWR are available as potentially utilizable groundwater resources (CWC 2000). However interpretation of this figure needs some caution. Part of the potentially utilizable groundwater resources is seemed to be double counted as utilizable surface resources of bothe surafce and groundwater in some basins are more than the RWR. Food and Agriculture Organization (FAO ) estimated that xxx km3 of grwoundwater supply is double counted.

### *Per Capita Water Resources*

India's per capita internal renewable water resource at present is 2011 $m^3$ (column xx, Annex table 1) Much of this is due to very high RWR generated in the Brahmaputra basin. Per capita water availability of India excluding the Brahmaputra river basin is only 1500 $m^3$. This falls in the category of water scarcity[2] as defined by Falkenmark criterion. (Falkenmark, Lundqvist and Widstrand, 1989). As shown in Figure 2, a substantial spatial variation of per capita RWR exists between river basins.

The per capita RWR of two basins, Sabarmati and the EFR2 (East flowing rivers between Pennar and Kanyakumari) is less than 500 $m^3$ and thus falls into severe water scarce category according to Falkenmark criterion. These two basins have 7 percent (59 million) of the total Indian population.

The per capita RWR of five basins, Pennar, Cauvery, Tapi, Mahi and EFR1 is less than 1000 $m^3$ thus falling into medium water scarce category. These five basins have 13 percent (119 million) of the total population.

The Indus, Ganga, Krishna, and Subernarekha have less than 1700 $m^3$ of per capita water supply and fall into moderate water scarce category. These basins have 56 percent (507 million) of the total population.

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[2] Falkenmark, Lundqvist and Widstrand (1989) used per capita renewable water resources to assess the water stress situation. If the per capita water availability falls below 500 m3 then areas in concern are experiencing constant water scarcities and the water shortage are severe constraints to human life.
If the water availability is between 500 and 1000 m3, then water scarcity is moderate that water shortages beginning to hamper health and human well being. If per capita water availability is between 1000 and 1700 m3 then areas faces seasonal or regular water stressed condition. Above 1700 m3 of per capita water supply, water shortages are rare and if exist are only in few localities..

These indicate that three-quarters of the total population are facing some form ranging from local and seasonal to severe and persistent water scarcities. It is interesting to study how these compare with the food consumption and production of different river basins.

## Crop Consumption: Past Trends and Present Status

The growth in population, growth in total per capita consumption, changes in consumption patterns and growth in usage of crops in feeding animals are key factors in the crop consumption side of the equation. The spatial distribution of the consumption patterns is not available for the present analysis. Therefore, the PODIUMSim India model considers the consumption drivers only at national level. The total consumption estimates for basins are assumed to be proportionate to the basin populations.

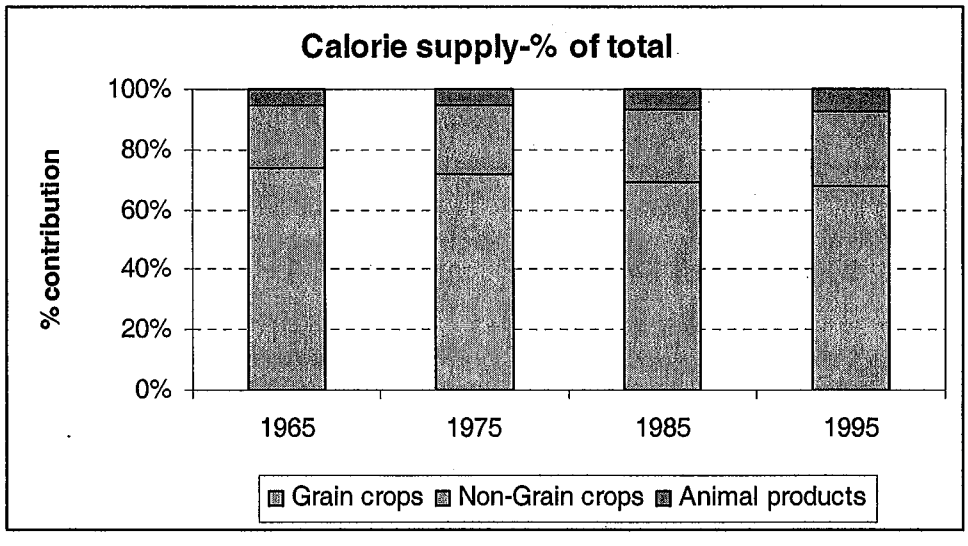
### *Nutritional Supply*

The daily per capita calorie supply and consumption of different crop or crop products in four periods are shown in Annex Tables 2 and 3 respectively. Only the salient features of trends are discussed here.

***Total calorie supply:*** The total daily calorie supply in India has increased by 21 percent from 2006 cal in 1965 to 2419 cal in 1995. If distributed equally, this level of total calorie supply exceeds the minimum required level for adequate nutrition per person in the Indian context (Ravellion xxxx). However, with vast variation of income and demand significant proportion of the population is still estimated to be malnourished (FAO xxx). (Spatial variation ?)

***Calorie supply from grain crop products:*** Grain products contribute to the majority of total daily the calorie supply. The per capita calorie supply of grain products was estimated to increase by 11 percent from 1480 cal in 1965 to 1645 cal in 1995. However, the contribution of grain products to the total has decreased over time from 74 percent of the total in 1961 to 68 percent of the daily total in 1995 (Figure 3).

Figure 3. Per capita per day Calorie supply from Grain crops, non-grain crops and animal products as a percent of total

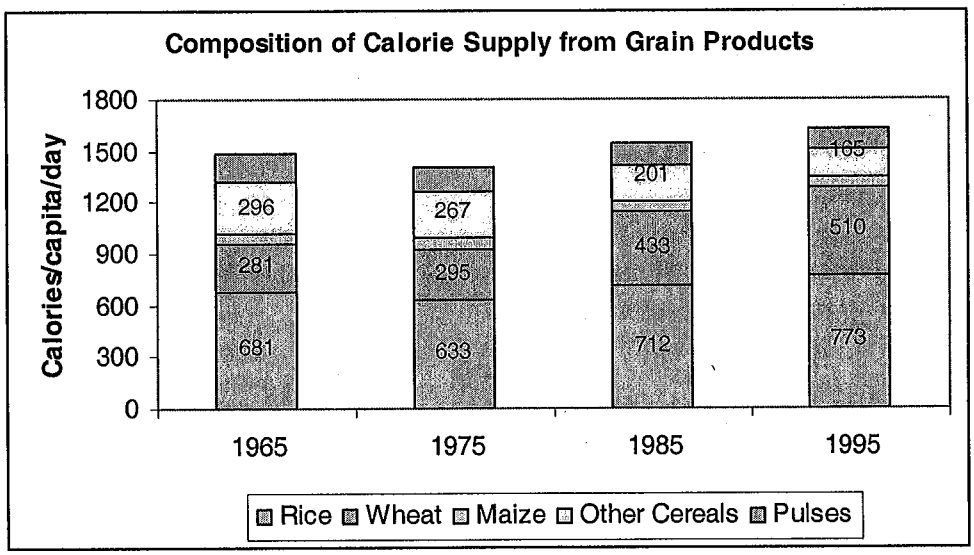


***Calorie supply from non-grain crop products:*** While the contribution of grain products to calorie supply has decreased, the contribution from non-grain crop products has increased from about 21 percent in 1965 to 25 percent in 1995 (Figure 3). The per capita calorie supply from non-grain crops has increased from 421 cal/pc/day in 1965 to 597 cal/pc/day in 1995 (Table 2). A major contribution to this comes from edible oils and sugar products (168 and 224 calories).

Overall, India still remains a major vegetarian country with vegetable products contributing to 93 of the total daily diet in 1995. In fact it is mentioned that (GWP 1999) this contribution will not expected to change significantly in the immediate future.

While not only the total contribution of grain products to the total has decreased, significant changes in the composition of calorie supply of grain products have also occurred over this period (Figure 4). Rice is still the major staple daily diet. The contribution of rice to total calorie supply –about 46 percent - remains constant over time as well the contribution of Maize products-4 percents (Appendix table 2). However, a major shift in the calorie supply from wheat consumption substituting the consumption of pulses and other cereals (such as Millet and Sorghum etc.) was recorded over this period. The composition of wheat products in the calorie supply of grains has increased from only 19 percent in 1965 to 31 percent in 1995 (Appendix Table 2). The combined contribution of pulses and other cereals was halved, from about 31 percent in 1965 to 17 percent in 1995.

Figure 4. Composition of food grains consumption




***Calorie supply from Animal products:*** The calorie supply from animal products has increased by 62 percents from 106 cal in 1965 to 167 cal in 1995. This increase has changed the composition of calorie supply from animal products to the total from 5 percent in 1965 to 7 percent in 1995.

The main contribution to animal products calorie supply is from milk and milk products. The contribution of milk, Butter and Ghee remains more or less same with 79

and 80 percents respectively in 1965 and in 1995. The other contribution comes from meat products, mainly poultry.

Figure 5. Show a graph of GDP and animal products including meat

Generally, in most developing countries, contribution of animal products to daily diet has been increasing with increasing per capita income (Figure 5). More over the contribution of meat to animal product consumption is also generally higher. Due to many reasons, including cultural values, India remains outside this loop of countries with respect to meat consumption. However, recent reports indicate that paltry is a booming business in some parts of the country (Raju, K.V 2002). This indicates an increasing consumption of meat products in some parts of Indian population, though small at the national level. If the trend spreads to other parts of India there will be an enormous increase on feed consumption of crop products due to significantly high population.

### *Food, Feed and Total Consumption*

***Per capita food consumption:*** India's per capita domestic food grain consumption has increased by 11 percent from about 440 grams per day to 490 grams per day (column 2, Annex Table 3). Increase in wheat consumption was the major contributor to this increase. The per capita wheat consumption has increased significantly by 85 percent from 89 grams per day in 1965 to 166 grams per day in 1995 (column 4, Annex table 3). The per capita consumption of rice has increased by 18 percent and per capita consumption of maize remains constant over this period. The per capita consumption of pulses and other cereals however has decreased by 27 and 42 percent respectively.

The per capita consumption of all non-grain crop products has also increased in the period between 1965 and 1995 (columns 8 –14, Annex Table 3). The roots and fiber consumption has the highest relative increase (about 70 percent) over the 30 year period, followed by vegetable oil (67 percent), oil crops (50 percent) and sugar products (23 percents).

***Total feed consumption:*** The grains, oil crops and sugar crops are the major feeds for animals in India. The feed consumption of grains has increased by 59 percent (Annex Table 4). The majority of the increase (89 percent) is from cereal products. Increases in crop products for feeding in general increases the feed conversion factors which is defined here as the total quantity (in kg) of crops or crop products required for producing 1000-calorie equivalent animal products. However this was not the case in India. The feed conversion ratio of grains has in fact decreased over time from 0.095 kg/1000cal in 1965 to 0.047 kg/1000cal in 1995.

The decrease in conversion factors indicates livestock production is still a cottage industry in India. However, in China and in elsewhere in Asia and also in developing countries the conversion factors have in fact increased. Use of grains in feeding has increased over time (Table 5). The livestock production has transformed from that of of a traditional grazing to commercial feeding business in recent times.

Table 5. Feed conversion factors of grains to animal products

| Time period | Feed conversion factors for different regions | | | | |
|---|---|---|---|---|---|
| | India | Asia (excluding India) | China | Developing countries | Developed countries |
| | Kg/1000cal | Kg/1000cal | Kg/1000cal | Kg/1000cal | Kg/1000cal |
| 1965-1995 | 0.095 | 0.402 | 0.396 | 0.327 | 0.987 |
| 1974-1976 | 0.086 | 0.561 | 0.700 | 0.446 | 1.100 |
| 1984-1986 | 0.058 | 0.569 | 0.551 | 0.462 | 1.175 |
| 1994-1996 | 0.047 | 0.512 | 0.499 | 0.451 | 1.075 |

Feed conversion factors of India not only has decreased but also is very low compared to other countries in the region. For example, feed conversion factor in other Asian countries is 9 times higher than the conversion factor of India and also has increased by 27 percent over the 30-year period. This indicates that commercial production of animal products, where grains are the main feeding stuff, is still in its infancy in India. However, due to the large population in India, a small shift in per capita consumption of animal products may translate to substantial increases of the demand for feed grains.

