FAWPIO-INDIA
PROGRESS REPORT
August 2005

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EXECUTIVE SUMMARY

The cluster of projects dealing with land and water issues funded under DFID's Forestry Research Programme has established that misguided views about water management are often leading to ineffective or counterproductive outcomes from watershed development projects with often the wastage of very significant amounts of development funds. In particular, it was shown that the promotion of forestry, irrigation and soil water conservation measures, without due regard to water resource constraints, can lead to perverse and inequitable outcomes.

The Forest, Land and Water Policy, Improving Outcomes (FAWPIO) programme is proposed as the means for encouraging more evidence based policies for land and water management through Bridging Research and Policy (BRAP) activities and through the development of an improved framework for land and water management. The framework will include modelling methodologies to determine the biophysical and societal impacts of watershed interventions.

The present Report outlines the progress that has taken place on the FAWPIO-India component of the programme since the inception workshop which took place in May 2005.

Progress items, mostly relating to strategy evaluation and the development of modelling methodologies in support of the DFID funded KAWAD (£12 Million) and World Bank funded JSYS and Sujala projects (First phase $ 200 Million), include:

- Scenario modelling at the DFID KAWAD watershed study site, Inchigeri. Here the impacts of soil-water conservation measures on the inflows to the Inchigeri and Jigivni tanks[1] were investigated for a 30 year historical record using two modelling methodologies: an EXCEL spreadsheet model and the HYLUC-Cascade model. These studies indicated that the density of soil-water conservation structures that had been installed had resulted in major reductions in tank flow. Without structures, tanks would have filled and spilled, allowed water to flow downstream, almost every other year. With structures tanks would only have filled sufficiently to result in downstream flows in only 2 years of the 30 year record;
- Bayesian network development. A Bayesian network has been developed to investigate and demonstrate the impacts of different types of watershed interventions on different typology social groups. The specific focus was directed towards investigating which groups would be beneficiaries (winners) and whether there may be some groups that were disadvantaged (losers) as a result of structural interventions involving soil and water conservation measures and tank rehabilitation;
- On-going development of the Exploratory Climate Land Assessment and Impact Management, EXCLAIM tool. The developments includes the incorporation of a new 'slider' which takes account of the impact of different densities of

[1] In India irrigation reservoirs are referred to as tanks

structures on catchment flows (both surface and groundwater) and its application on the Mustoor catchments;

- Presentation of a ‘quadrant’ approach to managing green water (evaporation) and blue water (liquid) flows from a catchment at the SEI-SIWI Green-Blue Water Initiative partners’ meeting in Stockholm, June 2005. This approach stresses the need to consider the sustainability of land uses within a catchment in terms of the evaporative water use (that this must be less than the precipitation) before decisions are made in relation to managing blue water flows through structural interventions.

Plans were also prepared for a workshop on project outputs. A provisional date of October 2005 has been suggested.

LIST OF ACRONYMS AND ABBREVIATIONS

BRAP	Bridging Research and Policy
CGIAR	Consultative Group on International Agriculture Research
CIFOR	Center for International Forestry Research
CLUWRR	Centre for Land Use and Water Resources Research
DFID	Department for International Development
EXCLAIM	EXploratory, Climate, Land, Assessment, Impact, Management
FAWPIO	Forest, Land and Water Policy: Improving Outcomes
FRP	Forestry Research Programme (DFID)
GBI	Green Blue Initiative
GIS	Geographic Information System
HYLUC	Hydrological Land Use Change Model
ILWRM	Integrated Land and Water Resource Management
IWMI	International Water Management Institute
JSYS	Jala Samvardhane Yojana Sangha (JSYS is implementing the Karnataka Community Based Tank Management Project)
KAWAD	Karnataka Watershed Development Society
NGO	Non Government Organisation
SCS	Surface Runoff Curves - United States Soil Conservation Service (relates to a runoff estimation technique)
SEI	Stockholm Environment Institute
SIDA	Swedish International Development Cooperation Agency
SIWI	Stockholm International Water Institute
WB	World Bank

1. Background to the FAWPIO Programme

1.1. Problem Statement and Objectives

The cluster of projects dealing with land and water issues funded under DFID's Forestry Research Programme (R7937, R8171, R8174, ZF0176) has established that misguided views (water related myths) about water management are leading to ineffective or counterproductive outcomes from many watershed development projects.

Water Related Myths

- Planting trees increases local rainfall and runoff
- Water harvesting is a totally benign technology
- Runoff in semi – arid areas is 30 – 40% of annual rainfall
- Rainfall has decreased in recent years
- Aquifers once depleted stay depleted
- Watershed development programmes drought – proof villages and protect village water supplies
- Introduction if drip and sprinkler irrigation frees up water for other uses

Figure 1 Water Related Myths

In particular, it was shown that the promotion of forestry, irrigation and soil-water conservation measures, without due regard to water resource constraints, can lead to many perverse and inequitable outcomes:

- Catchment closure, when no water issues from a catchment except in high rainfall years, causing damage to the environment and downstream users (many river basins in southern India e.g. Krishna and Cauvery, are now approaching closure);
- Reducing the availability of 'public' water in communal village irrigation reservoirs (known as tanks) yet increasing the availability of 'private' water to farmers with access to deep groundwater through boreholes;
- Excessive deepening of water tables which threaten traditional village water supplies, both through reduced availability and reduced water quality (increased levels of arsenic and fluoride contamination are associated with deep groundwater extraction);
- Boom and bust cycles in agricultural production, which cause extreme hardship and have been attributed as the cause of many farmer suicides when farmers become indebted in 'chasing down' the water table;
- Huge costs in terms of electric power generation for pumping groundwater from ever greater depths (some estimates are that ~2/3 of all electricity generated in some southern Indian states is used for pumping groundwater).

