Impact of biological control of water hyacinth on the flora and fauna of water bodies in Andhra Pradesh (Principal Investigator: Dr (Mrs.) Kaiser Jamil, Deputy Director, Indian Institute for Chemical Technology, Hyderabad)

Objectives:

1. To conserve water resources
2. Automatic diminishing of the mosquito menace which take shelter on the hyacinth plants.
3. To reduce the impediment of the flow of the water in canals.
4. To establish a safe and sound bio-control programme which is environmentally acceptable.

Findings:

Individually both the weevils and fungus were found to be very effective against water hyacinth in field conditions.

Combination of both the bio-control agents was more effective than an individual effect.

The conversion of biomass was observed after 2½ months in the case of the release of both the bio-control agents whereas the conversion period of weevils and fungus individually was found to be 3 and 5 months respectively.

Hence it is concluded that the combination of both the bio-control agents could reduce the weed population successfully.

It is an added advantage when the community of the study area, were also involved in the control programmes, so that they can take up the weevil multiplication and further release of infested plants into the thickly populated weed area at their level.

Aquatic weed management in irrigation and drainage channels of Krishna-Godavari Delta Area with special reference to Biological methods (Principal Investigator: Dr. K. Narayana Rao, Acharya N.G. Ranga Agricultural University, Bapatla)

Objectives:

1. Survey, identification and classification of aquatic weeds in irrigation and drainage channels of Krishna Godavari delta area
2. To assess the impact of bio-agent on floating aquatic weeds like water hyacinth, salvinia and other submerged weeds like Hydrilla, Vallisnaria, Ceratophyllum and other algae.
3. To test the efficacy of integration of biological and chemical methods of aquatic weed control
4. To assess the toxic effects of herbicides, if any, on aquatic weed fauna with special reference to fish.
5. To evaluate the role of indigenous fish in aquatic weed control in comparison with established herbivorous fish like grass carp, Tilapia etc.

Findings:

The trials for the control of aquatic weeds with herbicides proved successful especially of emergent weed like Typha and Ipomoea carnea and floating weeds like water hyacinth, Pistia, Ipomoea aquatica. Trials for the control of submersed weeds could not be conducted.

- For the control of floating weeds like Pistia and Ipomoea aquatica, application a paraquat at 0.6% + 2, 4-D sodium salt at 0.15% was effective.
- Pistia could be control even with paraquat alone at 0.6%.
- Water hyacinth can be control by spraying either of 2, 4-D formulations viz., sodium salt at 8.0 kg or amine at 3.0 kg or ethyl easter at 3.0 kg./ha or in combination with paraquat at 0.5 kg with reduced rates of 4.0, 2.0 and 2.0 kg/ha, respectively.
- Effective control of Ipomoea carnea can be achieve by spraying 2, 4-D amine at 3.0 kg/ha.
- Typha angustata was controlled most effectively first by manually removing the weed and spraying glyphosate at 2.0 kg./ha on the 2 months old regrowth to Typha.

Herbicide toxicity the fist was assessed and found that 2, 4-D ethyl ester was toxic to fish and should only be used where fish are not growing.

The trials for the control of water hyacinth with the bio-agents, Neochetina weevils were not successful. The weed was not completely control by the bio-agents. The multiplication was slow and the weevils could not perpetuate for long to have an impact on controlling the weed. The relation between the survival and the weather conditions need to be reassessed.

All the objectives of the project could not be fulfilled and all the proposed experiments could not be conducted.

Aquatic weed control in Tamiraparani basin: Biological options (Principal Investigator: Dr S. Ravichandran, Lecturer, Centre for Water Resources, Anna University, Chennai)

Objectives:
1. To study some biological options to control water hyacinth (Eichhorria crassipes)
2. To devise strategies for field trials at selected sties in Tamiraparani basin for field evaluation.

Findings:
Two biological agents, a weevil, Neochetina eichhornia, and a fungus Dreshlera sp; isolated from the natural environments are considered for the control of water hyacinth in this project.

A field survey on the natural habitat of water hyacinth indicated the following natural enemies; Sodoptera litura, a potential major agricultural pest, Tetranycus ludenii, a spider mite feeding on upper and lower surfaces of leaves gesonula Punctiferencs, a small variety of grass hopper, Orthogalumna terebrantis, a mite that scraps the leaf surface during feeding and Neochetina eichhomiea and Neochetina bruchi, the water hyacinth weevils.

The host range studies conducted at the CWR field laboratory indicated that the water hyacinth weevils are highly host specific and do not prefer any other crop grown or native vegetation in Tamiraparani command area.

Laboratory studies conducted on damage potential of the weevils with and without the mites showed the complete eradication of the water hyacinth plants in 64 to 90 days depending on the season when the experiments were conducted.

The field release of Neochetina sp. In the three tanks at Tamiraparani basin and the subsequent observations indicated that the insects have successfully established in the new habitat and indicated their impact on the plant density and biomass. The bio control process using weevils appear to be slower than expected in the natural conditions.

Dreshlera sp., a fungus was isolated during the general survey of aquatic habitats near the Chennai environs, isolated, purified in the culture laboratory. The fungal pathogen produced a leaf spot disease readily in laboratory experiments on water hyacinth plants. This fungus is reported for the first time in India, could be potential fungal agent for water hyacinth control.

The result of the project suggested that an integrated bio control using water hyacinth weevils and fungal pathogens might by faster and effective in controlling water hyacinth.

Use of Bio-manipulation techniques to control aquatic weed in river Kshipra, Ujjain (Principal Investigator: Dr S.K. Billore, Institute of Environment Management & Plant Science, Vikram University, Ujjain)

Objectives:
Root zone method for removal of nutrients from wastewater was developed through this research project.