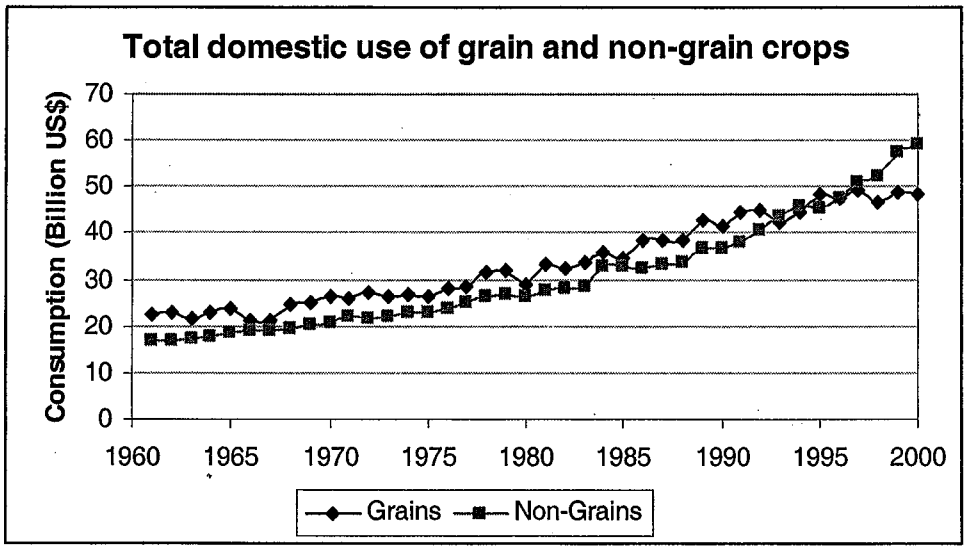
***Seeds, Waste and Other Uses:*** The total seeds, waste and other uses of grains in India are about 10 percent of the total domestic consumption (Table 4). The waste of grains in this category is highest in Maize and other cereals. The percentage of vegetables and fruits in the seeds, waste and other use category is about 6 and 13 percents of the total consumption. Of this most are wasted.

***Total Consumption:*** The total grain consumption (food+ feed+seed waste and other uses) has more than doubled (increased by 109 percent) from 89.7 million metric tons (MMt) in 1965 to 187.1 MMt in 1995 (column 2, total food consumption in annex Table 4, Figure 6). Most of the increase was due to increases in wheat consumption, mostly for food. The wheat consumption has increased by more than four times from 13.6 M Mt in 1965 to 63.0 M Mt in 1995 (column 4, annex table 4).

The rice consumption has, slightly more than doubled from 37 M Mt in 1965 to about 77 M Mt in 1995. The growth of consumption of other grains, though has increased slightly, was well below the population growth rate.

The total grain consumption (figure 6) has increased more than two times over the period 1965 to 1995. However, the total consumption after 1995 is seen to be more or less constant, indicating decreasing dependency of grain crops in recent times. Where as the non-grain crop consumption has steadily increased over time and has overtaken the grain consumption (in 1995 export prices) in recent times.

Figure 6. Consumption of grain and non-grain[3] crops




Two important features of the trends of crop consumption in the last few decades are

- Increasing share of wheat and decreasing share of maize and other cereals in daily diet
- Increasing contribution of non-grain crop products in daily diet, and

The increasing share of wheat and decreasing share of other grains except rice has resulted in more or less constant use of grains after 1995. However, this trend may again reverse in the near future. The change in growth of total grain use in the future will mainly depend on the increase in food consumption of wheat and increase in feed consumption of maize, other cereals and pulses. These have to be taken into account in projecting future scenarios.

[3] The average of the unit export prices of 1994, 1995 and 1996 are used for aggregating the grain and non-grain consumption (see annex B for details of methods of computation).

## Crop Production: Past Trends

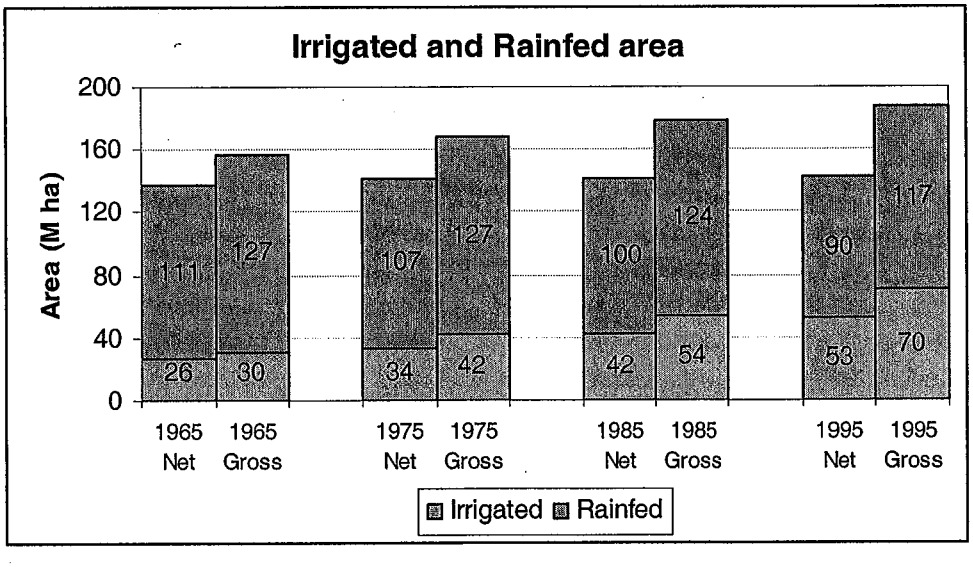
In the PODIUMSim model, the growth in irrigated and rainfed yields, and the growth in irrigated and rainfed crop areas through expansion and intensity growth are key variables in the demand side of the equation. The factors that affect the yield growth, such as fertilizer, high yielding varieties, pesticide etc. are exogenous to the PODIUM model. The trends of these factors are the only indicators for deciding future crop yield growth, and do not play a role in the computations of the growth of yield and production.

The past trends of crop harvested area of major crop categories in India are given in Appendix Table 6. The past trends of yields of irrigated and rainfed conditions are not available separately. Only the past trends of average yields are presented here.

### *Net and Gross Sown area*

Net sown area of all crops has increased slowly (annual rate of 0.13 percent) over the last three decades (Annex Table 6). In fact, the growth is flattening in the last two decades or so and stayed at 142 million ha level in the 1990's (Figure 7). However the cropping intensity has increased steadily at an annual rate of 0.46 percent. Thus the gross crop area thus increased at an annual rate of 0.59 percent and was 187 M ha in 1995. The main reason for increasing cropping intensity was irrigation expansion.

Figure 7. Irrigated and Rainfed Area of India




### *Net and Gross Irrigated Area*

Net irrigated area of India has doubled over the last three decades. The net irrigated area has increased between 1960's and 1990's with an annual rate of 2.34 percent and was 52.6 M Ha in 1995 (Figure 6, annex Table 6). The irrigation intensity has also increased steadily during this period at an annul rate of 0.47 percent. The gross irrigated area has increased by 130 percent (annual rate of 2.82 percent), from 30 million ha in 1965 to 70 million ha in 1995.

Growth rates of net sown area and net irrigated area show vastly different patterns. The net cropped area remains more or less constant while net irrigated area increased substantially. This indicates that some rainfed lands were either gone out of production or were converted into irrigated land. In 1965, only 19 percent of the net crop area were irrigated. This has increased to 30 percent of the net irrigated area in 1995.

### *Net and Gross Rainfed Area*

The net rain-fed area has decreased at an annual rate of 0.69 percent from 111 M Ha in 1965 to 90 M ha in 1995 (Annex Table 6, Figure 6). However cropping intensity in the rainfed areas is seems to be increasing with 114 percent intensity in 1965 and 131 percent intensity in 1995. The reason for this is that only the marginal rainfed lands, where cropping intensity was very low, were converted to irrigated lands or went out of production. At present the cropping intensity in the remaining rainfed lands are as high as the intensity in irrigated lands. The net result was that gross rainfed area decreased slowly at an annual rate 0.25 percent, from 126 M ha in 1965 to 117 M ha in 1995.

### *Crop Harvested Area*

The grain crop area accounted for three-quarters of the total crop area in 1965. The total grain area though increased till 1980's, has declined in the 1990's. Grain area has increased by 9 percent between 1960's and 1980's (from 117 M ha to 128 M ha between 1965 and 1985), but has declined by 4 percent to 124 M ha in 1994.

More than 20 percent of the grain area was irrigated in 1965. This has increased to 39 percent in 1995. The irrigated grain has increased from 23 M ha in 1965 to 48 M Ha in 1995.

The combined harvested area of rice, wheat and maize accounted for 46 percent of the total grain area in 1965. This has increased to 61 percent in 1995. Increases in wheat area accounted for most of the total increase in grain area.

The combined irrigated area of rice, wheat and maize accounted for 81 percent of the total irrigated grain area in 1965. This share has increased to 94 percent of the total irrigated grain area in 1995. Much of the increase was in wheat. The irrigated wheat area has increased by more than four times from 5 million ha in 1965 to 22 million ha in 1995.

The total area of other grain crops has substantially decreased over this period. Total area of other cereals and pulses has decreased by 24 percent from 63 million ha in 1965 to 48 million ha in 1995.

Oil crops, sugar crops and Cotton areas are the other major irrigated crops. Only 4 percent of the oil crop area was irrigated in 1965. This has increased to 25 percent in 1995. Most of the sugar crop area was irrigated (70 percent in 1965 and 80 percent in 1995). Total cotton area remains same, but the area under irrigation has increased from 16 to 34 percent during the 30 year period.

### *Average crop yield*

Time series data of irrigated and rainfed yields are not available. Here we only discuss the trends of average yield. Substantial increase in average yield was recorded over the last decades. The highest growth in yield was in the wheat crop. The wheat yield has more than tripled, from 0.82 tons/ha in 1965 to 2.47 tons/ha in 1995. Rice yield was doubled from 0.94 tons/ha to 1.86 tons/ha over the thirty-year period.

Yields of most other crops have increased over time. Yields of Maize, pulses and oil crops and sugar have increased by 59, 29, 71 and 51 percents respectively. The yield of cotton (cotton lint equivalent) has increased by 117 percent.

Though crop yields have increased over time they are still well below the yield levels of some other developing countries. For example, wheat and rice yields are xx and xx percent below the level of China and even lower than the overall yield levels of developed countries. Overall grain yields are much lower than the levels of other developing countries and developed countries.

The salient features of the growth in irrigated and rainfed crop areas over the last three decades can be summarized as below.

- Growth of net sown area is flattening.
- Cropping intensity on the net sown area is increasing and hence gross sown area is also increasing.
- Net irrigated crop area is increasing, and the irrigation intensity is increasing. Therefore gross irrigated area is increasing faster.
- Net rainfed crop area is decreasing. The intensity on the remaining rainfed areas is as high as in the irrigated areas. Gross rainfed area has decreased slowly.
- Though grain is the major cropping pattern, the total area is decreasing in the last decade
- However, the irrigated grain area is increasing at the expense of rainfed area. The rainfed grain area is decreasing
- Irrigated area of wheat crop has increased sharply. Irrigated rice and maize areas has increased slightly
- Irrigated areas of non-grain crops, mainly oil crops, vegetables, fruits, sugarcane and cotton is increasing.

## Crop Production: Spatial Variation

The India-PODIUM model considers the seasonal variation of crop production of different river basins. The model considers two seasons- Rabi and Kharif. However, for brevity we discuss only the annual production factors to highlight the spatial variation.

### *Crop area*

The irrigated, rainfed and total areas of 8 crop categories (rice, wheat, maize, other cereals, pulses, oilcrops, vegetables, roots and tubers, sugar, fruits and cotton) are given in Annex tables 7, 8 and 9 respectively. The summary of the spatial distribution of crop areas in 1995 is given below.

- About two-thirds of the total crop area is located in four basins: Ganga, Godavari, Indus and Krishna
- About three-quarters of the total irrigated area is located in the same four basins
- About two-thirds of the total rainfed area is located in four basins: Ganga, Godavari, Krishna and Mahanadi
- About 40 percent of the total crop area in India is irrigated at present. The share of the irrigated area to total crop areas of basins ranges from xx percent to xx percent in the Indus basin.
- Grain crops cover about 70 percent of the total irrigated area (31percent rice and 32 percent wheat), followed by oil crops (10 percent), sugar crops (6 percent) and cotton

(4 percent). Rest of the irrigated area contains vegetable and fruits and other crops including tobacco, fodder etc.

- More than 75 percents of the grain irrigated area is in the Ganga, Indus, Godavari and Krishna river basins
- About one-third of the rice irrigated area is in Ganga basin. Majority of the other rice irrigated area are distributed between Indus, Mahanaadi, Godavari, Krishna and east flowing rivers
- More than 85 percents of the wheat irrigated area are in the Indus and Ganga basins
- Three-fourths of the irrigated maize area are in the three basins, Ganga, Indus and Krishna
- Most of the irrigated pulses area are in the Ganga, Indus and Godavari basins (63, 8 and 7 percents respectively)
- Irrigated oil crop area distributed in several basins with Ganga, Krishna, Indus and and West flowing rivers of Kutch & Saurastra and Luni have 39, 10 and 9 percents respectively
- Irrigated vegetables are scatterd in all basins, but Ganga and Godavari have the highest share ( 38 and 10 percents)
- 73 percent of the irrigated sugar crop area are in Ganga, Godavari and Krishna basins (56, 8 and 9 percents respectively)
- Irrigated fruits are mostly located in the Ganga (47 percent), Godavari (9 percent), Indus, Krishna and East flowing rivers between Pennar and Kanyakumari have about 5 percent each.
- Most of the cotton irrigated area are located in Indus and Ganga basins

### *Crop yield*

The irrigated, rainfed and average yields of major crops in 1995 are given in Annex table 10, 11, 12. The spatial distribution of the yields of major crops is summarized here.