The FRP Booklet “From the Mountain to the Tap”, which summarises the findings of these research projects, calls upon policymakers to design water projects based on scientific evidence of benefits.

The Forest, Land And Water Policy, Improving Outcomes (FAWPIO) programme is proposed as the means for encouraging more evidence based policies through:

1. Mechanisms for Bridging Research and Policy (BRAP) which will involve sharing research knowledge and land and water policy developments between researchers and policymakers and between FAWPIO partner countries;
2. An improved framework for land and water management including:
    - Modelling methodologies and GIS based dissemination tools which can indicate both the water resource and societal impacts of proposed watershed interventions prior to implementation;
    - Poverty reduction assessment methodologies addressing the question: who are the winners and losers arising from watershed interventions;
    - Greater focus on managing the evaporation from a catchment through ‘green water’ policies. The new proposed ‘quadrant’ approach to managing catchment vapour (green) and liquid (blue) water flows is outlined below.

1.2. FAWPIO Funding

The inception phase of FAWPIO (March 2005 – January 2006) is currently being funded solely by DFID’s Forestry Research Programme. Discussions have been held with the DFID Water Energy and Minerals (WEM) team and with DFID India but no commitments to the continued funding of the programme have been given.

FAWPIO has also been invited as a research partner under the SEI-SIWI Green Blue Initiative (GBI). On behalf of FAWPIO, Ian Calder attended the planning meeting of GBI in June 2005 and will again be representing FAWPIO at the GBI meeting on 22nd August during the Stockholm Water Week. GBI has received seed funding from SIDA but the inclusion of FAWPIO within GBI will require additional funding which would provide DFID with the opportunity to ensure that the findings from its investments in land and water related research continue to influence other aid donors and national governments ensuring improved and more evidence based land and water policies.

1.3. FAWPIO India - Achieving the Inception Workshop Vision

At the inception meeting of FAWPIO India, which took place in Bangalore, 6-7th May, 2005, a vision for the future of watershed development within Karnataka was agreed amongst the participants. This provided the focus for the development of strategies for an improved land and water management framework and for the biophysical and societal modelling tools which would underpin this framework.

FAWPIO’s water –related vision is summarised in Figure 2.

FAWPIO Inception Workshop Water-Related Vision:

- By 2015, all households:
  a) have assured access to 55 lpcd of safe drinking water (incl. sanitation)
  b) have access to a minimum of 30 litres of water per animal for livestock watering or other small-scale productive uses

- By 2015, water resources are managed to achieve:
  a) each watershed unit releases 40% of mean annual flows to the downstream watershed without increasing the pollution load
  b) Annual groundwater extraction is 60-80% of natural (annual) recharge

- By 2015, improved farm-level water management of water contributes to:
  a) 20-30% increased rainfed agricultural productivity in irrigated and rainfed agriculture with assured fodder availability

- By 2015, improved awareness and planning leads to:
  a) improved ecological balance, biodiversity (species counts) and aquatic life

- By 2015, financing, legal framework, monitoring system and infrastructure are in place to meet domestic water, water for food and water for nature needs.

Figure 2 FAWPIO's Water-Related Vision

1.4. Strategy evaluation –Inchigeri, Doddahalla and Mustoor, Kolar District

At the Inception Workshop it was agreed that through knowledge of the biophysical and societal impacts of watershed interventions (forestry, soil-water conservation measures and irrigated area), different possible strategies would be evaluated to see if they have the potential to achieve the FAWPIO Inception Workshop Vision.

More specifically it was agreed that the evaluation studies would include:

- Water flows and socio economic impacts associated with soil-water conservation and forestry measures in a two tank cascade at Inchigeri, within the DFID funded KAWAD study area and
- Water flows and socio economic impacts associated with tank rehabilitation and proposed soil-water conservation measures and farm ponds at the World Bank funded Mustoor JSYS/Sujala project area.

The study sites comprise the Inchigeri and Mustoor catchments, located in the Karnataka State in Southern India. Their general location is illustrated in Figure 3.