Findings:
The root zone wetland filter for sewage treatment with local reed grass was installed for the experiment. The observation made for three years show that total solids, BOD, P, TKN, COD, TP, Turbility and chloride, TSS, TDS etc. were removed to a considerable extent from the waste water. Under the experiment biological physico and chemical quality of river Kshipra by analysis of samples taken at 12 locations over a period of three years was also observed. The growth of aquatic weeds in the river was attributed to heave eutrophication. It is concluded that though the overall aquatic weed control in Kshipra needs long term planning for complete water quality restoration, installation of several Reed Grass based treatment wetlands at several nallahs joining the river will help in reduction/eradication of the aquatic weeds (eutrophication) and improving overall water quality of river.

The root zone technology can be used to remove nutrients from domestic waste water and industrial effluents.

Weed Control and Moisture Conservation using LDPE (Principal Investigator: Dr P.V. Habeeburrhman, Kerala Agricultural University, Malappuram)

Objectives:
1. To assess the efficiency of soil solarization with LDPE transparent sheets as a method of weed control.
2. To determine the effect of thickness of polyethylene and duration of mulching on weed control
3. To study the influence of the method on germination of weed seeds buried in soil at different depths.
4. To determine the influence of mulch on soil moisture held at different depths of soil
5. To determine the deterioration and durability of LDPE sheet used for solarization.

Findings:
1. Soil temperature in plots solarised with transparent LDPE of 0.05mm thickness was increased by 7 to 9^{o}C whereas the temperature increase was only 4 to 6^{o}C in plots solarised with transparent LDPE of 0.10mm and 0.05mm thickness.
2. Solarisation with transparent LDPE of 0.05mm and 0.1mm was more effective than the normal practice of weed control in reducing the number of dry weight of weeds.

3. Among the two LDPE tried, the thinner one (0.05mm) was more effective in reducing number and dry weight of weeds. Considering the high cost and low efficiency of 0.1mm the solarisation is better done with 0.05mm LDPE
4. The rise in soil temperature above lethal levels of 45^0C for a period of 30 to 40 days resulted in poor germination and establishment of weed seeds and thereby caused increase in yield of Bhindi crop grown in solarised plots in comparison to normal practice.
5. Irrespective of the thickness of LDPE all the solarised plots conserved more moisture. Soil moisture content increased from 5% in non-solarised plots to 12% in non-solarised.
6. Solarisation during March-April with 0.05 mm LDPE and solarisation during March alone showed reduction in weeds almost on par and was much better than solarisation during either April-May, April alone and May alone.
7. The fact that the month of March experienced more days of high air temperature suggested that if the right period of the year is chosen the duration of solarisation can be reduced.
8. The weed number and growth were drastically less even at the end of the 5^{th} month in plots solarised with transparent LDPE of 0.05mm.
9. In the study on the effect of solarisation on buried weed seeds it was found that the increase in soil temperature was significant up to 10 cm depth but more pronounced at 5cm depth. Seeds of all the 10 species of weeds tried did show considerable decrease in germination when buried upto 10 cm depth.
10. Solarisation for 50 days did not give any advantage by way of reduction in weed seed germination as compared to solarisation for 40 days.

Management of Aquatic Weeds (Principal Investigator: Dr. Manwinder Singh, Research Officer, IPRI, Amritsar, Punjab)

Objectives:
The objective of this research scheme costing Rs.1.62 lakhs was to device efficient and economical methods for the control of aquatic weeds in irrigation and drainage systems. Study was carried out in drains and channels of UBDC track.

Findings:
Standardising the chemical control technique for control of Eichhornia Crassipes were done on macro scale. Effective biotic agents of Neochetina Bruchi and Neochetina Eichhorniae were taken up at selected reservoirs, drains and sites. The data were collected on the basis of experiments conducted in the laboratory and field.

1. Ethyl Ester of 2,4-Dichlorophenoxy acetic acid at the rate of 200 ppm and 1% sticker was able to completely eradicate the mat of Eichhornia plants in about 8 weeks. Slightly quicker eradication was obtained when a mixture of Ethyl Ester of 2,4-Dichlorophenoxy acetic acid at the concentration of 100 ppm and glyphosate at the rate of 1% was used along with 1% of nonionic sticker. The cost of eradication comes to Rs.30 per 100 sqm. When 1% solution of glyphosate is also added, this helps in quicker eradication of plant.
2. Both, Neochetina eichhorniae and Neohetina bruhi were found to be effective in controlling Eichhornia crassipes. The results are better in land locked ponds where there is least disturbance and at places where ponds do not dry up during summer season. Under the climatic conditions of Punjab where aerial portion of the Eicchhornia plants dry up during winter season more than 4 years are required for the biological control methods to be effective.
3. Grass crap fish readily consume most of the aquatic macriphytes and can be successfully used as a biotic agent for their control.

4. Algae can be effectively controlled by treating with copper sulphate solution at the concentration of 2.0 ï 3.0 ppm. The control is achieved within three weeks time.
5. Most of the submerged aquatic weeds can be controlled by subjecting the irrigation channels to three closures of 7 days duration each followed by a wetting cycle of 14 days. Some of the hard weeds like Vallisneria spirallis, Hydrilla verticellata & Botamogeton amplifolius require five drawing cycles of 7 days duration for the complete eradication

Techniques to prevent rodent damage and weed growth from embankments in water resources project (Principal Investigator- Dr. Manwinder Singh, Research officer, IPRI, Amritsar, Punjab)

Objectives:
Under this research scheme costing Rs.2.30 lakhs, experiments were conducted raising the plants of Vetiver grass on the embankments of the drains of Punjab which were badly affected by rodents and sterilizing the soil on the embankments of the drains, which had thick weed growth with different soil sterilants like sodium chloride, Borax etc, so as to prevent weed growth.