- Grain yields vary substantially between river basins. Irrigated rice yields vary from 1.4 Mt/ha more than 3.6 tons/ha. Rainfed rice yields vary between 0.78 Mt/ha to 1.9 Mt/ha. The average irrigated rice yield in all basins (2.36 Mt/ha) is 70 percent higher than the rainfed rice yield of all basins (1.39 Mt/ha).
- Irrigated wheat yield ranges from 1.5 Mt/ha to 5.8 Mt/ha. The rainfed wheat yields vary from 0.7 Mt/ha to 2.1 Mt/ha. Average wheat yields of all basins under irrigated conditions is 60 percent higher than the yield under rainfed conditions.
- Irrigated Maize yield vary from 1.5Mt/ha to 3.2 Mt/ha. Irrigated Maize yields are only 40 percent higher than rainfed yields.

### *Crop production*

The total production of various crops under irrigated and rainfed conditions are summarized below.

- 61 percent of the total grain production is from 39 percent of the irrigated grain area
- 63 percent of the total rice production is from 50 percent of the irrigated rice area
- 91 percent of the total wheat production is from 85 percent of the irrigated wheat area
- majority of the maize, other cereals and pulses production from rainfed areas

- 91 percent of the sugar production is from 88 percent of the irrigated sugar crop area
- 57 percent of the cotton production is from the 37 percent of the irrigated cotton area

## Production Surpluses or Deficits

The production surpluses or deficits, i.e., the production – consumption, of different crops such as rice, wheat, maize, pulses etc are given in Annex table 12. The surpluses/deficits of each crop as percents of total consumption are given in Annex table 13. While the information of surplus/deficits of individual crops is important, it is also important to know whether the total crop production of a basin has a surplus or deficit.

Production or consumption of grain crops can be aggregated in terms of their weight. However, production or consumption of non-grain crops and hence the production surpluses or deficits of all crops cannot be simply aggregated in terms of their weights. First, the quantities of production or consumption of different crop categories are required to be converted to an equivalent weight unit. Only the equivalent production and consumption can be aggregated for all crops.

The world's average export prices of different crop categories are use to convert the quantities of production and consumption into equivalent weights. The method of obtaining unit export price for a crop category is described briefly here and in detail in the appendix A. The world's export prices of different crops and their exported quantities are used to obtain the weighted export price per a unit weight of a crop category. The total production and consumption of crop categories are then expressed in terms of these export prices. The production and consumption in equivalent prices are use to obtain the production surplus or deficits.

The Spatial variation of production surpluses or deficits of grain crops, non-grain crops and total crops in export value term are shown in Figures 8, 9, and 10.

Overall, India is self sufficient in both grains and non-grain crops. The grain and non-grain crop productions have surpluses of about 1.4 and 2.1 percent of grain and non-grain consumption. The total crop production has a surplus of about of 3.5 percent of the total consumption. However, there are substantial spatial variation exist across river basins.

### *Grain Production Surpluses or Deficits*

The Indus, Bramhmani-Britani, Mahanadi, Pennar and Narmada basins recorded substantial production surpluses of grains (more than 50 percent of their consumption). The Brahmaputra, Subernarekha, Godavari, and EFR1 have moderate grain surpluses. Among the production deficit basins, the Megna, Mahi, Sabarmati and WFR2 stand out (more than 25 percent of the consumption) while moderate deficits are seen in other basins.

Several basins, prominently the Indus, have recorded rice surpluses and the total surpluses of these basins are adequate to offset the deficits of other basins. Overall, India has a slight surplus of rice production in 1995. The substantial wheat surpluses of the Indus and the slight surpluses of Narmada and WFR1 are adequate for meeting most of the wheat production deficits of other basins. India is more or less self sufficient in wheat in 1995.

The production surpluses of maize in the Indus and Ganga basins are more than adequate for meeting the deficits in most other basins. Overall there is a slight surplus of

other cereals in India. The production surpluses of other cereals recorded in Godavari, Krishna, Cauvery and Tapi basins resulted in slight production surplus of other cereals at national level. Similarly, the production surpluses of pulses in few basins off set the deficits in other basins.

### *Non-Grain Production Surpluses or Deficits*

All basins, except Ganga, Megna, Narmada, Mahi and Sabarmati are either more or less self sufficient, or have moderate to substantial non-grain production surpluses. The Ganga and Narmada basins have moderate non-grain production deficits while Mahi and Sabarmati basins have substantial production deficits.

Of the non-grain crops, only oil crops has a production deficit, equivalent to 5 percent of the total consumption. The production of oil crops vary from a production surplus of about 200 percent of consumption in Pennar and WFR1 to production deficits of more than 90 percents Subernerkha and Megna basins. The Ganga basin has a deficit of 50 percent. The production of all other non-grain crop categories also vary from substantial production surpluses to substantial production deficits

### *Total Crop Production Surpluses or Deficits*

Overall, India has a slight crop production surplus in 1995. Eleven basins- Brahmaputra, Krishna, Cauvery, WFR1, EFR 1 (5-15 percent of consumption), Subernarkha, Mahanadi, Godavari, Narmada (15 – 50 percent of consumption), Indus, Brahmani-Baitarani (50 to 103 percent of consumption) have crop recorded production surpluses. The other eight basins- Ganga , Tapi, EFR1, EFR2 (5-15 percents), Megna, Mahi, WFR2 (15-50 percent), and Sabarmati have recorded crop production deficits.

## Water Accounting - Present status

### *Agriculture Water Withdrawal*

The water demand of a basin in the Podium model is estimated for two seasons. First the net irrigation requirements (NET) for different crops are estimated. The net irrigation requirement is the difference between the crop evapotranspiration and the effective rainfall. Secondly the gross irrigation withdrawals of surface and ground water are estimated by dividing the NET by the respective irrigation efficiencies

Details of the estimation of basin wise seasonal net irrigation requirements (NET) of different crops are given in appendix A. The NET for two seasons are given in Appendix tables 14 and 15. Spatial variation of the surface and groundwater irrigated area, irrigation efficiencies, and irrigation water supply in 1995 are given in Annex Table 16. Only the salient features of these factors are discussed here.

*Groundwater irrigated area:*

- Groundwater is the source of irrigation for more than half the irrigated area in India.
- More than 60 percent of irrigated area in each of the river basins Ganga, Tapi, Mahi, Sabramati and WFR1 are under from groundwater
- Indus basin has 56 percent groundwater irrigated area.

- Brahmaputra and Barak river basins have the lowest groundwater irrigated area with 13 and 2 percents of the total irrigated area respectively.

***Irrigation withdrawals:***

- Ground water accounts for 42 percent of the total irrigation in 1995
- More than 80 percents of the total groundwater irrigation are in five basins: Ganga Godavari, Indus, WFR1 and EFR2
- Ganga basin accounts for 50 percent of the total irrigation water supply
- More than 70 percents of the total surface irrigation supply are in five basins: Ganga, Krishna, Godavari and Indus
- Overall annual surface and groundwater irrigation efficiencies of India in 1995 were 43 and 65 percents respectively
- Overall irrigation efficiency of India in 1995 was 50 percent.

### *Domestic Water Withdrawals*

The domestic water demand includes the demand for human and livestock consumption. Estimation of domestic water supply for humans depends on three factors, the population with access to safe drinking water supply and daily per capita water use in rural and urban sectors. The variations of per capita domestic water use between basins are not available. We assume that

- 75 percent of the total population in 1995 have access to domestic water supply
- per capita domestic water use in urban and rural areas respectively as 135 liters/day and 40 liters/day.
- The 30 percent of the urban water supply and 70 percent of the rural water supply are from groundwater

The total water use for humans is given in column 9 of table x. The water supply for livestock is estimated by the Central Water Commisssion, India (CWC 2000). These information are being used in the present analysis (Column 8 Table x). The estimates of total domestic water use for river basins are shown in column 10 of table x.

### *Industrial water withdrawals*

The industrial water demand depends on the number and types of industries located in river basins and their water requirements. Central water commission has recognized several constraints, including number of different types of industries, effluent treatment facilities etc. in estimating industrial water use at present in each basin (CWC 199x). Until these information are available we use the following method for estimating total water use in basins. The estimate of total industrial water withdrawals in India in 1995 is taken as 20 $km^3$ (IWMI 2000). The total water withdrawal in each basin is assumed to be proportionate to population in the basin. The total industrial water use in different basins is given in column 11 of table x. The groundwater supply is assumed to contributes to half of the industrial supply (CWC 199x).

### *Total water withdrawals*

The total water withdrawal of the 19 river basins in 1995 is estimated to be 591 $km^3$. Of the total,

- the agriculture, domestic and industrial sectors withdrawals accounted for xx, xx, and xx percent respectively
- more than half of the withdrawals is in the Ganga Basin alone, and
- the Indus, Mahanadi, Godawari and EPR1 basins account for another quarter of the total diversions
- xx percent of is estimated to be the consumptive use by each sector.

### Balance flow

The *balance flow* is the difference between the total water diversions and the process evaporation. The process evaporation is the consumptive use by the intended process such as crop evaporation, consumptive use by humans, livestock and Industries. The balance flow is distributed into four different components.

- ***return flow to surface water***
- ***recharge to groundwater***
- ***non-process evaporation*** through homesteads, and flows to swamps etc.,
- ***non-utilizable outflow*** such as flows to sea or downstream countries which cannot be captured for further use.

The Central Water Commission has given estimates of the different portions of the balance flow (CWC 2000). These estimates are used in estimating different components of the balance flow (Table x).

Table xx. Percent share of different components of the balance flow

| Components | Irrigation | Domestic | Industrial |
|---|---|---|---|
| | % | % | % |
| Return flows to surface water supply | 6 | 43 | 50 |
| Recharge to groundwater supply | 54 | 7 | 0 |
| Non-process evaporation through swamps, homesteds etc | 30 | - | - |
| Non-utilizable outflow to sea | 10 | 50 | 50 |

### Water Accounting

***Potentially Utilizable Water Resources (PUWR):*** The potentially utilizable surface and groundwater resources in all basins are estimated to be 1032 $km^3$. Of which

- groundwater contributes to 33 percent of the total PUWR,
- share of the Ganga basin to the total PUWR is 31 percent.
- Four basins, Godavari , Mahanadi , Indus and Brahmaputra accounts for another 28 percent of the total PUWR.

***Process evaporation:*** The total process evaporation is estimated to be 228 km3, a 22 percent of utilizable water resources.
***Non-process evaporation:*** The total non-process is the evaporation of the portion of the balance flow through homesteads, bare soil, and through flows to swamps. Non-process evaporation from all basins is estimated to be 124 km3, a 12 percent of the PUWR.
***Non-utilizable outflow from the return flow:*** The non-utilizable outflow from the return flow of all basins is estimated as 54 km3, 5 percent of the total PUWR.
***Utilizable outflow:*** The utilizable outflow is the sum of PUWR minus process evaporation and non-process evaporation, and not-utilized outflow from the return flows. This is estimated to be 624 km3, a 60 percent of the total PUWR.

### Primary Water Supply

The primary water supply is the amount of the utilizable water resources that is being diverted for the first time at present through the available storage and conveyance structures. This is the difference of UWR and utilizable outflow. In other words, the primary water supply is the sum of process and non-process evaporation and the non-utilized outflow of the return flows. The primary water supply of all basins is estimated to be 408 km3, a 40 percent of the utilizable water resources.

***Degree of Development (DoD):*** The degree of development is defined as the ratio of primary water supply to utilizable water resources. This indicates the degree water development at present. The degree of development ranges from as low as 7 and 8 percents in the Brahmaputra and Barak river basins to more than 60 percent in the Mahi, Sabramati, WFR 1 and EFR 2.

***Depletion Fraction or Basin Efficiency (DR):*** The depletion fraction of a basin is defined as the ratio of total depletion to primary water supply. The total depletion includes the process and non-process evaporation. It is interesting to note that though the overall irrigation efficiencies of all basins are lower than 50 percent, the depletion fraction of all basins are more than 75 percent. This indicates substantial reuse of primary water use. In fact, the depletion fraction of the primary water supply in India at present is estimated to be 87 percent. This indicates there is very little room for further depletion of the existing diversions through recycling.

***Groundwater Abstraction (GWAR):*** The groundwater abstraction of all of India is 46 percent of the total utilizable groundwater resources. This is more than 60 percent in the Indus, Sabrmati and WFR 1 basins, more than 50 percent in Ganga, Pennar and Mahi basins. Very little of the groundwater resources is being used at present in the Brahmaputra and Megna basins.

### *Water Scarcity and Food Security*

Four indicators are used for explaining the basin food security and basin water scarcity status. These are total crop production surplus or deficit as a percent of consumption (TCPSD), degree of development of water resources (DOD), the groundwater abstraction ratio (GWAR) and the depletion fraction (DF) of the primary water resources. The first is an indicator of the extent of crop production status of the basin. The last three indicate the extent of water resources utilization of the basin.

The cluster analysis technique of k-mean clustering (SPSS 2000) using the five indicators is used to group the basins into 5 homogenous clusters. The cluster information is given in table xx. The basin in each cluster is given in column xx and the values of the indicators are given in columns 3, 4, 5 and 6. The last two columns give the disaggregated crop production surplus or deficit for grain and non-grain crops.