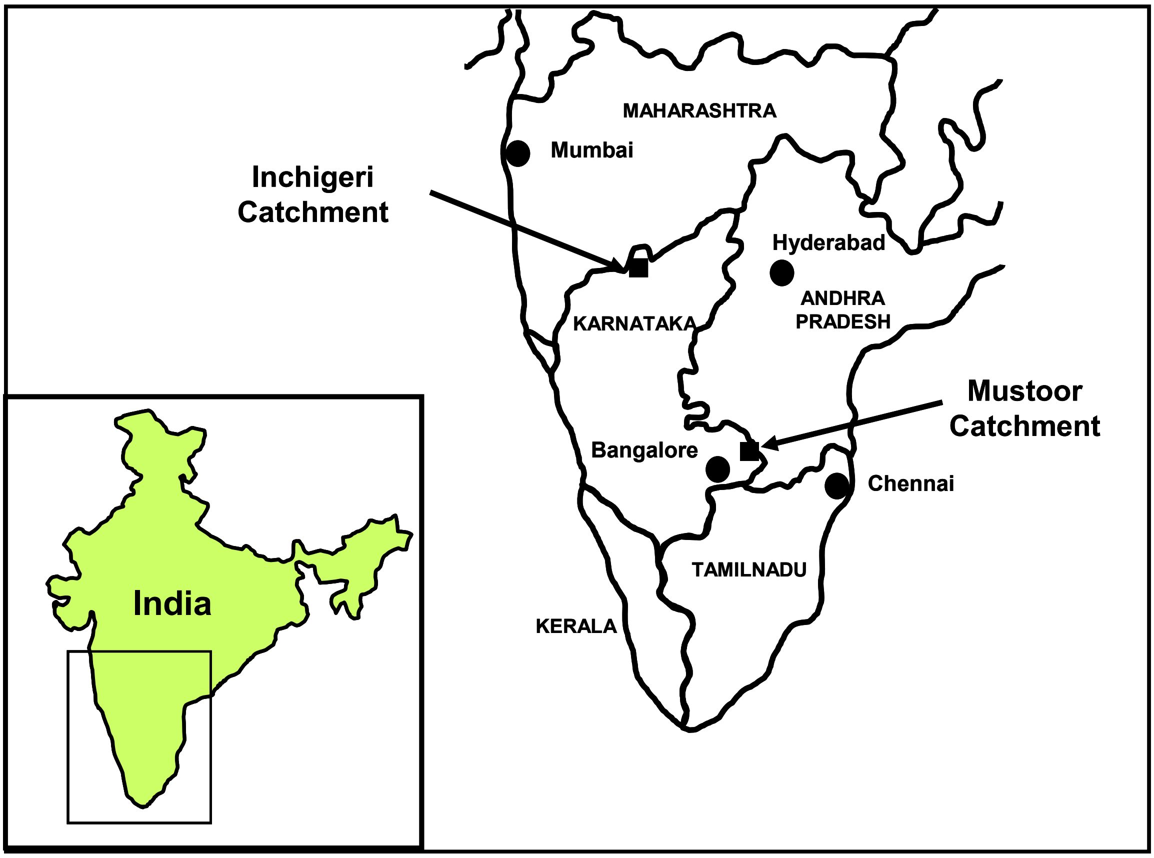


Figure 3 Location of the Inchigeri and Mustoor Catchments

2. Improved Framework for Land and Water Management – Biophysical and Societal Modelling Developments

2.1. Scenario modelling at the DFID KAWAD watershed study site, Inchigeri

A serious water crisis is currently being experienced by a large majority of the villages in Bijapur District, Southern India. There are many possible contributing factors to the problem, such as over-extraction of groundwater, changes in cropping patterns and an extended period of low rainfall. Another potential contributing factor is the rapid increase in density and relatively ad hoc planning processes involved in rainwater harvesting structure interventions (also referred to as soil-water conservation structures). Rainwater harvesting structures in many parts of the world have been found to improve agricultural yields by providing farmers with additional irrigation water. However, when installed in high densities in semi-arid or arid catchments there is the potential for these structures to create a shift in the availability of water, favouring inhabitants situated in the immediate location of these structures and potentially disadvantaging those downstream. The catchments upstream of the Inchigeri and Jijivni tanks , Southern India, are semi-arid catchments with a very high intensity of structural interventions for rainfall harvesting. For this reason, and due to the fact that data exist on the physical characteristics and location of these structures which make it an ideal study area for investigating the potential impacts of rainwater harvesting structures.

The preliminary model has been set up using EXCEL and applies water balance principles for each rainfall harvesting structure within the catchment. It is conceived in the form of a cascade of water harvesting structures, where spills from upstream structures discharge into those on connecting drainage lines downstream.

Runoff into the cascade system is determined by using the HYLUC runoff model. This model was calibrated for the catchment by comparing the runoff to that obtained using a local (SCS) rainfall to runoff relationship. So far, only the upstream half of the catchment has been modelled. This stage comprises one tank and around 30 rainwater harvesting structures. However the whole catchment will be modelled at a later stage to enable an assessment of a two-tank system.

2.2. Results to Date

The provisional results obtained at this stage of the modelling process indicate that the high density of structures in Inchigeri is having a significant effect on spills out of the downstream tank, as shown in Figure 4.

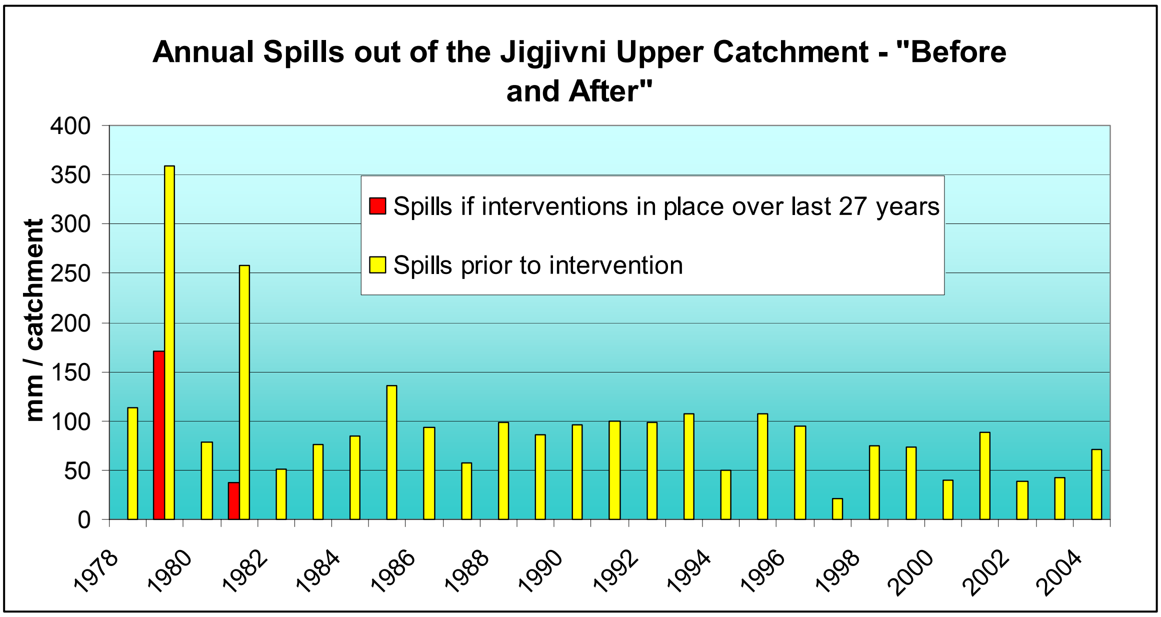


Figure 4 Initial modelling predictions showing spills from Inchigeri tank, with and without SWC interventions

At present, methods are being devised to incorporate the results of the cascade modelling into two decision making tools: EXCLAIM and Bayesian Networks, where:

- Relationships between spills and total catchment evaporation with increasing density of structures will be incorporated into the EXCLAIM model, and
- Relationships between annual rainfall and the volumes captured by the structures as well as annual spills will be used to populate Bayesian Networks.
- Further scenario modelling will be undertaken to examine the sensitivity of the model to uncertainties such as infiltration, climate change and evaporation effects.