Findings:
Field observations for observing the effectiveness of Vetiver grass were made of the experimental channels. During the period of observations during the period of observations no rodent hole was observed on the embankments of all these drains.

Semi-field experiments were continued in the Instituteôs premises to make the embankments free from emergent aquatic weeds. For this research work, an experimental channel was constructed in the Institute. On the embankments, all types of aquatic weeds were allowed to grow. Later on, the channel embankments were divided into number of portions and different soil sterilants were tried on these portions. Various methods of applications were used for applying the soil sterilants like broadcasting, spray and soil mulching etc. All the vegetation disappeared from the treated portions of the embankments within six weekôs time.

The conclusions are :
1. Vetiver grass (Vetiveria Zizaniodes) are the plants which propagate at a high speed as compared to other studied plants.
2. The roots of the Vetiver grass are the most effective part of the plant to scare away the rodents since the fragrance of the moist roots of the Vetiver plant keeps away the rodents.
3. Sodium chlorate @500 ppm (52.5 gm/m^2), Sodium Carbonate @5000 ppm (525gm/m^2) & Potassium Chlorate @ 138 gm/m^2 have proved to be effective soil sterilants for the lining. These help in the control of weeds in the sub surface of lining. Although Potassium Chlorate is slightly costlier in comparison to Sodium Carbonate, it is more effective in controlling the weed growth. Hence use of Potassium Chlorate is preferably recommended as a soil sterilant in canal lining.
4. It has further been concluded that two doses of equal magnitude are better than one higher dose equivalent to the sum of two lower doses.

Canal lining for efficient use under the command area of Katepurna and Morna Project (Principal Investigator: Prof. R.C. Bhuyar, Punjabrao Deshmukh Vishwavidyalaya, Akola)

Objectives:

1. To estimate the seepage losses from the canal of the different size, slope and length of various bed materials.
2. To test different lining materials for its effectiveness.
3. To find out economics of the various lining materials.
4. To select suitable lining materials for various size of canals.
5. To make effort to prepare lining from locally available materials and to generate employment to rural area.
6. To test the durability of lining materials.
7. To find out proper methodology for carrying out various types of lining materials.

Findings:

In the canal network the representative cross sections and sites were selected.

Water delivered from the head regulator was 9.415 m^3/sec and losses occurred within 300m length of main canal was 0.002m^3/sec. in first phase of canal upto 750 m it is in cutting however seepage losses were more because the flow through canal was more than designed capacity. But losses were comparatively less than other two phases of the canal. The average total loss per 1000 sq.m. was found 0.0098m^3/sec.

It is observed that the total losses in Dhaga minor is 0.085 m^3/sec per 1000 sq.m. In the lavali area of the minor the water losses were too much. Similarly in Pailpada minor and Khadka minor total losses were upto the extent of 0.3625m^3/sec per 1000 sq.m.

The major portion of water was lost by the lack of maintenance of main, and improper design of field water courses.

Evaluation of different non-conventional lining materials for seepage control in small irrigation channels (Principal Investigator: Dr. S. Mallick, Bidhan Chandra Krishi Vishwavidyalaya, Gayeshpur, Nadia)

Objectives:

1. To assess the effectiveness, economics and durability of different lining materials in controlling seepage losses.
2. To evaluate the actual benefit of lining for water courses
3. To demonstrate and persue the achievement to the actual users.

Findings:

1. The dices for making half circle (50 cm dia) precast concrete sections with bamboo-reinforcement and burnt clay tiles (30 to 35 cm dia) have been designed, fabricated and successfully used. The dices are proved to be capable of producing huge number of sections.
2. The bamboo sticks can suitably be used as the substitute of steel reinforcement in precast concrete sections used for lining the irrigation channels.
3. The half round section with maximum of 50 cm dia, 150 cm length and the minimum thickness of 2.54 cm could be fabricated by using the bamboo reinforcements.

4. The size and spacing of bamboo reinforcements have little effects in the performances of seepage losses of the channels. However, the reinforcements of higher spacing (15cm x 15cm) and lower cross section (5mm x 7mm) have shown some advantages over lower spacing (10cm x 10cm) and higher cross section (7mm x 10mm) in casting the sections.
5. The average seepage losses were found 0.04069 and 0.01205 m^3/m^2/day which could save 96.90 and 99.08% of water losses through earthen channels for precast bamboo reinforced concrete and burnt clay tile channels, respectively.
6. The cost of channel construction for burnt clay tiles of cross section 450 cm^2 were Rs.65 and 135/m length of the channels, respectively. For the comparable capacity of the lined channel made of bricks, the cost was calculated as Rs.295 and 390/m length and which are 4.53 and 2.88 times more than burnt clay tiles and precast bamboo reinforced concrete channel, respective.
7. The longevity of the channels are expected to be 15 and 20 years with a yearly maintenance cost of 5% to the construction costs for the burnt clay tiles and precast bamboo-reinforced concrete channels, respectively.
8. The channels may be constructed in a short time by using these lining materials. These type of channels can be recommended where there is some constraints in funds, works to be completed in a short time and the discharge is within the limit of 15 lit/sec at the field slopes not less than 0.20%.

Performance Studies on LDPE as compared to concrete canal lining for improved canal water management (Principal Investigator: Dr R. Rajkumar, Annamalai University, Chennai-25 Tamil nadu)

Objectives

To compare the LDPE lining with that of cement concrete lining for improved canal water management.

Findings:

LDPE saves more amount of water compared to other conventional lining. Majority of the farmers prefer LDPE lining than Random Rubble masonry or any other type of conventional lining. However, the durability of LDPE lining is predicted to be less than conventional lining. The cost of LDPE lining is proved to be approximately three times cheaper than the conventional lining i.e. Random Rubble masonry lining. Therefore, LDPE lining can be recommended in lining the irrigation channel for its advantages of water saving, cheaper than conventional lining and preferences of the farmers.