*Cluster 1:* The basins in cluster 1, the Indus and Pennar have high degree of development, high depletion ratios and high groundwater abstraction. These basins are physically water scarce according to IWMI water scarcity indicators (IWMI 2000). That is they do not have enough water resources to be developed for meeting future demand. High groundwater abstraction in these basins indicates existence of pockets of severe groundwater overdraft and hence unsustainable water resources development.

However, basins in this cluster have significant crop production surpluses. In Indus, there is slight deficit of non-grain crop production but the grain production surplus is so high that there is substantial total production surplus. In Penner, both grain and non-grain crop production surplus are significant. The two basins have 5 percent of the total Indian population (about 56 million) and produce 19 percent of the total grain production and 6 percent of the non-grain crop production.

The water scarcities in these basins are due to over development of their water resources, especially for irrigation water use. Increasing demand of domestic and industrial and environmental sectors in the future will have to be met from transferring water from the agriculture sector. Without such approach water development of these basins will continue to be unsustainable.

*Cluster 2:* Four basins, EFR 2, Mahi, Sabarmati, WFR 1 fall into cluster 2. These basins, also have high degree of development, depletion ratios, and ground water abstraction ratios, are also already physically water scarce according to IWMI water scarce criterion. High depletion and groundwater abstraction also indicate similar problems related to water resources development as in the basins in cluster 1.

Unlike in cluster 1 basins, the water scarcities in these basins are exacerbated by their high crop production deficits. In fact, both grain and non-grains have substantial production deficits in these basins. Thus the water scarcity and food security issues can be considered as more critical in these basins than the basins in cluster 1. These basins have 10 percent of the Indian population (about 94 million people) and contribute to about 7 percent of the grain and non-grain crop production.

Substantial production deficits of the basins in this cluster indicate, in relative terms, severe water scarcities than the basins in the first cluster. The food dependency

these basins will most probably increase in light of the increasing demand of the other sectors of water use.

*Cluster 3:* Eight basins, Tapi, Ganag, WFR 2, Narmada, Krishna, Cauvery, Godawari and EFR 1, are included in this cluster. With respect to the basins in cluster 1 and 2, basins in cluster 3 have low degree of development. Except Ganga basin, all have lower groundwater abstraction ratios. However, the depletion fractions in general are as high as in clusters 1and 2. The high groundwater abstraction ratio in the Ganga basin indicates unsustainable water use in some parts of the basin.

All basins except Godavari and ERF 1 have high to moderate food production deficits. The Tapi and Ganga basins, with 43 percent of the population have more than 10 percent crop production deficits of their total consumption. The production deficits of Narmada, Krishna and Cauvery with 12 percent of the total population have low production deficits.

The two basins, Godawari and EFR 1 in this cluster have substantial production surpluses. The issues of water scarcities and food security are not as serious as the issues in Tapi or Ganga basins.

*Cluster 4:* Three basins, Subernarekha, Brahmani-Braitarni and Mahanadi are in cluster 4. These basins though have high depletion fractions, have relatively low degree of development, relatively low groundwater abstraction and high significant production surpluses. The water scarcity and food security issues in these basins are not as serious as in previous in the basins of previous groups. These basins have only 5 percent of the Indian population and contribute to 8 and 11 percent of the total grain and non-grain production respectively.

*Cluster 5:* Two basins, Brhamaputra and Megna fall into this category. They have low degree of development, low depletion fractions, low groundwater use and very significant crop production surpluses. These basins have only 4 percent of the total Indian population and contribute to only 4 percent of the total grain and non-grain production.

## Water productivity

We conclude part I of the paper with a discussion of water productivity of irrigated grains and non-grains crops. Production in irrigated areas contributes to 60 percent of the total grain production and 30 percent of the total non-grain crop production. However, the water productivity of irrigated grain crops (0.17 $ per m3 of diversions) is only 42 percent of the water productivity of irrigated non-grain crops (0.42 $/m3 of diversions). This indicates that substantial production increase can be obtained by slight reallocation of irrigation water from grains to non-grains crops. Table xx shows the production gains and changes in production surplus or deficits by such a reallocation of irrigation water resources.

A reallocation of 5 percent of the water diverted grain crops to non-grain crops, i.e., a reallocation of about 21 km3, would have reduced the irrigation grain crop production by 1.4 Million M Tand the production surplus from 3.3 percent of consumption to 0.2 percent of consumption. The irrigated non-grain crop production would have increased by 4.4 Million MT and total non-grain crop production surplus by

2.9 percent of the consumption to 7.1 percent of the consumption. The total crop production surplus thus would have almost doubled, from 2.7 percent of the consumption to 4.9 percent of the total consumption by such a scenario of water reallocation.

A 10 percent irrigation water reallocation scenario, though would record a production deficit of cereals (about -2.9 percent of the total consumption), would record a substantial production surplus of non-grains crops (about 12.3 percent of the consumption). The total crop production surplus under a such a scenario would have increased the production surplus to 7.1 percent of the total consumption.

This above analysis at national level shows the extent of gains that can be achieved by water reallocation from grains to non-grain crops. In deed, the water productivity differences of grains and non-grains crops are different between basins. Some basins could offer substantial gains in production surpluses or deficits. Also it could offer opportunities for mitigating water scarcities in some basins. These would be our focus in the next part of the paper. We generate business as usual scenario of the World Water Vision (Rijisberman 2000) for Indian river basins, and generate other alternate scenarios which could either increase production surpluses or decrease production deficits and also could result in less water stress in the basins.

## *Annex Table 1. Area, Population and Water Resources of Indian River Basins*

| River Basin | Catchment Area[1] | Population | | | Renewable Water resources[4] (RWR) | Potentially utilizable water resources (PUWR) | | | Per capita water resources | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total[2] | Density | Rural - % of total[3] | | Surface | Ground water[5] | Total | RWR/pc | PUWR/pc |
| | $Km^2$ | Million | No. people/ $km^2$ | % | $Km^3$ | $Km^3$ | $Km^3$ | $Km^3$ | $m^3$ | $m^3$ |
| 1. Indus | 321,289 | 45.1 | 140 | 71 | 73.3 | 46.0 | 14.3 | 60.3 | 1611 | 1325 |
| 2. Ganga | 861,452 | 386.5 | 449 | 75 | 525.0 | 250.0 | 136.5 | 386.5 | 1353 | 996 |
| 3. Brahmaputra | 194,413 | 31.3 | 161 | 86 | 585.6 | 24.3 | 25.7 | 48.0 | 17108 | 1529 |
| 4. Barak& Others | 41,723 | 6.7 | 160 | 82 | 48.4 | 1.7 | 8.5 | 10.2 | 7224 | 1522 |
| 5. Subernarekha | 29,196 | 10.1 | 347 | 76 | 12.4 | 6.8 | 1.7 | 8.5 | 1216 | 833 |
| 6. Brahmani-Baitarni | 51,822 | 10.6 | 204 | 87 | 28.5 | 18.3 | 3.4 | 21.7 | 2689 | 2047 |
| 7. Mahanadi | 141,589 | 28.6 | 202 | 80 | 66.9 | 50.0 | 13.6 | 63.6 | 2331 | 2216 |
| 8. Godavari | 312,812 | 58.1 | 186 | 85 | 110.5 | 76.3 | 33.5 | 109.8 | 1877 | 1865 |
| 9. Krishna | 258,948 | 65.4 | 253 | 68 | 78.1 | 58.0 | 19.9 | 77.9 | 1186 | 1183 |
| 10. Pennar | 55,213 | 10.4 | 189 | 78 | 6.3 | 6.30 | 0.0 | 10.9 | 601 | 1040 |
| 11. Cauvery | 81,155 | 31.5 | 389 | 70 | 21.4 | 19.0 | 8.8 | 27.8 | 676 | 878 |
| 12. Tapi | 65,145 | 15.9 | 245 | 63 | 14.9 | 14.5 | 6.7 | 21.2 | 931 | 1325 |
| 13. Narmada | 98,796 | 15.8 | 160 | 79 | 45.6 | 34.5 | 9.4 | 43.9 | 2868 | 2761 |
| 14. Mahi | 34,842 | 11.3 | 324 | 77 | 11.0 | 3.1 | 3.5 | 6.6 | 973 | 584 |
| 15. Sabarmati | 21,674 | 11.3 | 521 | 54 | 3.8 | 1.9 | 2.9 | 4.8 | 239 | 302 |
| 16. WFR1 | 55,940 | 23.8 | 425 | 72 | 15.1 | 15.0 | 9.1 | 24.1 | 478 | 763 |
| 17. WFR2 | 378,028 | 62.9 | 166 | 57 | 200.9 | 36.2 | 15.6 | 51.8 | 3184 | 821 |
| 18. EFR1 | 86,643 | 25.4 | 293 | 74 | 22.5 | 13.1 | 12.8 | 25.9 | 946 | 1089 |
| 19. EFR2 | 100,139 | 48.4 | 484 | 60 | 16.5 | 16.7 | 12.7 | 29.4 | 340 | 605 |
| Total | 3,190,819 | 899.0 | 282 | 73 | 1838.3 | 690.3 | 34.2.5 | 1032.8 | 2011 | 1130 |

1 – Source: CWC 1993. (Reassessment of Water Resources Potential of River basin)
2 – Source for total population (UN 1998)
3 - Source for Renewable and potentially utilizable water resources is CWC 2000.
4 – Potentially utilizable ground water resources is the ground water replenished from normal natural recharge

***Annex Table 2. Daily per capita Calorie supply***

| Time period (average) | Per capita per day Calorie supply | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Vegetable products | | | | | | | | | | | | | | Animal products | | |
| | | Total | Grain products | | | | | | Oil crops | Vegetable oils | Starchy roots | Vegetable | Fruits | Sugar crops | Sweeteners | Total | % of total Animal products | |
| | | | Total | % of total Grain products | | | | | | | | | | | | | | |
| | | | | Rice | Wheat | Maize | Other cereal | Pulses | | | | | | | | | Milk | Butter /Ghee |
| | Cal | Cal | Cal | % | % | % | % | % | Cal | Cal | Cal | Cal | Cal | Cal | Cal | Cal | % | % |
| 1965-1995 | 2006 | 1901 | 1480 | 46 | 19 | 4 | 20 | 11 | 30 | 98 | 27 | 27 | 32 | 8 | 182 | 106 | 59 | 20 |
| 1974-1976 | 1964 | 1853 | 1406 | 45 | 21 | 5 | 19 | 10 | 27 | 110 | 41 | 31 | 29 | 8 | 183 | 111 | 60 | 18 |
| 1984-1986 | 2229 | 2075 | 1548 | 46 | 28 | 4 | 13 | 9 | 28 | 135 | 41 | 34 | 35 | 8 | 223 | 154 | 67 | 14 |
| 1994-1996 | 2419 | 2242 | 1645 | 47 | 31 | 4 | 10 | 7 | 48 | 162 | 42 | 37 | 43 | 9 | 224 | 177 | 61 | 19 |

Annex Table 3. Daily per capita food consumption

| Time Period | Daily per capita food consumption | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain products | | | | | | Other crop products | | | | | | | Animal products | |
| | Total | Rice | Wheat | Maize | Other cereals | Pulses | Oil crops | Vegetable oils | Starchy roots | Vegetable | Fruits | Sugar crops | Sweeteners | Milk | Milk and butter |
| | Kg | kg | kg | Kg | Kg | kg | kg | kg | kg | kg | kg | kg | kg | kg | kg |
| 1965-1995 | 0.440 | 0.187 | 0.089 | 0.022 | 0.094 | 0.048 | 0.014 | 0.011 | 0.034 | 0.109 | 0.072 | 0.029 | 0.052 | 0.002 | 0.091 |
| 1974-1976 | 0.420 | 0.175 | 0.096 | 0.022 | 0.087 | 0.039 | 0.014 | 0.012 | 0.052 | 0.126 | 0.067 | 0.028 | 0.052 | 0.002 | 0.098 |
| 1984-1986 | 0.461 | 0.197 | 0.139 | 0.021 | 0.066 | 0.038 | 0.013 | 0.016 | 0.054 | 0.142 | 0.080 | 0.028 | 0.063 | 0.002 | 0.139 |
| 1994-1996 | 0.490 | 0.212 | 0.166 | 0.022 | 0.055 | 0.035 | 0.023 | 0.018 | 0.058 | 0.153 | 0.094 | 0.032 | 0.063 | 0.004 | 0.160 |