2.3. Development of the GIS based Exploratory Climate Land Assessment and Impact Management, EXCLAIM Tool

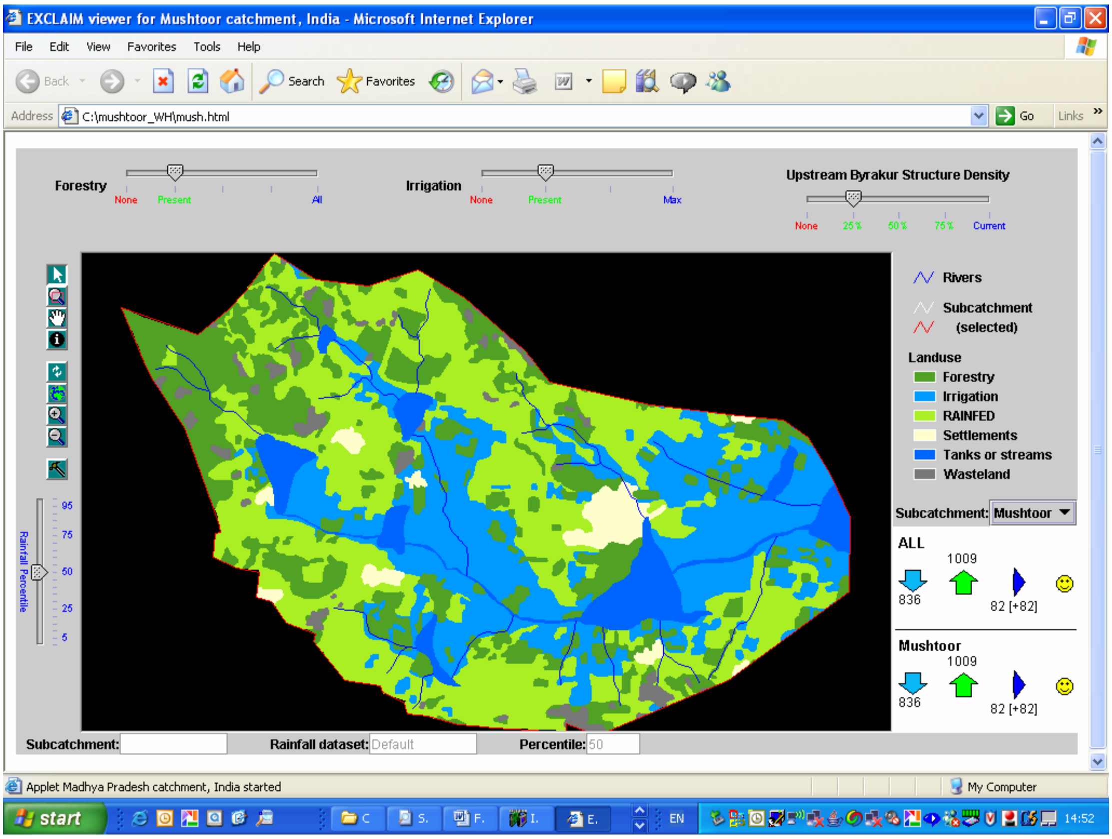


Figure 5 Current state of development of the EXCLAIM tool for the Mustoor Catchment

The new development of the EXCLAIM tool involves the joint incorporation of "sliders" which determine the extent of irrigation and forested areas within a catchment, and of a "slider" which controls the extent of soil-water conservation measures within a catchment. Together these sliders will show:

- How different land uses determine the sustainability of the catchment with respect to evaporative use and how large areas under irrigation or combinations of areas under irrigation and forestry can lead to unsustainable rates of evaporation that exceed the precipitation input;

- That increasing densities of soil-water -retention structures will reduce annual flows from a catchment.

Development is in progress to incorporate a third ‘arrow’ which will show how the management of land use affects evaporation (green water), and how the management of surface water (blue water) through water retention structures affects groundwater recharge. This development will take place in parallel with the Mustoor study.

Together, these developments should be able to demonstrate and present through simple visualisations, how the existing and proposed watershed interventions at Mustoor will modify surface and groundwater flows from the catchment. They will also indicate which combinations of interventions can be implemented to maximise the benefits to catchment inhabitants whilst meeting long-term sustainability requirements.

2.4. A Proposed ‘Quadrant’ Approach to Managing Green Water (evaporation) and Blue Water (liquid) Flows from a Catchment[2]

Many watershed development programmes have reaped benefits through the promotion of soil-water conservation measures, forestry and groundwater-based irrigation. The question is: under what circumstances might these interventions result in beneficial or untoward outcomes?