Fabric based material for canal lining (Principal Investigator : Prof. B.L. Deopura, Deptt. of Textile Technology, Indian Institute of Technology, New Delhi)

Objectives:

Findings:

A fabric based shear material has been developed for water lining applications, General LDPE films are used in India for lining in canals and water ponds, but these films get punctured during construction itself and hence serve little purpose in controlling water seepage. Internationally, HDPE sheets with thickness of around 2mm are used. However, as these are thick sheets, there is significant cost of transpiration and installation. Geomembrane developed at IIT, Delhi is of around 0.5 mm thickness with puncture and other properties comparable to the ones used internationally. The cost of this product is in the range of Rs.80/- to Rs.150/- sq.meter. these sheets are typically used in buried versions to protect from (a) stealing/vandalism and (b) direct

sunrays to increase the life. These sheets supports all type of protective layers like soil cover, stone pitching, brick layer with or without mortar, concrete layer etc.

These sheets have been used successfully, to line a channel at Water Technology Centre, Indian Agricultural Research Institute (IARI), a pond at IIT, Delhi as well as at Water Technology Centre for Eastern Region (WTCER), Bhubaneswar.

The results show that the seepage is significantly controlled with these sheets. IARI experience demonstrated that there is increased flow of water in the channel and the sheets could be reused. Thus, the geomembranes developed at IIT, Delhi are useful for seepage control of a range of applications i.e. canal, tanks, dams, and other water bodies. These could also be used in rehabilitation of canals, dams, etc. These may prove most effective in expansive soils where concrete lining would result into cracks.

Evaluation of performance of beneficiary farmers association under command area development programme in Kerala (Principal Investigator: Dr S.K. Madhavchandran, CWRDM, Kozhikode)

Objectives:

1. To study the impact of and functioning of BFAôs under representative distributaries of two CADA projects in Kerala.
2. To identify the social/economic/technological factors related to proper sustenance and functioning of BFAôs
3. To study the role of CADA in the functioning of BFAôs
4. Based on study, to suggest suitable model for improving the performance of BFAôs

Findings:

These are based on interview with farmers and group discussions with farmers of BFAs and officials of CADA and Irrigation Department.

Farmerôs participation in both Malampuzha and Cheerakuzhy Irrigation Project (MIP & CIP) was found to be very low i.e. around 30% only. The main activity of more than 50% farmers in both command relate to (i) contribution of labour and money for maintenance of field channels, (ii) attending BFAôs meetings and sharing their knowledge/experience.

a. BFAs have helped to develop a sense of ñWeò feeling/co-operation among members farmers
b. The main activity undertaken by BFAs in MIP and CIP is maintenance work on field channels using management subsidy from CADA and contributions from members
c. Conflicts between BFAs do not exist in both the study areas
d. Most of the farmers are not aware of their rights and responsibilities as well as legislative/ legal backing available to the BFAs under CADA. Even the main objective behind formation of BFAs namely, improvements in on-farm water management has not been realized by majority of the farmers. This is confirmed by the absence of the system of channel of field irrigation (below the length of field channels constructed by CADA) in the command areas of most of the BFAs in both MIP and CIP.
e. It has not been possible for farmers to achieve any notable increase in crop yield due to the activities of the BFAs
f. Majority of the farmers opposed the idea of changing the cropping pattern from the rice to other remunerative crops in order to improve the level of participation.
g. Farmers were of the opinion that programmes/schemes of CADA and Agricultural Department may be co-ordinated within the command areas so as to enable them to get benefits in an easier manner.
h. CADA had adopted basically an administrative approach as ñexternal actorsò in the formation of BFAs without involving the farmers from the grass root level right from the process of decision making in the participatory programme. Even the absence of motivators during the formation stage has been pointed out by CADA officials.
i. Many of the BFAs are not functioning properly and they do not renew after getting management subsidy from CADA for a period of three years.
j. From this study, it may be inferred that both farmers and officials favour the idea of decentralizing responsibility of operation and maintenance (O&M) of the irrigation system to the farmers associations. Under this approach, Government and farmers can work us

ñPartnersò (as termed by Ambler 1994) under a joint management set up, with decision making and investment shared between them.

k. Participatory Irrigation Management (PIM) scheme planned for implementation in Kerala would be right step in the above mentioned direction, with Irrigation Department maintaining its responsibility of O&M in the upper levels of the canal system.

Performance evaluation of water users cooperative societies in Maharashtra (Principal Investigator: Director-General, WALMI, Aurangabad)

Objectives:

To study the impact of Water Userôs Associations (WUAôs) and their performance through analyzing the water distribution pattern amongst beneficiaries irrigation efficiency, economic benefits, conflict resolution, process of formation, attitudinal behaviour of officers etc.

Findings:

- Present model of Water Userôs Cooperative Societies (WUCS) is in general accepted by the farmers.
- NGOs should be entrusted with the work of motivation of farmers for the formation of WUCS.
- Attitude of majority of the farmers towards WUCS is positive.
- The issues like water rates, enrolling members, distribution of water to non-members and collecting water rates from non-members are found to be conflicting issues. Necessary guidance, changes in procedure and empowerment of office-bearer of WUCS are some of the steps to help conflict resolution.
- There is a need to conduct training programme on large scale for all óstakeholdersô in PIM.
- Emphasis is required for conjunctive use of canals and well water.
- The new scheme of Ministry of Water Resources, Government of India of giving one time management subsidy Rs.500/- ha is more beneficial for WUCS and same need to be implemented in Maharashtra State.
- The success stories of PIM need to be developed/documented in print and electronic media.