Annex Table 4. Total crop consumption

| Time period | Total crop consumption details | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grains | | | | | | Oil crops | | Starchy roots | Vegetable | Fruits | Sugar | | Cotton | Total |
| | Total | Rice | Wheat | Maize | Other cereal | Pulses | Oil crops | Veg. oils | | | | Sugar crop | Sugar | | |
| | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | MMt | BUS$ |
| **Total food consumption** | | | | | | | | | | | | | | | |
| 1965-1995 | 79.5 | 33.8 | 16.2 | 3.9 | 17.0 | 8.7 | 2.6 | 2.0 | 6.1 | 19.8 | 13.0 | 5.3 | 9.4 | - | |
| 1974-1976 | 95.1 | 39.7 | 21.7 | 5.0 | 19.8 | 8.9 | 3.1 | 2.8 | 11.9 | 28.6 | 15.3 | 6.4 | 11.8 | - | |
| 1984-1986 | 128.7 | 55.0 | 38.8 | 5.9 | 18.3 | 10.7 | 3.5 | 4.3 | 15.0 | 39.8 | 22.4 | 7.7 | 17.6 | - | |
| 1994-1996 | 165.9 | 71.8 | 56.1 | 7.6 | 18.6 | 11.9 | 7.7 | 6.3 | 19.5 | 51.7 | 31.9 | 10.9 | 21.4 | - | |
| **Total Feed Consumption** | | | | | | | | | | | | | | | |
| 1965-1995 | 1.8 | 0.1 | 0.1 | 0.1 | 0.5 | 1.0 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.3 | - | |
| 1974-1976 | 2.2 | 0.2 | 0.3 | 0.1 | 0.6 | 1.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.4 | - | |
| 1984-1986 | 2.5 | 0.2 | 0.5 | 0.1 | 0.5 | 1.1 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.5 | - | |
| 1994-1996 | 2.9 | 0.3 | 0.7 | 0.2 | 0.4 | 1.2 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.4 | - | |
| **Total Seeds, Waste and Other uses** | | | | | | | | | | | | | | | |
| 1965-1995 | 8.2 | 3.0 | 0.9 | 0.9 | 2.3 | 1.1 | 1.0 | 0.2 | 1.4 | 1.7 | 1.9 | 7.7 | 0.0 | - | |
| 1974-1976 | 11.3 | 3.9 | 2.0 | 1.3 | 3.1 | 1.1 | 1.1 | 0.2 | 2.4 | 2.3 | 2.2 | 9.4 | 0.0 | - | |
| 1984-1986 | 14.4 | 4.4 | 3.6 | 1.5 | 3.7 | 1.2 | 1.2 | 0.8 | 3.7 | 3.1 | 3.2 | 11.4 | 0.0 | - | |
| 1994-1996 | 18.3 | 5.6 | 4.9 | 1.9 | 4.7 | 1.2 | 2.1 | 1.0 | 5.2 | 3.5 | 4.8 | 17.3 | 0.0 | - | |
| **Total domestic use (= Food + Feed + Seeds, Waste & Other uses)** | | | | | | | | | | | | | | | |
| 1965-1995 | 89.5 | 36.9 | 17.2 | 5.0 | 19.8 | 10.7 | 4.7 | 2.2 | 7.5 | 21.5 | 14.9 | 13.9 | 9.7 | 1.1 | |
| 1974-1976 | 108.6 | 43.7 | 24.0 | 6.4 | 23.6 | 10.9 | 4.9 | 3.1 | 14.2 | 30.9 | 17.5 | 16.9 | 12.2 | 1.2 | |
| 1984-1986 | 145.6 | 59.6 | 42.9 | 7.6 | 22.5 | 13.0 | 5.3 | 5.1 | 18.7 | 42.8 | 25.6 | 20.9 | 18.1 | 1.3 | |
| 1994-1996 | 187.1 | 77.7 | 61.7 | 9.7 | 23.7 | 14.3 | 10.7 | 7.2 | 24.7 | 55.2 | 36.8 | 29.9 | 21.9 | 2.2 | |

Source: FAO 2002

***Annex Table 6. Trends of irrigated area, rainfed area and average yield of different crops***

| Time period | Crop area and average yields | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net area | Intensity | Gross area | Grain Total | Rice | Wheat | Maize | Other cereal | Pulses | Oil crops | Starchy roots | Vegetables | Sugar crops | Fruits | Cotton |
| | M ha | % | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha | M Ha |
| Irrigated | | | | | | | | | | | | | | | |
| 1965-1995 | 26.3 | 116 | 30.4 | 23.7 | 13.2 | 5.0 | 0.6 | 2.7 | 2.1 | 0.9 | | | 1.8 | 1.2 | 1.2 |
| 1974-1976 | 33.6 | 124 | 41.8 | 32.0 | 14.9 | 11.5 | 1.0 | 2.7 | 1.8 | 2.2 | | | 2.2 | 1.4 | 1.7 |
| 1984-1986 | 42.0 | 129 | 54.2 | 40.2 | 17.7 | 17.6 | 1.0 | 2.0 | 1.9 | 4.9 | | | 2.5 | 1.7 | 2.2 |
| 1994-1996 | 52.6 | 133 | 70.1 | 48.4 | 21.3 | 21.6 | 1.3 | 1.4 | 2.8 | 8.9 | | | 3.4 | 1.2 | 3.0 |
| **Rainfed** | | | | | | | | | | | | | | | |
| 1965-1995 | 110.7 | 114 | 126.6 | 93.2 | 22.5 | 8.1 | 4.2 | 37.0 | 21.3 | 24.3 | 0.8 | | 0.7 | 0.5 | 6.8 |
| 1974-1976 | 106.8 | 119 | 126.7 | 91.8 | 23.7 | 7.5 | 4.9 | 34.4 | 21.2 | 23.3 | 1.2 | | 0.6 | 0.6 | 5.6 |
| 1984-1986 | 99.5 | 124 | 123.9 | 87.8 | 23.4 | 6.2 | 4.8 | 31.7 | 21.7 | 22.6 | 1.3 | | 0.5 | 0.7 | 5.1 |
| 1994-1996 | 89.9 | 131 | 117.4 | 74.2 | 21.7 | 3.7 | 4.8 | 24.1 | 19.8 | 27.3 | 1.5 | | 0.5 | 2.1 | 5.7 |
| **Total** | | | | | | | | | | | | | | | |
| 1965-1995 | 136.9 | 115 | 157.0 | 116.9 | 35.7 | 13.2 | 4.8 | 39.7 | 23.4 | 25.2 | 0.8 | 3.1 | 2.6 | 1.7 | 8.0 |
| 1974-1976 | 140.4 | 120 | 168.5 | 123.8 | 38.6 | 19.0 | 6.0 | 37.1 | 23.1 | 25.5 | 1.2 | 3.9 | 2.8 | 2.0 | 7.3 |
| 1984-1986 | 141.5 | 126 | 178.1 | 128.0 | 41.2 | 23.7 | 5.8 | 33.7 | 23.6 | 27.5 | 1.3 | 4.8 | 3.0 | 2.5 | 7.3 |
| 1994-1996 | 142.5 | 132 | 187.4 | 122.6 | 43.0 | 25.3 | 6.1 | 25.5 | 22.6 | 36.3 | 1.5 | 5.0 | 3.8 | 3.3 | 8.7 |
| Average Yield | | | | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha | Ton/ha |
| 1965-1995 | - | - | - | 0.67 | 0.99 | 0.82 | 0.99 | 0.42 | 0.46 | 0.13 | 8.8 | 6.9 | 45.7 | 8.9 | 0.12 |
| 1974-1976 | - | - | - | 0.87 | 1.15 | 1.31 | 1.07 | 0.58 | 0.47 | 0.16 | 11.9 | 7.9 | 50.6 | 8.9 | 0.15 |
| 1984-1986 | - | - | - | 1.15 | 1.48 | 1.92 | 1.29 | 0.62 | 0.53 | 0.18 | 14.1 | 8.9 | 57.9 | 10.5 | 0.18 |
| 1994-1996 | - | - | - | 1.53 | 1.86 | 2.47 | 1.58 | 0.82 | 0.61 | 0.24 | 17.1 | 11.2 | 68.7 | 11.1 | 0.25 |

Sources: Directorate of Economic and Statistics (2002), CWC 2002, FAO 2002

Annex Table 7: Irrigated crop area in 1995: Total and spatial distribution.

| | ***Irrigated area in 1995 (in Million Ha)*** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net | Gross | Grains | Paddy | Wheat | Miaze | Other cereals | Pulses | Oil crops | Vegetables | Starchy roots | Sugar crop | Fruits | Cotton | Other area |
| | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha |
| 1. Indus | 5.961 | 10.201 | 7.301 | 2.470 | 4.347 | 0.159 | 0.108 | 0.217 | 0.613 | 0.063 | 0.000 | 0.141 | 0.065 | 1.027 | 0.991 |
| 2. Ganga | 24.555 | 33.035 | 24.167 | 7.073 | 14.307 | 0.705 | 0.448 | 1.633 | 2.631 | 0.539 | 0.000 | 1.865 | 0.488 | 0.900 | 2.447 |
| 3. Brahmaputra | 0.930 | 1.019 | 0.795 | 0.752 | 0.035 | 0.000 | 0.000 | 0.007 | 0.032 | 0.009 | 0.000 | 0.000 | 0.008 | 0.000 | 0.175 |
| 4. Barak& Others | 0.127 | 0.143 | 0.074 | 0.073 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.065 |
| 5. Subernarekha | 0.522 | 0.642 | 0.581 | 0.377 | 0.162 | 0.028 | 0.002 | 0.012 | 0.023 | 0.028 | 0.000 | 0.005 | 0.015 | 0.000 | 0.000 |
| 6. Brahmani-Baitarni | 0.816 | 0.986 | 0.872 | 0.615 | 0.186 | 0.034 | 0.004 | 0.033 | 0.036 | 0.056 | 0.000 | 0.012 | 0.026 | 0.001 | 0.000 |
| 7. Mahanadi | 1.849 | 2.071 | 1.573 | 0.980 | 0.406 | 0.009 | 0.010 | 0.168 | 0.112 | 0.091 | 0.000 | 0.031 | 0.050 | 0.029 | 0.185 |
| 8. Godavari | 3.531 | 4.238 | 2.744 | 1.756 | 0.556 | 0.052 | 0.187 | 0.193 | 0.355 | 0.079 | 0.000 | 0.275 | 0.112 | 0.106 | 0.568 |
| 9. Krishna | 3.139 | 3.996 | 2.338 | 1.729 | 0.152 | 0.164 | 0.210 | 0.083 | 0.676 | 0.049 | 0.000 | 0.314 | 0.086 | 0.149 | 0.385 |
| 10. Pennar | 0.787 | 1.018 | 0.794 | 0.740 | 0.003 | 0.025 | 0.019 | 0.006 | 0.155 | 0.002 | 0.000 | 0.050 | 0.006 | 0.023 | 0.000 |
| 11. Cauvery | 1.551 | 1.974 | 1.045 | 0.870 | 0.018 | 0.049 | 0.070 | 0.039 | 0.359 | 0.029 | 0.000 | 0.140 | 0.065 | 0.065 | 0.270 |
| 12. Tapi | 0.633 | 0.750 | 0.366 | 0.126 | 0.135 | 0.007 | 0.058 | 0.041 | 0.050 | 0.019 | 0.000 | 0.069 | 0.032 | 0.031 | 0.183 |
| 13. Narmada | 1.228 | 1.303 | 0.884 | 0.256 | 0.475 | 0.004 | 0.015 | 0.135 | 0.105 | 0.011 | 0.000 | 0.023 | 0.022 | 0.063 | 0.195 |
| 14. Mahi | 0.465 | 0.552 | 0.252 | 0.039 | 0.157 | 0.003 | 0.019 | 0.034 | 0.134 | 0.007 | 0.000 | 0.010 | 0.008 | 0.056 | 0.085 |
| 15. Sabarmati | 0.290 | 0.354 | 0.136 | 0.029 | 0.075 | 0.002 | 0.017 | 0.013 | 0.089 | 0.008 | 0.000 | 0.011 | 0.009 | 0.051 | 0.050 |
| 16. WFR1 | 1.781 | 2.173 | 0.847 | 0.167 | 0.481 | 0.014 | 0.102 | 0.083 | 0.554 | 0.044 | 0.000 | 0.065 | 0.050 | 0.302 | 0.312 |
| 17. WFR2 | 1.181 | 1.490 | 0.732 | 0.496 | 0.092 | 0.034 | 0.073 | 0.037 | 0.302 | 0.028 | 0.000 | 0.096 | 0.055 | 0.063 | 0.214 |
| 18. EFR1 | 1.237 | 1.569 | 1.269 | 1.196 | 0.006 | 0.024 | 0.017 | 0.026 | 0.184 | 0.034 | 0.000 | 0.058 | 0.018 | 0.021 | 0.000 |
| 19. EFR2 | 2.015 | 2.565 | 1.503 | 1.370 | 0.004 | 0.025 | 0.061 | 0.043 | 0.399 | 0.035 | 0.000 | 0.162 | 0.083 | 0.064 | 0.321 |
| Total | 52.60 | 70.080 | 48.273 | 21.113 | 21.599 | 1.336 | 1.422 | 2.804 | 6.808 | 1.133 | 0.000 | 3.327 | 1.200 | 2.948 | 6.390 |