It is suggested that to resolve this question consideration should be given to two issues:

I. The sustainability of land uses within the watershed with respect to evaporative use. It is important to determine if the long-term precipitation (P) still exceeds the total long-term evaporation (E) from the present land uses, comprising for example dryland agriculture, rangelands, forestry and irrigated areas, ie, to determine if $P > E$;

II. Whether surface flows, (Qs), exceed an agreed minimum flow, (Qm). Minimum flow criteria could be defined variously. Conventionally this would be defined in terms of an agreed seasonal or annual minimum volume flow. Alternatively, for reservoired catchments, criteria could be defined in terms of return periods of surface flow exiting the catchment, for example one year, or a more severe criteria of say, 5 years. The (Qs-Qm) criteria could then be regarded as positive, if the return period for flows was less than one year or five years. This definition would then approximate conditions, if there are reservoirs in the watershed, of whether or not the final reservoir (or tank using Indian terminology) has spilt within the last year or has spilt within the last five years. The four combinations resulting from this analysis indicate preferred options for the management of evaporation from land uses and for the management of surface flows. Using the green and blue water terminology derived by M. Falkenmark , these could be referred to as the green water and blue water management options:

[2] The following text is loosely based on the FAWPIO presentation given by Ian Calder at the SEI-SIWI Green Blue Initiative meeting in Stockholm in June 2005

1) $P > E$, $Qs > 0$

Green Water Management: Opportunities for enlarged areas of land uses with increased evaporation, eg. Irrigated areas and forestry.

Blue Water Management: Benefits may be gained from further SWC measures and water retention structures. Increase density of structures, rehabilitate structures.

2) $P < E$, $Qs > 0$

Green Water Management: Reduce areas of land uses with increased evaporation, eg reduce irrigation and forestry. Increase areas of 'water providing' land uses such as dryland agriculture.

Blue Water Management: Only local benefits (at the expense of downstream users) will be gained from further soil and water conservation (SWC) measures and water retention structures. Consider increasing efficiency of existing structures through measures such as deepening (to reduce evaporative losses through reducing the surface to volume ratio).

3) $P < E$, $Qs = 0$

Green Water Management: Reduce areas of land uses with increased evaporation , eg reduce irrigation and forestry. Increase areas of 'water providing' land uses such as dryland agriculture.

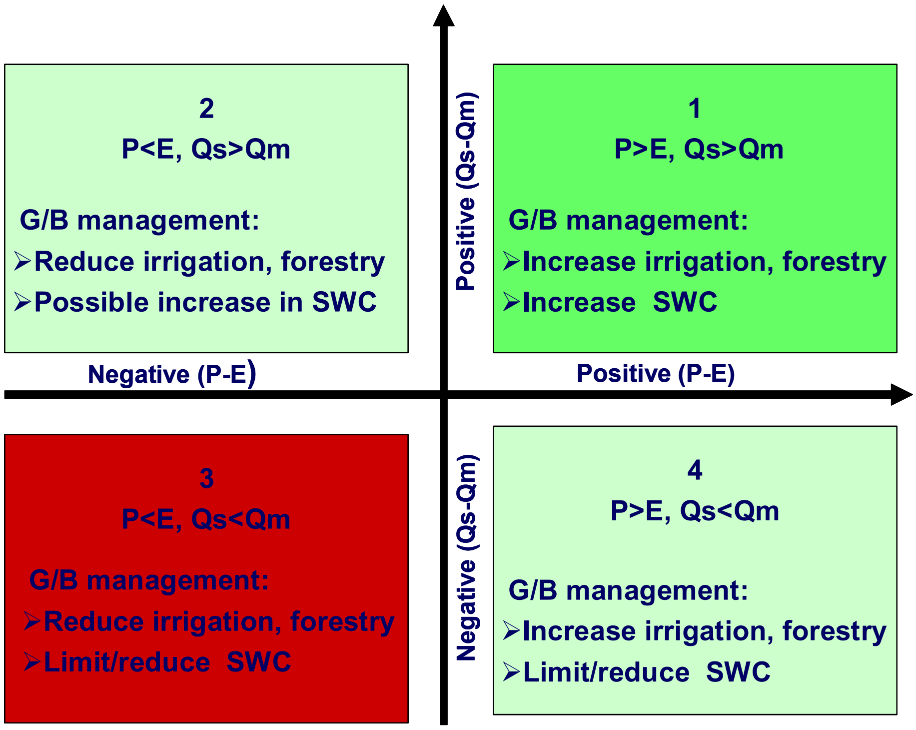
Blue Water Management: No overall benefits from further SWC measures and water retention structures. Consider reducing density of structures and/or increasing efficiency of existing structures through measures such as deepening.

4) $P > E$, $Qs = 0$

Green Water Management: Opportunities for enlarged areas of land uses with increased evaporation, eg. Irrigated areas and forestry.

Blue Water Management: No overall benefits from further SWC measures and water retention structures. Consider reducing density of structures and/or increasing efficiency of existing structures through measures such as deepening.

These outcomes can be illustrated with a quadrant diagram, as shown in Figure 6.



Notes: *E and P represent average annual evaporation and precipitation respectively. Qs and Qm represent actual and agreed minimum flows respectively. Minimum flow criteria could be defined variously eg. a proportion of the volume flow in a median rainfall year; reservoir spill return periods of say one or five years .*

Quadrant 1 exhibits benefits from further soil water conservation (SWC) measures; quadrant 3 and 4 exhibit no benefits; quadrant 2 shows local benefits but at the expense of downstream users.

Figure 6 Catchment conditions which can be used to identify green and blue water management options and whether benefits would be derived from further soil water conservation measures and water retention structures.

This approach, shown in the 'quadrant' diagram, in Figure 6, may help to direct development funds to those situations where further structural measures are likely to have an overall benefit (quadrant 1) and to scale back investments in catchments which are approaching conditions of catchment closure(quadrants 3 and 4). The approach also makes clear the interconnecting management options regarding green and blue water management and shows that in quadrants 2 and 3 development efforts would be much better directed at green water management, by reducing catchment evaporation losses, than by managing blue water through further water retention measures.