Organising Community participation at Micro level in Akama-Cheruru M.J. Tank of Narsapurguda, Kottur Mandal, Mehboobnagar, Distt. (Principal Investigator and Research Station : Shri T. Desh Bhakt, Director-General, WALAMTARI, Hyderabad).

Objectives:

1. Evolving suitable strategy for organizing farmers under minor irrigation scheme.
2. Developing awareness among beneficiaries about the positive impact of environment due to participatory management of the tanks.
3. To form Water Users Associations.
4. Demonstration of socio-economic benefits from self-management by farmers.

Findings

It is inferred that due to the existence of trained Water Usersô Association (WUAs), net economic benefit for the farmers in terms of agriculture production is about Rs.12.00 lakhs with the meager quantity of water available in the tank. Subsequent maintenance work taken up on the tank bund and canal system has its impact of the training given by the WALAMTARI through INCID research project. This achievement is in terms of demonstration of economic benefits that accrue from the management of the scheme by farmers themselves, which forms a part of the scheme objective.

The strategy of forming a viable Farmersô Association is location and situation specific, which takes time to evolve, depending on the dynamics of the farmersô community that are influenced by ever changing socio-economic and political development in the areas.

Necessity of formation of WUAs and awareness among farmers, which resulted in increased agricultural production, cannot thus be ignored and results can be used/replicated in other minor tanks.

Encouraging women's participation in irrigated agriculture (Principal Investigator: Dr Kamalam Joseph, CWRDM, Kozhikode)

Objectives:

1. To provide better opportunities for women in the irrigated agriculture sector.
2. To make the farm women critically aware of the problems in irrigated agriculture and the possibility of best exploitation
3. To promote the access of women in irrigated agriculture by making them more visible and important through the process of period contacts, discussions and deliberations
4. To increase the agriculture income of the poor rural women by developing their abilities and skills, and
5. To disseminate the information on allied aspects that can lead to better irrigation management.

Findings:

The Centre for Water Resources Development and Management (CWRDM), Kozhikode, Kerala took up a project in the command are of Ichannur sub-distributory of the Kuttiyadi irrigation project to encourage women of the areas to actively participate in irrigated agriculture. The major objective of the project was to promote the access of women in irrigated agriculture by making them self confident through a variety of means.

Action was initiated for formation of small women groups by various steps i.e. seminars, socio-economic survey and interaction, group meetings, etc. Once informal groups were formed in the study area, awareness class were arranged and they were strengthened to work in group with elected office bearers. All the technical support/guidance needed was given. The different groups raised various crops like paddy, vegetable, banana, etc. On collective basis they gained lot of knowledge and experience from these activities. Each group had discussion and interaction within the group, between groups and with experienced technical persons. Training programmes and awareness classes were arranged, which strengthened the technical capability of the groups. The groups gained certain extent of financial benefit from the sale of agricultural produce. Three groups started agri-business activities like vermin-compost making.

In addition to the activities in the study area, the women groups were taken to research stations, agricultural farms and irrigation project sites. This helped them to gain further knowledge in the allied technical areas.

The surveys conducted before the start and after the termination of the project gave a clear idea that the project was of great use to the beneficiaries. Majority of the target group could improve knowledge on technical aspects through various activities. They could establish a strong linkage with the service departments of the areas and also with the panchayat officials. Even though there was little opposition from male members in the beginning later all the problems could be solved and the womenôs activities were appreciated not only in the study area but also in the neighbouring panchayats. An appreciable change in the attitude of people favouring the

mainstreaming of women could be experienced. Few cases of differences in opinion was report but these were solved and a congenial and smooth functioning could be effected throughout the course of action.

Since there were only women in the group, they could develop strong communication skills and organizing ability. It could be seen that the group expressed very good team spirit and interest. It is now felt that they gained enough confidence for working in mixed groups in future. The leaders of different activities had been identified by the service departments and local panchayats as contract persons to propagate their activities. The experiences in the project show that when properly sensitized and given opportunities, rural woman participate actively in the meetings, training and field activities was the lack of access of suitable land. If the local authority can ensure easy access for the group to land suited to raise irrigated crops, the women group/mixed group can take up and sustain participatory activities in a better manner.

The approach employed in the project could generate the spirit of cooperation, caring and sharing adjustment, harmony, self-help and self reliance to the women beneficiaries.

There is scope and need of extending the concept i.e. encouraging Womenôs participation, in other regions/projects in the State and other States as well.

Computerised water management planning for small irrigation projects (Principal Investigator: Dr D.K. Agrawal, Indira Gandhi Agricultural University, Raipur)

Objectives:
Water management studies at various places have indicated the deficiencies not only in planning at farm level but in planning at main system level as well (Aberrethy, 1985, Hunt et al., 1976 and Wade, 1982). It is further, well established now that the effective management of any irrigation project relies heavily on collection, analysis and interpretation of timely and reliable information (Holmes, 1983 and Howarth et al, 1986). Taking into consideration thee facts, this project was undertaken to develop computerized water management plan for an identified small irrigation project and then study its practical usefulness and limitations under actual field conditions.

Findings:
The present study on computerized water management planning for small irrigation projects was undertaken to develop the software for rainfall forecasting and water requirement estimation and canal irrigation schemes. It was also envisaged to last the workability of the same under actual field conditions. Apropos to the objectives, software have been developed and tested. The salient features can be summarized as below:

1. The Gompertz trend curves fits very well to data of weekly cumulative rainfall and cumulative week number for various years.
2. Their exists a strong correlation between the coefficients of the Gompertz trend curves. Also, the coefficients are significantly correlated to the data of previous years cumulative rainfall.
3. The above points enables rainfall forecasting for the time interval ahead. The model when tested for Raipur, it indicated that rainfall can be forecasted with +25% variation.
4. A software has been developed for estimation of crop water requirements based on the actual layout of the canals and cropping pattern data. Standard methodology has been adopted for computing evapotranspiration requirements of the crops grown in the command. The software is user friendly and allows user to interact frequently.
5. The software was tested utilizing data from the command area of a tubewell irrigation project. Irrigation releases were made as per the results obtained from the software and monitoring on field basis was undertaken. This indicated that results were within +25% of the predicted values.