Sources: Directorate of Economic and Statistics (2002), CWC 2002

Annex Table 8: Rainfed crop area in 1995: Total and spatial distribution

| River Basin | Rainfed crop area 1995 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grains | Paddy | Wheat | Miaze | Other cereals | Pulses | Oil crops | Vegetables | Starchy roots | Sugar crop | Fruits | Cotton |
| | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha |
| 1. Indus | 3.314 | 0.043 | 0.476 | 0.822 | 1.170 | 0.803 | 0.395 | 0.084 | 0.072 | 0.002 | 0.089 | 0.025 |
| 2. Ganga | 28.738 | 10.725 | 1.352 | 2.288 | 7.020 | 7.352 | 4.194 | 1.473 | 1.056 | 0.312 | 0.264 | 0.278 |
| 3. Brahmaputra | 3.246 | 2.797 | 0.102 | 0.138 | 0.054 | 0.156 | 0.437 | 0.334 | 0.141 | 0.037 | 0.148 | 0.006 |
| 4. Barak& Others | 0.491 | 0.442 | 0.013 | 0.019 | 0.003 | 0.015 | 0.054 | 0.054 | 0.009 | 0.005 | 0.053 | 0.005 |
| 5. Subernarekha | 0.947 | 0.621 | 0.014 | 0.043 | 0.037 | 0.232 | 0.123 | 0.119 | 0.035 | 0.011 | 0.025 | 0.001 |
| 6. Brahmani-Baitarni | 1.563 | 0.877 | 0.020 | 0.070 | 0.087 | 0.508 | 0.295 | 0.205 | 0.025 | 0.013 | 0.050 | 0.003 |
| 7. Mahanadi | 4.267 | 1.767 | 0.295 | 0.219 | 0.564 | 1.421 | 1.192 | 0.365 | 0.016 | 0.004 | 0.081 | 0.096 |
| 8. Godavari | 9.011 | 1.388 | 0.497 | 0.249 | 4.294 | 2.584 | 3.002 | 0.230 | 0.011 | 0.031 | 0.172 | 1.793 |
| 9. Krishna | 6.320 | 0.448 | 0.179 | 0.105 | 3.726 | 1.862 | 2.817 | 0.155 | 0.025 | 0.014 | 0.206 | 1.192 |
| 10. Pennar | 0.725 | 0.013 | 0.006 | 0.041 | 0.358 | 0.306 | 0.572 | 0.036 | 0.002 | 0.000 | 0.089 | 0.137 |
| 11. Cauvery | 1.548 | 0.091 | 0.022 | 0.011 | 0.897 | 0.528 | 0.843 | 0.094 | 0.008 | 0.000 | 0.107 | 0.172 |
| 12. Tapi | 2.246 | 0.263 | 0.121 | 0.040 | 1.250 | 0.571 | 0.633 | 0.027 | 0.002 | 0.010 | 0.006 | 0.538 |
| 13. Narmada | 2.756 | 0.771 | 0.348 | 0.194 | 0.631 | 0.812 | 0.939 | 0.035 | 0.013 | 0.000 | 0.000 | 0.152 |
| 14. Mahi | 0.818 | 0.076 | 0.039 | 0.083 | 0.371 | 0.249 | 0.274 | 0.007 | 0.003 | 0.000 | 0.000 | 0.044 |
| 15. Sabarmati | 0.393 | 0.021 | 0.015 | 0.044 | 0.203 | 0.109 | 0.220 | 0.004 | 0.003 | 0.000 | 0.000 | 0.052 |
| 16. WFR1 | 2.488 | 0.120 | 0.088 | 0.280 | 1.297 | 0.703 | 1.283 | 0.026 | 0.014 | 0.000 | 0.000 | 0.290 |
| 17. WFR2 | 2.429 | 0.496 | 0.075 | 0.033 | 1.255 | 0.570 | 1.584 | 0.302 | 0.007 | 0.012 | 0.503 | 0.446 |
| 18. EFR1 | 1.488 | 0.429 | 0.002 | 0.076 | 0.361 | 0.619 | 0.808 | 0.171 | 0.002 | 0.001 | 0.139 | 0.149 |
| 19. EFR2 | 1.288 | 0.012 | 0.004 | 0.019 | 0.705 | 0.547 | 0.778 | 0.093 | 0.001 | 0.000 | 0.116 | 0.169 |
| Total | 74.076 | 21.401 | 3.668 | 4.775 | 24.284 | 19.948 | 20.441 | 3.814 | 1.445 | 0.454 | 2.049 | 5.549 |

Sources: Directorate of Economic and Statistics (2002), CWC 2002

Annex Table 9: Total crop area in 1995: Total and spatial distribution

| | Total crop area 1995 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grains | Paddy | Wheat | Miaze | Other cereals | Pulses | Oil crops | Vegetables | Starchy roots | Sugar crop | Fruits | Cotton |
| | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha | Mha |
| 1. Indus | 10.615 | 2.513 | 4.823 | 0.981 | 1.278 | 1.021 | 1.008 | 0.147 | 0.072 | 0.143 | 0.154 | 1.052 |
| 2. Ganga | 52.905 | 17.798 | 15.659 | 2.992 | 7.468 | 8.986 | 6.824 | 2.012 | 1.056 | 2.177 | 0.751 | 1.178 |
| 3. Brahmaputra | 4.041 | 3.549 | 0.137 | 0.138 | 0.054 | 0.163 | 0.469 | 0.343 | 0.141 | 0.037 | 0.156 | 0.006 |
| 4. Barak& Others | 0.565 | 0.514 | 0.013 | 0.019 | 0.003 | 0.016 | 0.054 | 0.055 | 0.009 | 0.006 | 0.056 | 0.005 |
| 5. Subernarekha | 1.528 | 0.999 | 0.176 | 0.070 | 0.039 | 0.244 | 0.146 | 0.147 | 0.035 | 0.016 | 0.040 | 0.001 |
| 6. Brahmani-Baitarni | 2.435 | 1.492 | 0.206 | 0.104 | 0.091 | 0.541 | 0.331 | 0.261 | 0.025 | 0.025 | 0.076 | 0.004 |
| 7. Mahanadi | 5.840 | 2.747 | 0.702 | 0.229 | 0.574 | 1.589 | 1.304 | 0.456 | 0.016 | 0.034 | 0.131 | 0.125 |
| 8. Godavari | 11.755 | 3.144 | 1.053 | 0.300 | 4.480 | 2.777 | 3.357 | 0.310 | 0.011 | 0.306 | 0.284 | 1.899 |
| 9. Krishna | 8.658 | 2.177 | 0.331 | 0.268 | 3.937 | 1.944 | 3.493 | 0.204 | 0.025 | 0.327 | 0.292 | 1.341 |
| 10. Pennar | 1.519 | 0.754 | 0.009 | 0.066 | 0.377 | 0.313 | 0.726 | 0.038 | 0.002 | 0.050 | 0.095 | 0.159 |
| 11. Cauvery | 2.593 | 0.961 | 0.040 | 0.060 | 0.967 | 0.566 | 1.203 | 0.124 | 0.008 | 0.141 | 0.172 | 0.236 |
| 12. Tapi | 2.612 | 0.389 | 0.256 | 0.046 | 1.308 | 0.612 | 0.682 | 0.046 | 0.002 | 0.079 | 0.038 | 0.570 |
| 13. Narmada | 3.640 | 1.027 | 0.824 | 0.198 | 0.646 | 0.946 | 1.044 | 0.046 | 0.013 | 0.024 | 0.023 | 0.215 |
| 14. Mahi | 1.071 | 0.115 | 0.197 | 0.086 | 0.390 | 0.283 | 0.409 | 0.014 | 0.003 | 0.010 | 0.008 | 0.100 |
| 15. Sabarmati | 0.529 | 0.050 | 0.090 | 0.047 | 0.221 | 0.121 | 0.309 | 0.012 | 0.003 | 0.011 | 0.009 | 0.103 |
| 16. WFR1 | 3.335 | 0.286 | 0.569 | 0.294 | 1.399 | 0.786 | 1.837 | 0.069 | 0.014 | 0.065 | 0.050 | 0.591 |
| 17. WFR2 | 3.161 | 0.993 | 0.167 | 0.067 | 1.328 | 0.607 | 1.885 | 0.330 | 0.007 | 0.108 | 0.558 | 0.509 |
| 18. EFR1 | 2.758 | 1.625 | 0.008 | 0.100 | 0.379 | 0.646 | 0.992 | 0.205 | 0.002 | 0.059 | 0.157 | 0.170 |
| 19. EFR2 | 2.790 | 1.382 | 0.008 | 0.044 | 0.766 | 0.590 | 1.177 | 0.127 | 0.001 | 0.162 | 0.199 | 0.233 |
| Total | 122.35 | 42.51 | 25.27 | 6.11 | 25.71 | 22.75 | 27.25 | 4.95 | 1.44 | 3.78 | 3.25 | 8.50 |

Sources: Directorate of Economic and Statistics (2002), CWC 2002

Annex Table 10. Yields of irrigated crops 1995

| River Basin | Irrigated crop yields in 1995 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grains | Paddy | Wheat | Miaze | Other cereals | Pulses | Oil crops | Vegetables | Starchy roots | Sugar crop | Fruits | Cotton |
| | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha |
| 1. Indus | 4.74 | 3.45 | 5.84 | 2.10 | 1.74 | 0.73 | 1.60 | 11.20 | 0.00 | 6.21 | 11.10 | 0.56 |
| 2. Ganga | 1.48 | 1.54 | 1.51 | 1.57 | 1.54 | 0.91 | 1.47 | 11.20 | 0.00 | 6.28 | 11.10 | 0.40 |
| 3. Brahmaputra | 2.18 | 2.13 | 3.56 | 0.00 | 1.93 | 0.70 | 1.35 | 11.20 | 0.00 | 5.57 | 11.10 | 0.00 |
| 4. Barak& Others | 1.40 | 1.41 | 0.00 | 0.00 | 0.00 | 0.37 | 0.00 | 11.20 | 0.00 | 4.40 | 11.10 | 0.00 |
| 5. Subernarekha | 2.15 | 1.85 | 2.96 | 2.31 | 1.11 | 0.55 | 1.35 | 11.20 | 0.00 | 5.55 | 11.10 | 0.00 |
| 6. Brahmani-Baitarni | 1.98 | 1.78 | 2.86 | 2.24 | 1.10 | 0.53 | 1.33 | 11.20 | 0.00 | 5.95 | 11.10 | 0.13 |
| 7. Mahanadi | 2.11 | 1.92 | 3.25 | 1.56 | 1.23 | 0.59 | 1.52 | 11.20 | 0.00 | 5.14 | 11.10 | 0.13 |
| 8. Godavari | 2.39 | 2.50 | 3.03 | 2.57 | 1.16 | 0.64 | 1.33 | 11.20 | 0.00 | 7.66 | 11.10 | 0.17 |
| 9. Krishna | 2.66 | 2.86 | 2.41 | 3.20 | 1.66 | 0.54 | 1.17 | 11.20 | 0.00 | 8.37 | 11.10 | 0.26 |
| 10. Pennar | 2.89 | 2.93 | 2.17 | 3.20 | 1.98 | 0.50 | 1.27 | 11.20 | 0.00 | 8.25 | 11.10 | 0.27 |
| 11. Cauvery | 3.30 | 3.58 | 2.12 | 2.78 | 2.03 | 0.51 | 1.70 | 11.20 | 0.00 | 9.74 | 11.10 | 0.30 |
| 12. Tapi | 1.97 | 1.71 | 3.00 | 1.71 | 1.06 | 0.68 | 1.48 | 11.20 | 0.00 | 7.66 | 11.10 | 0.19 |
| 13. Narmada | 2.51 | 1.84 | 3.44 | 1.89 | 1.29 | 0.64 | 1.81 | 11.20 | 0.00 | 5.02 | 11.10 | 0.22 |
| 14. Mahi | 2.57 | 1.93 | 3.31 | 1.45 | 1.33 | 0.61 | 1.53 | 11.20 | 0.00 | 6.93 | 11.10 | 0.33 |
| 15. Sabarmati | 2.79 | 2.02 | 3.84 | 1.44 | 1.27 | 0.70 | 1.75 | 11.20 | 0.00 | 7.74 | 11.10 | 0.32 |
| 16. WFR1 | 2.77 | 2.04 | 3.74 | 1.44 | 1.28 | 0.68 | 1.71 | 11.20 | 0.00 | 7.71 | 11.10 | 0.32 |
| 17. WFR2 | 2.43 | 2.56 | 3.03 | 2.98 | 1.45 | 0.62 | 1.22 | 11.20 | 0.00 | 8.36 | 11.10 | 0.27 |
| 18. EFR1 | 2.61 | 2.68 | 0.00 | 2.94 | 1.85 | 0.51 | 1.31 | 11.20 | 0.00 | 7.92 | 11.10 | 0.26 |
| 19. EFR2 | 3.40 | 3.58 | 1.62 | 1.64 | 2.07 | 0.55 | 1.98 | 11.20 | 0.00 | 10.03 | 11.10 | 0.30 |
| | 2.35 | 2.36 | 2.62 | 2.04 | 1.52 | 0.79 | 1.50 | 11.20 | 0.00 | 7.08 | 11.10 | 0.41 |
| All basins | 4.74 | 3.45 | 5.84 | 2.10 | 1.74 | 0.73 | 1.60 | 11.20 | 0.00 | 6.21 | 11.10 | 0.56 |
| All india Average yield | 1.53 | 1.86 | 2.47 | 1.58 | 0.82 | 0.61 | 1.07 | 11.20 | - | 6.87 | 11.10 | 0.25 |