2.5. Bayesian Networks

2.5.1 *In support of the Quadrant approach*

In conjunction with the Quadrant approach outlined above, Bayesian networks are being developed to both identify which quadrant a particular catchment lies within and the management options which are available to: either move towards the sustainable quadrant (1) or to retain a catchment within this sustainable, quadrant 1, status.

An example of a Bayesian network appropriate to the Mustoor catchment is given in Figure 7.

> **Bayesian Networks**
>
> A Bayesian Network is a decision analysis framework, based on Bayesian probability theory, which allows the integration of biophysical and societal knowledge, and the uncertainty associated with this knowledge. The approach involves describing a system in terms of variables and linkages, or relationships between variables, at a level appropriate to the decision making. This is achieved through representing linkages as conditional probability tables and propagating probabilities through the network to give the likelihood of variable outcomes. Therefore, the approach ensures that treatment of risks and uncertainties is an intrinsic part of the decision-making processes. The approach is dynamic and interactive, and hence if a network previously developed does not fit a user's conceptual understanding of the system, it can be adapted quickly and simply to represent the cognitive understanding of the users or stakeholders. An on-line tutorial on the use Bayesian Networks can be found on: http://www.norsys.com

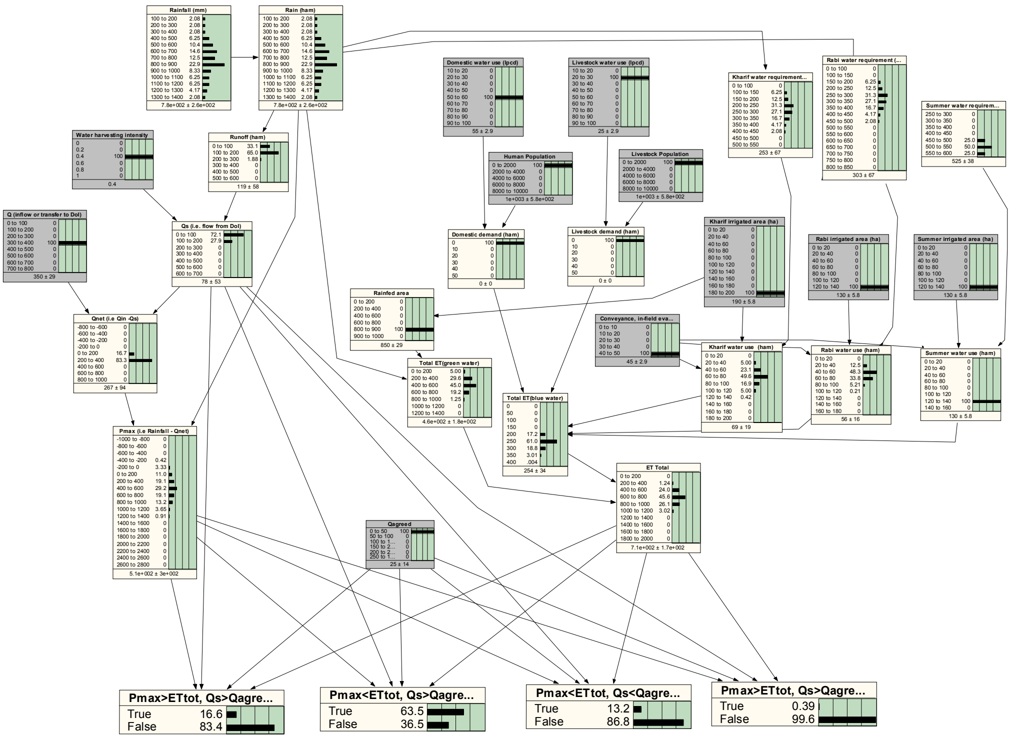


Figure 7 Proposed Bayesian Network for Mustoor

2.5.2 *Societal Impacts*

HG Halli Tank in Mustoor sub-watershed

Discussions during the FAWPIO (India) inception workshop, held in Bangalore in May 2005, highlighted the many biophysical and societal factors which have to be considered when developing and implementing water management strategies. Some of these factors are distinct and relatively easy to monitor and analyse (e.g. rainfall, population etc) whereas others, whilst being equally important, are much more difficult to define and quantify (e.g. awareness, resistance to change, social cohesion etc). Bayesian Networks (also known as Belief Networks) provide a relatively simple method of representing and analysing relationships between variables. The methodology is particular relevant to water management and the understanding of societal impacts because it works well even if these relationships involve uncertainty, unpredictability or imprecision.

In conjunction with supporting the Quadrant approach Bayesian Networks are also being employed to:

- Reach a common understanding amongst stakeholders on the nature and causal linkages between biophysical and societal factors central to the success of the JSYS and Sujala Projects;
- Investigate the potential of JSYS and Sujala to improve strategic and tactical land and water management decision-making at range of spatial and temporal scales. Both projects routinely collect large amounts of information and first indications are that Bayesian Network analysis can help the projects make much better use of this information.

2.5.3 *Network developments*

Farm pond under construction near Pujenahalli Tank

- The design of the networks was discussed in meetings with Mr Boregowda (E.D. JSYSY Project), Mr Muniyappa (Commissioner, Water Development) and others. These meetings resulted in many excellent suggestions being made for potential improvements to the network designs;
- With the assistance of Sujala and JSYS staff, information for populating networks has been collected in the Mustoor sub-catchment. Particular attention

was given to developing a robust typology of potential beneficiaries of JSYS and Sujala interventions;

- Capacity building and Bayesian Network training for staff involved in the JSYS project has started;
- A prototype stepwise approach to making decisions regarding levels of tank siltation, sanctioning water harvesting structures and designing other interventions has been developed. Discussions to date have focused on the way in which Bayesian Networks (and other outputs from the FAWPIO (India) Project) can be used to support and/or improve existing decision making processes.