Development of simulation model for dynamic regulation of canal network (Principal Investigator: Prof. G.S. Parthasarathy, Water Resources Engineering Management Institute, Samiala, Gujarat)

Objectives:
To develop a model for evaluating hydraulic response of a conveyance and distribution network to change in inflow, type and setting of control structures and channel physical features, as well as for determining best combination of controllable parameters to meet the predetermined system performance goals.

Findings:
From the studies carried out it can be concluded that the steady state simulation model with graphical user interface for canal operation is quite suitable for developing operational philosophy for a canal network and can be used for establishing relationship among different parameters for a canal control structure. Steady state simulation provides initial condition for the simulation of

unsteady state operation. To put this steady state model for actual operation it is required to calibrate the roughness values for canal lining and coefficient of discharge for each gate.

In future, Model can be upgraded for Window environment. A Java based internet application can be prepared to transfer data. An unsteady model can also be linked to study the changes between two steady state profiles due to gate operation.

Development of data storage and retrieval systems for evaporation control purpose (Principal Investigator: Prof. G.S. Parthasarathy, Water Resources Engineering and Management Institute, Samiala, Gujarat)

Objectives:
The immediate objective of DSR System is to make use of data easier, cheaper, faster and more flexible.

Findings:
Using standard model for storing data will help in maintaining it and retrieval it. As meteorological information is the key information for planners, long term data can be maintained on computer format which is easy to store and retrieval and it can be helpful in future projects for designing and forecasting. It can be also helpful in reducing paper handling and transferring data from place to place. Computer program development is going on satisfactory. Query- Analysis, Backup/Restore, Graphical Presentation features can also be added to the software.

Geographic Information System application for environmental impact assessment of irrigation project – A case study of Nagarjunasagar Right bank Canal Command Area (Principal Investigator: Dr I.V. Muralikrishna, Jawaharlal Nehru Technological University, Hyderabad, Andhra Pradesh)

Objectives : Environmental Impacts and socio-economic aspects of water resources projects.

- To design GIS as a methodology for environmental impact assessment and database establishment.
- To quantify the micro-climatic changes, if any, in general due to the Nagarjunasagar Project within the study region.
- To evaluate the impact of the project on environmental parameters.
- To provide a decision support system in terms of GIS, so that socio-economic analysis can be carried out.
- To provide data (within the study region of the part of Nagarjunasagar Right Bank Canal Command Area) pertaining to the natural resources environment and socio-economic conditions in a database at mandal/village level.
- To attempt to evaluate the cost benefit ration of water usage.
- To assess and diagnose the irrigation system performance.
- To evaluate the adequacy of the irrigation system to meet demands of farmers and match cropping plans and calendars.

Findings :
Satellite data, environmental attributes, socio-economic data and topographic information have been used to conceptualize, define, formulate and demonstrate a Geographic Information System (GIS) for irrigation management and environmental impact assessment of Nagarjunasagar Right Bank Canal Command Area.

Prior to Nagarjunasagar Project (NSP) the entire command area was dependent on monsoon for crop production. With the irrigation through NSP, the overall socio-economic status of farmers has improved considerably. Various socio-economic impacts of irrigation due to the project, such as impact of irrigation on farm economy and household economy, cropping pattern, yields of principal crops, have been examined. Various problems such as salinisation, alkalization, Waterlogging, increased incidence of water related diseases, water quality, ecological degradation, groundwater table changes, etc. have been identified and mitigation measures suggested.

Determination of optimal cropping pattern and release policy for a conjunctive use of surface and groundwater by linear programming. Principal Investigator: Prof. D.T. Shete, Water Resources Engineering and Management Institute (WREMI), Samiala)

Objectives:
To develop optimal management decisions regarding the use of surface and groundwater water for the existing cropping pattern of selected command area under Vaghodia Branch Canal of Deo Irrigation Scheme. A mathematical model will be formulated for this system and will be solved using simplex algorithm of linear programming.

Findings:
- At present 40% to 100% irrigation intensity in achieved in the command area. Therefore by optimization technique in different strategies (Strategy-1 Considering unit costs of surface and groundwater; Strategy-2 Considering space integration; Strategy-3 Considering space time integration) the irrigation intensities from 100% to 170% can be achieved.
- For space-time integration the maximum irrigation intensity can be achieved and the water (either surface water and groundwater or both) is also available in any month and hence, this strategy is recommended.
- Results suggests that the change in 20% increase in selling price/yield gives maximum benefits and the change in 20% decrease in selling price yield gives minimum benefits to whatsoever minor or strategy is being considered.
- The benefits for space integration are comparatively less than space ï time integration which have the maximum benefits. The primary goal is to maximize the total area under cultivation and then to maximize the economic benefits. Hence the space ï time integration having more area under cultivation and maximum benefits is to be implemented.

Aquifer response modeling of evaluation of conjunctive use of surface and groundwater in Hindon Kali Nadi-Doab (Principal Investigator: Dr P.L. Chawla, Research Officer, Uttar Pradesh Irrigation Research Institute, Roorkee)

Objectives:
1. To procure the data for the area under study from various agencies and to fill the gap in the data by factual measurements wherever required.
2. To analyse the data and to estimate the availability of surface water and groundwater storage and the permissible level of groundwater development.
3. To optimize allocation of surface and groundwater supply and to work out the optimal plan of two systems in space and time and maximize the agricultural potential of the command area with the help of linear programming model.
4. To arrive at the best cropping pattern, that can be devised to maintain reasonable water budget.
5. To develop mathematical models for the area to predict future behaviour of groundwater table as a result of rainfall recharge, groundwater development and expected trend in water utilization.