Annex Table 11. Yields of Rainfed crops 1995

| River Basin | Rainfed crop yields in 1995 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grains | Paddy | Wheat | Miaze | Other cereals | Pulses | Oil crops | Vegetables | Starchy roots | Sugar crop | Fruits | Cotton |
| | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha | Mt/ha |
| 1. Indus | 1.06 | 0.78 | 2.31 | 1.57 | 0.56 | 0.55 | 1.23 | 11.20 | 18.28 | 3.85 | 11.10 | 0.30 |
| 2. Ganga | 1.07 | 1.38 | 1.86 | 1.45 | 0.70 | 0.71 | 0.94 | 11.20 | 17.69 | 5.11 | 11.10 | 0.15 |
| 3. Brahmaputra | 1.45 | 1.52 | 1.66 | 1.28 | 0.34 | 0.57 | 0.91 | 11.20 | 13.30 | 4.04 | 11.10 | 0.21 |
| 4. Barak& Others | 1.08 | 1.08 | 1.27 | 1.30 | 0.00 | 0.75 | 0.87 | 11.20 | 6.87 | 4.54 | 11.10 | 0.15 |
| 5. Subernarekha | 1.18 | 1.38 | 2.14 | 1.73 | 1.05 | 0.48 | 0.48 | 11.20 | 16.25 | 4.72 | 11.10 | 0.57 |
| 6. Brahmani-Baitarni | 0.99 | 1.26 | 1.90 | 1.54 | 0.94 | 0.41 | 0.35 | 11.20 | 10.34 | 4.80 | 11.10 | 0.35 |
| 7. Mahanadi | 1.01 | 1.31 | 1.36 | 1.24 | 0.88 | 0.57 | 0.52 | 11.20 | 12.01 | 6.06 | 11.10 | 0.14 |
| 8. Godavari | 0.86 | 1.42 | 1.32 | 1.48 | 0.78 | 0.55 | 0.91 | 11.20 | 13.09 | 7.40 | 11.10 | 0.14 |
| 9. Krishna | 0.83 | 1.79 | 1.07 | 2.27 | 0.87 | 0.41 | 0.98 | 11.20 | 19.17 | 7.43 | 11.10 | 0.16 |
| 10. Pennar | 0.78 | 1.88 | 1.09 | 2.27 | 0.88 | 0.42 | 1.24 | 11.20 | 19.17 | 0.00 | 11.10 | 0.21 |
| 11. Cauvery | 0.87 | 1.93 | 0.70 | 2.92 | 1.04 | 0.35 | 1.12 | 11.20 | 19.17 | 5.72 | 11.10 | 0.22 |
| 12. Tapi | 0.83 | 1.52 | 1.29 | 1.19 | 0.76 | 0.55 | 0.84 | 11.20 | 16.42 | 7.43 | 11.10 | 0.13 |
| 13. Narmada | 1.02 | 1.16 | 1.35 | 1.22 | 0.86 | 0.82 | 0.73 | 11.20 | 14.32 | 7.43 | 11.10 | 0.16 |
| 14. Mahi | 0.72 | 1.12 | 1.28 | 0.98 | 0.59 | 0.63 | 0.96 | 11.20 | 20.67 | 3.23 | 11.10 | 0.24 |
| 15. Sabarmati | 0.71 | 1.06 | 1.04 | 1.02 | 0.67 | 0.57 | 0.94 | 11.20 | 24.67 | 3.23 | 11.10 | 0.26 |
| 16. WFR1 | 0.70 | 1.06 | 1.05 | 1.00 | 0.64 | 0.57 | 0.95 | 11.20 | 24.65 | 3.06 | 11.10 | 0.26 |
| 17. WFR2 | 0.95 | 1.74 | 1.13 | 1.44 | 0.83 | 0.45 | 0.82 | 11.20 | 20.37 | 6.69 | 11.10 | 0.15 |
| 18. EFR1 | 0.87 | 1.41 | 1.97 | 1.88 | 0.84 | 0.38 | 1.06 | 11.20 | 11.06 | 6.26 | 11.10 | 0.21 |
| 19. EFR2 | 0.81 | 1.78 | 0.89 | 2.31 | 1.08 | 0.37 | 1.41 | 11.20 | 19.17 | 0.00 | 11.10 | 0.23 |
| All basins | 0.99 | 1.39 | 1.64 | 1.45 | 0.78 | 0.58 | 0.93 | 11.20 | 17.05 | 5.33 | 11.10 | 0.16 |
| All india Average yield | 1.53 | 1.86 | 2.47 | 1.58 | 0.82 | 0.61 | 1.069 | 11.20 | 17.10 | 6.87 | 11.10 | 0.25 |

Annex Table 12. Production Surplus or Deficit

| | Paddy | Wheat | Maize | Other cereals | Pulses | Oil crops | Starch y roots | Vegeta bles | Sugar crop | Fruits | Cotton | Grain crops | Non-grain crops | Total crops |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M Mt | M Mt | M Mt | M Mt | M Mt | M Mt | M Mt | M Mt | M Mt | M Mt | M Mt | B US$ | B US$ | B US$ |
| 1. Indus | 4.8 | 23.3 | 1.2 | -0.2 | -0.1 | -0.1 | -1.0 | 0.1 | -0.4 | -0.1 | 0.5 | 5.8 | -0.4 | 5.4 |
| 2. Ganga | -6.8 | -2.8 | 0.4 | -3.2 | 0.7 | -5.3 | -0.4 | 8.6 | 2.6 | -7.0 | -0.5 | -2.9 | -3.7 | -6.6 |
| 3. Brahmaputra | 3.2 | -1.9 | -0.1 | -0.7 | -0.4 | -0.6 | 2.0 | 1.1 | -0.7 | 0.5 | -0.1 | 0.5 | 1.6 | 2.1 |
| 4. Barak& Others | 0.0 | -0.5 | 0.0 | -0.2 | -0.1 | -0.2 | 0.2 | -0.1 | -0.2 | 0.4 | 0.0 | -0.1 | 0.2 | 0.1 |
| 5. Subernarekha | 0.7 | -0.2 | 0.0 | -0.2 | 0.0 | -0.3 | 1.0 | 0.3 | -0.2 | 0.0 | 0.0 | 0.2 | 0.8 | 0.9 |
| 6. Brahmani-Baitarni | 1.3 | -0.2 | 0.1 | -0.2 | 0.1 | -0.2 | 2.3 | 0.0 | -0.2 | 0.4 | 0.0 | 0.4 | 2.0 | 2.4 |
| 7. Mahanadi | 1.8 | -0.3 | 0.0 | -0.1 | 0.5 | -0.2 | 3.4 | -0.6 | -0.6 | 0.3 | 0.0 | 0.7 | 2.5 | 3.2 |
| 8. Godavari | 1.5 | -1.7 | -0.1 | 2.3 | 0.6 | 1.2 | 0.0 | -1.4 | 0.7 | 0.8 | 0.1 | 0.7 | 1.0 | 1.7 |
| 9. Krishna | 0.3 | -4.0 | 0.1 | 2.1 | -0.2 | 1.4 | -1.6 | -1.2 | 0.9 | 0.6 | 0.1 | -0.4 | -0.4 | -0.8 |
| 10. Pennar | 1.3 | -0.7 | 0.1 | 0.1 | 0.0 | 0.6 | -0.2 | -0.2 | 0.1 | 0.6 | 0.0 | 0.3 | 0.4 | 0.7 |
| 11. Cauvery | 0.6 | -2.2 | -0.2 | 0.4 | -0.3 | 0.5 | -0.5 | -0.7 | 0.5 | 0.7 | 0.0 | -0.2 | 0.1 | -0.1 |
| 12. Tapi | -0.7 | -0.6 | -0.1 | 0.7 | 0.1 | 0.1 | -0.4 | -0.4 | 0.2 | -0.2 | 0.0 | -0.2 | -0.4 | -0.7 |
| 13. Narmada | 0.0 | 1.0 | 0.1 | 0.2 | 0.5 | 0.3 | -0.4 | -0.2 | -0.3 | -0.4 | 0.0 | 0.4 | -0.6 | -0.2 |
| 14. Mahi | -0.8 | -0.2 | 0.0 | 0.0 | 0.0 | 0.1 | -0.5 | -0.2 | -0.2 | -0.4 | 0.0 | -0.3 | -0.7 | -1.0 |
| 15. Sabarmati | -0.9 | -0.5 | -0.1 | -0.1 | -0.1 | 0.0 | -0.5 | -0.2 | -0.2 | -0.4 | 0.0 | -0.4 | -0.8 | -1.2 |
| 16. WFR1 | -1.5 | 0.2 | 0.1 | 0.4 | 0.1 | 1.4 | -0.6 | -0.3 | -0.2 | -0.4 | 0.1 | -0.4 | -0.3 | -0.7 |
| 17. WFR2 | -3.1 | -4.0 | -0.5 | -0.3 | -0.7 | -0.5 | 0.0 | -1.5 | -0.9 | 3.7 | -0.1 | -2.1 | 1.2 | -0.9 |
| 18. EFR1 | 1.7 | -1.8 | 0.0 | -0.3 | -0.1 | 0.2 | 0.8 | -0.6 | -0.2 | 0.7 | 0.0 | 0.2 | 0.9 | 1.0 |
| 19. EFR2 | 0.9 | -3.4 | -0.4 | -0.2 | -0.5 | 0.2 | -1.4 | -1.2 | 0.3 | 0.3 | -0.1 | -0.6 | -1.2 | -1.8 |
| Total | 4.2 | -0.3 | 0.3 | 0.6 | 0.0 | -1.3 | 2.1 | 1.1 | 1.0 | 0.3 | 0.0 | 1.5 | 2.1 | 3.6 |

1 –per capita consumption is assumed to be same in every basin.

Annex Table 13. Production Surplus or Deficit as a Percent of Consumption[1]

| | Paddy | Wheat | Maize | Other cereals | Pulses | Oil crops | Starchy roots | Vegetables | Sugar crop | Fruits | Cotton | Grain crops | Non-grain crops | Total crops |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % | % | % | % | % |
| 1. Indus | 126 | 741 | 248 | -17 | -13 | -4 | -38 | 12 | -29 | -5 | 450 | 255 | -8 | 81 |
| 2. Ganga | -21 | -11 | 11 | -36 | 12 | -40 | -2 | 84 | 24 | -46 | -56 | -15 | -10 | -11 |
| 3. Brahmaputra | 123 | -87 | -46 | -97 | -80 | -58 | 107 | 129 | -83 | 39 | -98 | 32 | 52 | 45 |
| 4. Barak& Others | 4 | -97 | -65 | -100 | -89 | -79 | 56 | -64 | -86 | 133 | -95 | -39 | 35 | 10 |
| 5. Subernarekha | 84 | -28 | 32 | -82 | -25 | -74 | 174 | 112 | -71 | 11 | -99 | 33 | 78 | 63 |
| 6. Brahmani-Baitarni | 148 | -23 | 69 | -64 | 38 | -57 | 367 | -6 | -55 | 102 | -95 | 80 | 190 | 153 |
| 7. Mahanadi | 74 | -14 | -4 | -22 | 105 | -18 | 201 | -74 | -77 | 28 | -74 | 48 | 90 | 76 |
| 8. Godavari | 30 | -42 | -17 | 172 | 71 | 63 | 1 | -91 | 45 | 36 | 90 | 24 | 17 | 19 |
| 9. Krishna | 5 | -88 | 12 | 143 | -20 | 61 | -41 | -72 | 50 | 24 | 49 | -11 | -7 | -8 |
| 10. Pennar | 150 | -98 | 60 | 50 | -19 | 157 | -31 | -89 | 43 | 154 | 41 | 63 | 34 | 44 |
| 11. Cauvery | 24 | -98 | -49 | 51 | -57 | 46 | -26 | -81 | 56 | 52 | -22 | -14 | 4 | -3 |
| 12. Tapi | -54 | -50 | -64 | 182 | 38 | 12 | -46 | -93 | 37 | -33 | 100 | -29 | -27 | -28 |
| 13. Narmada | 3 | 90 | 49 | 56 | 210 | 64 | -45 | -57 | -73 | -60 | 1 | 50 | -40 | -9 |
| 14. Mahi | -83 | -28 | -27 | -4 | 2 | 22 | -77 | -82 | -79 | -80 | 10 | -54 | -66 | -62 |
| 15. Sabarmati | -91 | -62 | -58 | -42 | -60 | -5 | -80 | -79 | -72 | -78 | 12 | -77 | -69 | -71 |
| 16. WFR1 | -77 | 14 | 22 | 72 | 24 | 169 | -45 | -44 | -25 | -41 | 209 | -31 | -14 | -20 |
| 17. WFR2 | -60 | -92 | -77 | -19 | -71 | -22 | -1 | -91 | -49 | 148 | -43 | -67 | 19 | -10 |
| 18. EFR1 | 78 | -100 | -19 | -46 | -36 | 28 | 52 | -96 | -34 | 72 | -38 | 12 | 35 | 27 |
| 19. EFR2 | 21 | -100 | -83 | -19 | -70 | 15 | -50 | -98 | 21 | 15 | -48 | -23 | -25 | -25 |
| Total | 5.6 | -0.5 | 3.6 | 2.8 | 0.0 | -4.2 | 3.9 | 4.5 | 4.0 | 0.8 | 0.0 | 3.3 | 2.3 | 2.7 |

1 –per capita consumption is assumed to be same in every basin.