Further developments include:

- Modification to take into account the suggestions made by JSYS and Sujala staff, as well as information collected during the Mustoor fieldwork stage;
- Strategy evaluation. Networks will be used to test the potential long-term benefits (or otherwise) of different water management strategies;
- Capacity building. Further attention will be given to improving the capacity of JSYS and, possibly Sujala, staff in Bayesian Network development and use;
- Decision Support System. More attention will be given to the development of a decision support system that is geared towards the specific needs of the JSYS and Sujala Projects.

3. Application and Development of the Framework at the Mustoor (World Bank) Project Site

3.1. Assessment of the biophysical impacts of watershed interventions

The basic structure of the Inchigeri model (refer to 2.1) is currently being adapted to the Mustoor catchment, situated in Southern India to the south of Inchigeri in the district of Kolar, which drains into the Palar River (Figure 3).

The key difference between the two catchments (Inchigeri and Mustoor) with regards to major interventions is that, while the Inchigeri catchment has a greater than average intensity of rainwater harvesting structures the Mustoor catchment has a greater than average density of tanks. The latter is illustrated in Figure 8. However, there are proposals to construct many rainwater harvesting structures in the near future in Mustoor.

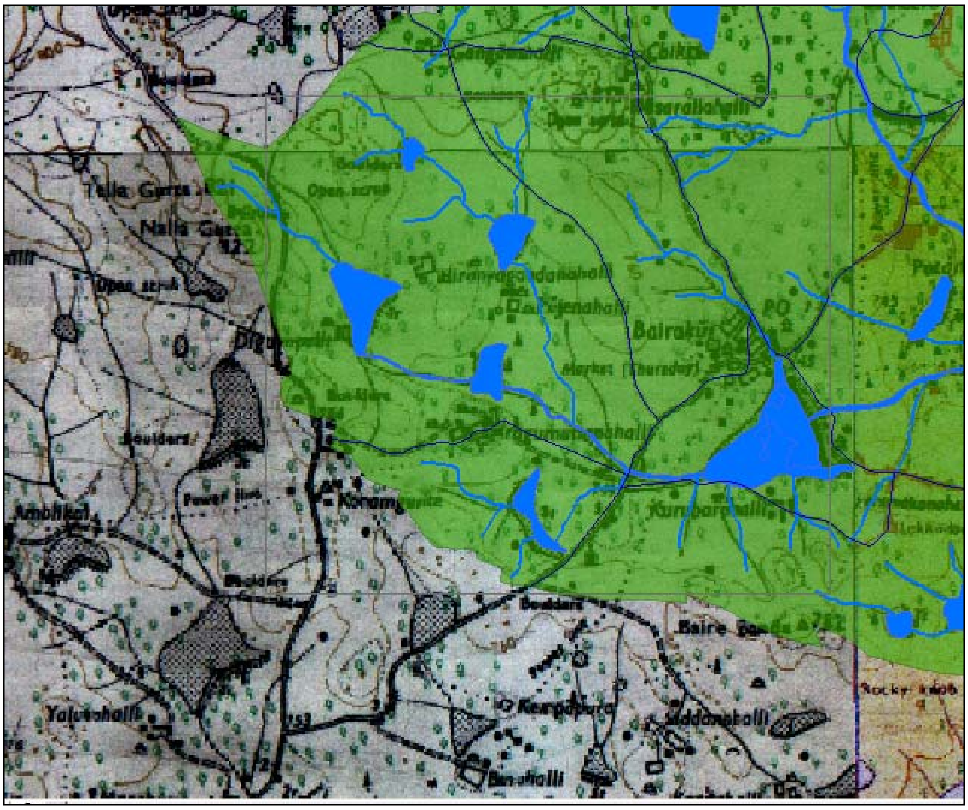


Figure 8 Mustoor Catchment Tank System

Key biophysical data collected in Kolar includes:

- GIS data for the catchment;
- Tank characteristic data from NGOs and the Minor Irrigation Department in Kolar;
- Site characterisations for each tank location obtained from field visits to each tank;
- Catchment characterisation and boundary delineation for each tank sub-catchment based on field visits to each tank sub-catchment;
- Land-use data;
- Previous SCS rainfall runoff calculation outputs for the catchment;
- Local rainfall data for 35 years; and
- Irrigation water usage from the tanks.

3.2. Assessment of the societal impacts of watershed interventions

Information on Mustoor's societal setting has been consolidated and groundtruthed. A large proportion of this information was collected in 2004 by Prakruthi (a local NGO) as part of the Sujala Project's planning phase. Using semi-structured interviews in each village, additional information was collected in the July field visit on the following:

- Trends in water availability and use (i.e. water-related time lines);
- The existence and functionality of village-level institutions;
- The status of domestic water supplies;
- The status and functionality of water-related infrastructure (e.g. the condition of tanks, the frequency of tank surplusing, the number of wells and borewells, the number of these wells that fail regularly or that are defunct;
- The impact that water shortages have had on livelihoods and the adaptations that different groups are having to make.

Secondary information and additional information obtained from semi-structured interviews has been used to develop a water-related typology of water users. This information will be used in the coming months to analyse the benefits (or otherwise) of various interventions of water management strategies.