Findings:
Through the area between Hindon and Kali Nadi in district Saharanpur and Muzaffarnagar is receiving canal water from Upper Ganga Canal, yet the allocation of canal water in lower reaches of area (specially Budhana Tehsil) is quite less than required. Due to this, farmers are using more

groundwater for irrigation of their crops. As a result of extensive use of groundwater, the groundwater table in zones III and IV has already declined to an alarming stage and is progressively going down. A feasible approach of arresting the groundwater table may be (i) by reducing the area under sugarcane crop which requires maximum water in non-monsoon period and (ii) by increasing the surface water allocation in the affected area either by diverting more discharge in Deoband branch during September to November or by constructing a new canal for utilizing monsoon supply or river Hindon in zones III and IV. The main recommendations are:

(i) 80% irrigation level be maintained in the study area:
In few trails of cropping pattern in which crop water requirement is adopted at 100% of irrigation level with present surface water allocation, the groundwater table is found to decline by 0.54 m to 0.33 m per year. Moreover, there is hardly any increase in the average yield of crops when irrigation level is increased from 80% level to 100% level. Hence it is recommended that 80% irrigation level may be continued.

(ii) Sugarcane cultivation should be discouraged:
Farmers in the study area and especially in zone III and IV should be advised to reduce the sugarcane cultivation by about 10% of total culturable command area. They should be encouraged to increase the cultivation of other crops like wheat in Rabi season and paddy in Kharif season.

(iii) More surface water be introduced:
The supply of Deoband branch may be increased by about 5 cumecs (175 cusecs) during September to November. This additional discharge is to be allotted to zones III and IV. It will increase monthly surface water allocation by 1000 ha.m. in these zones. Out of this, share of zone III is 400 ha.m. and that of zone IV, the share is 600 ha.m.

As an alternative of recommendation (iii) a new canal of capacity of about 5.0 cumecs (175 cusecs) may be constructed to divert the discharge of river Hindon of specially during the period from September to November. This canal will off take from left bank of Hindon near the boundary of Blocks Charthawal and Shahpur, the proposed locations of the canal in zones III and IV.

Conjunctive management in tank commands through community wells (Principal Investigator: Dr N.V. Pundarikanthan, Centre for Water Resources, Annamalai University, Chennai)

Objectives:
1. To formulate a two dimensional unsteady groundwater flow model for unconfined aquifer using finite element method
2. To incorporate the groundwater flow model in a surface water release simulation model for the conjunctive use of surface and groundwater.
3. To develop a non-linear optimization model (based on the Hooke and Jeeves algorithm or Conjugate gradient method) for the combinatorial optimization of the selected parameters. This non-linear optimization model uses the simulation model iteratively.

Findings:
A simulation optimization methodology has been demonstrated in this study for the conjunctive management of surface and groundwater resources in a tank irrigation system. In this study, a conjunctive use model was developed. It consists of surface water release model and groundwater flow model. The surface water release model was developed using simulation technique based on

mass balance method. Groundwater flow model was developed using Galerkin approach, a finite element method. This model can be applied to any similar tank irrigation system. The groundwater flow model developed can be easily extended for an isotropic case and also for three-dimensional flow. The optimization problem is formulated as a non linear programme problem and has been solved using Hooke and Jeeves algorithm and conjugate gradient method.

From the study, it was found that groundwater is not being utilized effectively because the farmers have to spend money for sinking of wells, energisation and installing pump sets etc. Farmers may need to pay for electricity (In Tamilnadu electricity is free of charge to farmers) or diesel that makes the use of groundwater expensive. Hence water charges should be made uniform so that the farmers can utilize the groundwater resources in conjunction with surface water.

Design of Conjunctive Irrigation System (Principal Investigator – Prof. A.K. Sinha, Centre for Water Resources Studies, Bihar College of Engineering, Patna)

Objectives:
The objective of the research project was to develop a technique for design an irrigation project for conjunctive use of surface and groundwater for optimum use of available waters. Bagmati command area was selected for the study.

Findings
For the total water requirements best suited strategy for the available surface and groundwater was worked out through various computations.

Strategies for Conjunctive use of poor quality underground water and canal water for controlling soil salinity/alkalinity and sustain crop productivity in Kaithal Circle of Bhakra System, Principal Investigator: D.K. Sharma, Sr Scientist, Central Soil Salinity Research Institute (CSSRI), Karnal; Estimated Cost: Rs.5.22 lakhs)

Objectives:
a. Analyse the degree and extent of soil salinity/ alkalinity due to continuous use of poor quality underground waters in the area
b. To know the effect of conjunctive use of poor quality water with canal water on crop productivity and soil properties at farmerôs field and at the experimental farm.
c. Develop crop water production functions for canal and poor quality waters through various experiments in the area.
d. To suggest a proper canal water scheduling under existing/improved cropping pattern.

Findings:
This research project has taken up in March, 1996 and was completed in February, 2000. Availability of good quality surface water is limited and underground water of poor and marginal qualities are available in arid and semi-arid climatic condition in the country. The productivity of crops has been decreasing due to continuous use of these waters in rice-wheat sequence. To optimize the conjunctive use of these waters through crop-diversification present study was taken.

Necessary primary and secondary data were collected and analysed. Field experiments for important crops of the area were done in four underground water quality zones, viz. good marginal saline and sodic at farmerôs field and experimental farm to develop crop production function in term of quality and quantity of water. Two experiments were done under each water

quality zones in an area of 1.5 acres for different crop sequences and different treatments (more of water application). Modified Penmanôs equation was used to calculate with reference of crops. A crop water production function using relationship between yield and sequential application of poor quality waters was determined.