Annex Table 14. Water supply to irrigation, Domestic and Industrial sectors

| River Basin | Irrigation water supply | | | | | | Domestic water supply | | | Industrial water supply | Total water supply | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Tube well irri. Area | Irrigation efficiency | | | Ground water | Surface water | For Livestock | For People | Total | | Surface | Groundwater | Total |
| | | Surface | Tube well | Overall | | | | | | | | | |
| | % | % | % | % | km3 | km3 | km3 | km3 | km3 | km3 | km3 | km3 | km3 |
| 1. Indus | 56 | 39 | 65 | 50 | 13.0 | 17.0 | 0.5 | 0.8 | 1.3 | 1.3 | 18.2 | 14.4 | 32.53 |
| 2. Ganga | 60 | 39 | 65 | 52 | 133.3 | 146.4 | 2.5 | 6.8 | 9.3 | 10.7 | 158.2 | 144.7 | 302.87 |
| 3. Brahmaputra | 13 | 40 | 65 | 43 | 0.4 | 4.7 | 0.2 | 0.5 | 0.6 | 0.9 | 5.6 | 1.3 | 6.90 |
| 4. Barak& Others | 2 | 42 | 65 | 42 | 0.0 | 0.8 | 0.1 | 0.1 | 0.2 | 0.2 | 1.0 | 0.2 | 1.27 |
| 5. Subernarekha | 45 | 40 | 65 | 48 | 1.5 | 3.1 | 0.1 | 0.2 | 0.3 | 0.3 | 3.4 | 1.9 | 5.25 |
| 6. Brahmani-Bait. | 44 | 40 | 65 | 48 | 2.4 | 4.9 | 0.1 | 0.2 | 0.3 | 0.3 | 5.3 | 2.7 | 7.97 |
| 7. Mahanadi | 45 | 40 | 65 | 48 | 4.8 | 9.5 | 0.2 | 0.5 | 0.7 | 0.8 | 10.3 | 5.7 | 16.00 |
| 8. Godavari | 50 | 40 | 65 | 49 | 15.1 | 24.6 | 0.4 | 0.9 | 1.3 | 1.6 | 26.3 | 16.8 | 43.14 |
| 9. Krishna | 30 | 40 | 65 | 45 | 7.2 | 27.5 | 0.5 | 1.3 | 1.7 | 1.8 | 29.6 | 9.2 | 38.76 |
| 10. Pennar | 38 | 41 | 65 | 48 | 2.5 | 6.6 | 0.1 | 0.2 | 0.3 | 0.3 | 6.9 | 2.9 | 9.78 |
| 11. Cauvery | 30 | 40 | 65 | 45 | 3.1 | 11.8 | 0.2 | 0.6 | 0.8 | 0.9 | 12.8 | 4.1 | 16.85 |
| 12. Tapi | 64 | 39 | 65 | 52 | 3.9 | 3.7 | 0.1 | 0.3 | 0.4 | 0.4 | 4.2 | 4.4 | 8.55 |
| 13. Narmada | 53 | 39 | 65 | 49 | 5.3 | 7.9 | 0.1 | 0.3 | 0.4 | 0.4 | 8.4 | 5.8 | 14.14 |
| 14. Mahi | 66 | 39 | 65 | 53 | 2.6 | 2.2 | 0.1 | 0.2 | 0.3 | 0.3 | 2.6 | 2.9 | 5.49 |
| 15. Sabarmati | 75 | 39 | 65 | 56 | 1.9 | 1.1 | 0.5 | 0.3 | 0.7 | 0.3 | 1.6 | 2.5 | 4.08 |
| 16. WFR1 | 69 | 39 | 65 | 54 | 10.6 | 8.0 | 0.3 | 0.4 | 0.7 | 0.7 | 8.7 | 11.4 | 20.13 |
| 17. WFR2 | 46 | 40 | 65 | 48 | 3.7 | 7.1 | 0.2 | 1.4 | 1.6 | 1.7 | 9.1 | 5.4 | 14.51 |
| 18. EFR1 | 39 | 41 | 65 | 48 | 3.6 | 8.9 | 0.2 | 0.4 | 0.6 | 0.7 | 9.6 | 4.3 | 13.97 |
| 19. EFR2 | 47 | 40 | 65 | 49 | 9.3 | 17.0 | 0.3 | 1.0 | 1.3 | 1.3 | 18.6 | 10.7 | 29.27 |
| All basins | 53 | 40 | 65 | 50 | 224.0 | 313.0 | 6.7 | 16.2 | 22.9 | 25.0 | 340.3 | 251.1 | 591.0 |

Annex Table 15: Water Balance of Indian River Basins

| River basin | Utilizable water Resources | | Total Water Diversions | | Consumptive use | | Flows to sea/ down stream countries | Return Flow | | Primary water Supply | Degree of Development | Depletion Fraction | Effective Efficiency | Recycling factor | Groundwater abstraction - % of recharge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface | Groundwater | Surface | Groundwater | Process Evap. | Non-Process Evap. | | Surface | Groundwater | | | | | | |
| | Km3 | Km3 | Km3 | Km3 | Km3 | Km3 | Km3 | Km3 | Km3 | Km3 | % | % | % | % | % |
| 1. Indus | 46.0 | 14.3 | 18.2 | 14.4 | 9.2 | 8.4 | 3.1 | 2.2 | 11.6 | 20.8 | 35 | 85 | 52 | 56 | 56 |
| 2. Ganga | 250.0 | 136.5 | 158.2 | 144.7 | 131.7 | 51.3 | 24.5 | 17.7 | 83.2 | 207.5 | 54 | 88 | 72 | 46 | 66 |
| 3. Brahmaputra | 22.3 | 25.7 | 5.6 | 1.3 | 0.5 | 1.5 | 1.2 | 1.0 | 2.7 | 3.2 | 7 | 62 | 26 | 115 | 5 |
| 4. Barak& Others | 1.7 | 8.5 | 1.0 | 0.2 | 0.2 | 0.4 | 0.2 | 0.2 | 0.4 | 0.8 | 8 | 69 | 28 | 59 | 3 |
| 5. Subernarekha | 6.8 | 1.7 | 3.4 | 1.9 | 1.6 | 1.0 | 0.6 | 0.4 | 1.7 | 3.2 | 38 | 82 | 61 | 63 | 55 |
| 6. Brahmani-Bait. | 18.3 | 3.4 | 5.3 | 2.7 | 2.5 | 2.2 | 0.8 | 0.5 | 2.7 | 5.4 | 25 | 86 | 53 | 47 | 45 |
| 7. Mahanadi | 50.0 | 13.6 | 10.3 | 5.7 | 3.5 | 4.6 | 1.8 | 1.3 | 6.1 | 9.9 | 16 | 82 | 43 | 61 | 29 |
| 8. Godavari | 76.3 | 33.5 | 26.3 | 16.8 | 16.0 | 12.7 | 3.8 | 2.7 | 10.8 | 32.5 | 35 | 88 | 56 | 33 | 38 |
| 9. Krishna | 58.0 | 19.9 | 29.6 | 9.2 | 12.5 | 12.1 | 5.1 | 2.9 | 11.4 | 29.6 | 38 | 83 | 51 | 31 | 29 |
| 10. Pennar | 6.9 | 4.0 | 6.9 | 2.9 | 2.9 | 2.6 | 0.9 | 0.6 | 2.8 | 6.4 | 59 | 86 | 53 | 52 | 42 |
| 11. Cauvery | 19.0 | 8.8 | 12.8 | 4.1 | 5.0 | 4.2 | 1.8 | 1.3 | 5.6 | 11.0 | 40 | 84 | 54 | 53 | 28 |
| 12. Tapi | 14.5 | 6.7 | 4.2 | 4.4 | 3.8 | 2.5 | 0.8 | 0.6 | 2.2 | 7.1 | 33 | 89 | 61 | 21 | 49 |
| 13. Narmada | 34.5 | 9.4 | 8.4 | 5.8 | 6.1 | 3.2 | 1.1 | 0.8 | 3.9 | 10.4 | 24 | 89 | 66 | 36 | 43 |
| 14. Mahi | 3.1 | 3.5 | 2.6 | 2.9 | 2.6 | 1.4 | 0.5 | 0.4 | 1.3 | 4.5 | 68 | 89 | 65 | 22 | 61 |
| 15. Sabarmati | 1.9 | 2.9 | 1.6 | 2.5 | 1.8 | 0.6 | 0.6 | 0.5 | 0.8 | 3.0 | 62 | 81 | 74 | 36 | 68 |
| 16. WFR1 | 15.0 | 9.1 | 8.7 | 11.4 | 10.1 | 3.3 | 1.5 | 1.1 | 4.8 | 14.9 | 62 | 90 | 75 | 35 | 82 |
| 17. WFR2 | 36.2 | 15.6 | 9.1 | 5.4 | 4.8 | 4.6 | 2.2 | 1.8 | 3.8 | 11.6 | 22 | 81 | 51 | 26 | 28 |
| 18. EFR1 | 13.1 | 12.8 | 9.6 | 4.3 | 3.9 | 2.7 | 1.5 | 1.1 | 4.8 | 8.1 | 31 | 81 | 59 | 73 | 24 |
| 19. EFR2 | 16.7 | 12.7 | 18.6 | 10.7 | 10.1 | 5.2 | 2.9 | 2.1 | 9.2 | 18.2 | 62 | 84 | 66 | 61 | 49 |
| All Basins | 690.2 | 342.5 | 340.3 | 251.2 | 228.7 | 124.5 | 54.9 | 39.2 | 169.8 | 408.2 | 40 | 87 | 65 | 45 | 49 |

## *Appendix A. Irrigation Demand Estimation*

Several factors are important drivers in water demand calculations. These are: 1). Seasonal cropping patterns, 2). Crop calendar (starting dates and the duration of seasons), 3). Crop coefficients in different growth periods, 4). Effective rainfall, 5). Potential evapotranspiration and 6). Surface and groundwater irrigated areas and irrigation efficiencies

First we discuss the importance of each factor in the estimation of future water demand.

***Cropping pattern:*** As discussed in a previous section, the irrigated areas of some crops, such as wheat, sugar, cotton have substantially increased in the past decades while irrigated areas of some crops have decreased. These changes may remain the same or even intensify in the future due to changing consumption patterns, prices or due to scarce water conditions in the basins. The virtual water, or increase trade of water in crops, could also have a significant effect on cropping pattern changes. Since the net irrigation requirement for different crops are different, cropping pattern changes is an important driver in gross irrigation demand estimation.

***Crop calendar:*** Climatic changes (though the short-term effects are not clearly known), introduction of drought tolerant or short duration varieties through improved crop genetics may affect the seasonal crop calendars and hence the irrigation requirement

***Crop coefficients***: Improved crop genetics could alter the magnitudes of crop coefficients.

***Effective rainfall and evapotranspiration*:** Climate changes, or environmental degradation or combination of both factors may affect the rainfall patterns and temperature, thus affecting effective rainfall and evpotranspiration requirements.

***Surface and groundwater irrigated area:*** Efficiencies of surface and groundwater application are significantly different for most basins. Therefore changes in the composition of surface and groundwater irrigated area would also have a significant impact on the water demand.

***Efficiencies:*** Basin efficiency of surface irrigation is much lower than the groundwater surface irrigation. If efficiencies are to be improved significant reduction could be effected in irrigation water demand.

***Irrigation efficiency:*** The India-PODIUM assumes following percolation requirement and irrigation efficiencies for all river basins.

Table 9. Irrigation efficiencies

| | First season | Second season |
|---|---|---|
| Percolation requirement for paddy | 200 mm | 250 mm |
| Surface irrigation efficiency – Paddy | 35% | 40% |
| Surface irrigation efficiency - other crops | 40% | 45% |
| Tubewell irrigation efficiency – all crops | 65% | 70% |

Then the total water demand in 1995 is estimated from

$$Surface\ irrigation\ demand^{paddy} = \sum_{i=seasons} \frac{(NET_i^{paddy} + percol_i) \times area_i^{paddy} \times (1 - \%tubewell\ area_i)}{surface\ irrigation\ efficiency_i^{paddy}}$$

$$Surface\ irrigation\ demand^{other} = \sum_{i=seasons} \frac{\sum_{j=other\ crops} (NET_i^j \times area_i^j)}{surface\ irrigation\ efficiency_i^{othercrops}} \times (1 - \%tubewell\ area_i)$$

$$Groundwater\ irrigation\ demand = \sum_{i=seasons} \frac{\sum_{j=all\ crops} (NET_i^j \times area_i^j) \times Tubewell\ irri\ area_i}{tubewell\ irrigation\ efficiency_i}$$