Provisional findings from the societal studies include (not in order of importance):

- There has been a dramatic decline in tank inflows in recent years that can not be explained entirely by lower than average rainfall during the same period of time;
- Increased groundwater extraction (primarily for irrigation) during the last 10-15 years has led to falling groundwater levels and the failure of most hand-dug wells;
- Landless and resource poor farmers are having to migrate annually to urban areas or to rely heavily on remittances from family members who are working in urban areas;
- In some villages domestic water supplies have become increasingly unreliable as a result of declining groundwater levels. Villagers have reported a concurrent increase in health problems;
- In the last 25 years, there has been a decline in forested area;
- There are few livelihood opportunities in the area which are not linked to agriculture and, thereby, that are not highly dependent on rainfall and stored water (i.e. water stored in tanks or in aquifers);
- Although previous projects have supported the construction of latrines, these are not being used. In general, drainage in the villages is very poor and this is creating unsanitary conditions;
- Yields of a large number of bore wells have declined. This has impacted severely on the incomes of many farmers and their ability to repay loans.
- It is anticipated that additional information will emerge once the village survey analysis has been completed.

A provisional water-user typology is summarised in Table 1 and a provisional timeline analysis, based on villagers perceptions, is shown in Table 2. Further developments include:

Group	Characteristics
Whole village	Problems common to large majority of households that require "whole-village" solutions. These include: • Drinking water shortages during summer months and, in some cases, drinking water quality problems; • Lack of drainage; • Lack of sanitation; • Limited and unreliable electricity supplies.
Landless and resource poor households	Low income and a need to migrate. Often "distress" migration in low rainfall years. Less likely to be distress migration in high rainfall years because of improved local employment opportunities and possibly better returns from livestock and small land holdings; In case of landowners, low levels of income from agricultural activities as a result of small and/or poor land capability holdings and lack of access to reliable water supplies even in good rainfall years High levels of indebtedness. Large proportion of income used to pay off debt during good rainfall years Unlikely to be able to invest in borewell construction
Landowners and resource rich during periods of good rainfall	• Good returns from agricultural activities during periods of high rainfall as a result of good land resources; • Have borewells but the yields of these wells dwindle during summer months and fail completely during dry years; • Tendency to slip into debt during periods of poor rainfall and to have to repay debts using a large proportion of income during periods of good rainfall; • Will be tempted to borrow and/or invest additional money in drilling additional borewells in hope of constructing a high yielding well; • Unlikely to have sufficient income to be able to diversify out of agriculture.
Land owners and resource rich all the time. Diversified sources of income	• Good returns from agricultural activities even during low rainfall years; • Have been lucky in constructing a reliable high-yielding borewell; • Unlikely to be in debt and probably a moneylender. As a result, a high level of status and power in the village; • Able to use cropping systems that are geared towards marketing opportunities and maximising profits; • Able to diversify out of agriculture; • Will invest in additional borewell construction out of choice rather than distress.

Table 1 Water User Typology

	1955-65	1975	1985	1995	2005
Open wells	10-20 ft	50 ft	Water used to be there during rainy season	Dry	Dry
Bore wells	No borewells	No borewells	First borewells with 450 ft	20 - 50 borewells with 500 ft depth	50 -100 bore wells with 800 ft depth but limited number functioning except in Byrukuru
Tank	Full every other year	Full every other year (prolonged dry period at some stage during 1970s	Full every other year	Full every other year	Dry for the last five years
Forest	Some forestry	Limited forestry	No	No	No
Rainfall	Every month two three showers	Every month two three showers	Dry spells	Average rainfall	Average to very low rainfall
Livestock	Livestock used to be more	Reduced	Reduced	Reduced	Reduced to very little but the number is going up as dairying has become the subsidiary occupation
Crops	Ragi, groundnut, paddy (byruvadlu)	Ragi, groundnut, paddy (byruvadlu)	Ragi, groundnut, paady (byruvadlu)	Ragi, silk, tomato	Ragi, tomato, groundnut and very little silk.
Health	Healthier	Healthier	Average	Average	Lot of diseases but treatments are available unlike the previous years

Table 2 Timeline Analysis

4. Recommendations and Future Developments

The data collection and analyses carried out so far on the Inchigeri (KAWAD) and Mustoor (World Bank) watershed development sites have highlighted some of the problems which may arise as a result of excessive use of engineering interventions and of water demand that is outstripping supply.

At the Inchigeri site the modelling study has shown that soil and water conservation (SWC) structures upstream of the Inchigeri tank have significantly reduced inflows to the tank. The study shows that, by using a thirty year rainfall record, the tank would have spilled and provided water flows to downstream users almost every other year if the SWC structures had not been in place. With the structures in place spills, which provide water for downstream users as well as for environmental flows, would have occurred in only 2 years of the thirty year record. The SWC structures combined with high levels of groundwater extraction have contributed to the closure of this catchment and of the wider Krishna Basin within which it is located, as downstream flows are not provided, except during the wettest years.

By contrast, the Mustoor catchment, although not having at present a high density of SWC structural engineering interventions (other than traditional tanks), does have a high concentration of boreholes which are being used for irrigation. The unsustainable nature of groundwater abstraction at this site is evidenced by groundwater tables approaching 800 ft in some areas – which in turn are causing problems to domestic water supplies in some of the villages. It is believed, and modelling studies are underway to test this hypothesis, that the depleted groundwater tables are affecting the baseflow inputs to the Mustoor tanks. This may be a contributing factor (in addition to the blockage and diversion of feeder channels to the tanks) towards the reduced inflows and spills from these tanks which are believed to have occurred in recent years.

A workshop, where the outputs from the present modelling studies will be presented is planned for October 2005 and this may usefully coincide with a World Bank project review workshop that is planned at that time.

5. Acknowledgements

This publication is an output from a research project funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID. [DFID Forestry Research Programme project ZF 0176]

The FAWPIO team also wishes acknowledge the excellent support and assistance that they have received from the senior officers, specialist staff and field teams involved in the implementation of the Sujala and JSYS Projects. Staff from the DFID-supported KAWAD Project, KAWAD IAs and NGOs and Prakruthi (a NGO based in Kolar District) have also provided invaluable assistance.