With the determined crop-water production functions Linear/dynamic Programming techniques were utilized to find out optimal conjunctive use solution based on available quantity and quality of water. The relationship may successfully be used for different crops under similar agro-climatic conditions. The results show that the yield of Jowar forage was higher and grain yield of rice was also higher with the application of canal water and alternative use of canal and tubewell waters as compared with tubewell waters alone. During Rabi season, the equivalent grain yield of wheat (yield of bersem forage and mustard was computed in term of wheat equivalent) was significantly higher in rice-mustard than the remaining crop sequences and lowest yield was obtained in rice-bersem rotation. Soil data was also collected and analysed to determine the soil deterioration. To suggest a proper canal water scheduling under existing/improved cropping pattern study was conducted in two minors viz. Batta and Rohera in the Kaithal Circle of Bhakra Canal System during 2001 & 2002. The rigid water delivery schedule and inadequate water supply provide very little opportunity to the farmers for effective decision making in respect of canal water allocation. The canal water use was mainly focused on overcoming salinity stress developed due to use of marginal quality of groundwater. Water management decision taken by the farmers were analysed and improvements suggested.

Augmenting groundwater resources through tank recharges and conjunctive use of surface and groundwater in tank in irrigation (Principal Investigator: Institute for Techno-Economic Studies, Chetpet, Chennai)

Objectives:
The main objective of the study was to explore how far the desilting of tank bed will be helpful to augment the groundwater resources, including its practical and economic aspects and to establish a schedule for conjunctive use of surface and groundwater after atleast partially restoring the recharging areas in the tank bed to it optimum capacity for interaction.

Findings:
The studies were conducted on the following Non-systems tanks i.e. tanks which depend only on monsoon rainfall for their storage.

1. Pinchivakkam Tank of Thiruvallore Taluk of Chengai MGR Distt.
2. Pennalur Tank of Uthiramerur Taluk of Chengai MGR Distt.
3. Thylakulam Tank of Srivilliputhur Taluk of Kamarajar Distt.

Appropriate conclusion have been arrived at from the analysis of the studies made which are broadly summarized below:

1. Tanks in Tamil Nadu are mostly fed by North-eastern monsoon during October-December. The storage realization in tanks depends on intensity of rainfall, favourable distribution during monsoon and its location, hence it varies from tank to tank.
2. Farmers generally prefer raising long term paddy crop of 150 days duration coinciding with rainy season. The commands of all the three selected tanks are adequately provided with wells by the farmers to supplement tank irrigation source since it lasts 2 or 3 months and north-eastern monsoon is not also very dependable. They use the available water during November-December and revert to groundwater after exhausting the storage. They raise

second crop and summer crops in parts of command depending on extent of availability of groundwater. Thus a form of conjunctive use of surface and groundwater a already prevalent in Tamil nadu.

3. The available stored water must be utilized to the extent of 50 to 60% to minimize evaporation losses. It is observed that keeping the water unutilized though may help to argument the groundwater recharge, but it results in irretrievable evaporation losses. In such a case the evaporation losses could be kept around 16% of the stored water.
4. Groundwater recharge is realized through four sources in the cases of rainfed tanks (a) from rainfall (b) tank seepage (c) return flows from surface water irrigation (d) seepage from canal or river. Of the three selected tanks, only Pinchivakkam Tank get benefit of recharge from an adjacent river.
5. These tank beds, in the present state are badly silted up as a result the infilteration capacity of the tank bed is very much impeded. It is confirmed through study that desilting of tank bed will definitely bring an improvement in the rate of infilteration and consequently groundwater recharge.

   It is found that desilting of the tank bed will be economically viable and practicable to execute if in small tanks with ayacut from 20 to 60 ha such desilting is done over an area of 15000 sq.mt. in the deeper portions of tank bed.
6. Studies show that about 6% of the present tank irrigated area can be additionally sown utilizing the gain from desilting of tank bed.
7. In order to effectively use the groundwater and surface water to the optimum benefit, a schedule for releases of stored surface water is prepared for adoption by the farmers for each of the three tanks. The water management of tanks is now entirely with the village irrigation committees.

Impact of groundwater regime in the D/53 distributory command Sriramsagar Project, A.P. and scope for conjunctive use. (Principal Investigator and Research Station: Shri T. Desh Bhakt, Director-General, WALAMTARI, Hyderabad).

Objectives

1. To conduct detailed hydrological/hydro-geological and hydro-chemical investigation.
2. To establish monitoring stationôs for rainfall runoff, evaporation, deep percolation, groundwater levels and quality, soil moisture, salt problems and nutrient status.
3. To collect and analyse the parameters at item (2) above periodically and evolve the variation and trends.
4. To conduct diagnostic analysis of the total system.
5. To evaluate the values and constraints of the system.
6. To propose a model for future adoption.
7. To study the scope for conjunctive use/other drainage methods.

Findings

The area is not feasible for bore wells because of absence of fracture zone. It is mostly suitable for open wells upto depths 6 to 9 mts., because of shallow water table and good permeability in weathered zones.

The conjunctive utilization is taking place at a few places in D-53 area. From the resource estimation, it is clear that there is ample scope to implement it in large scale through out head and middle reach areas. It may be possible to cut down the canal supplies in head and middle areas once the groundwater structures in large scale come into existence. Though the D-53 is designed to irrigate (localized ayacut) 24,602 ha or area, the actual figures show that it is about 65%. The

balance ground water resource of this area is sufficient to irrigate 8303 ha. Hence by way of conjunctive utilization it is possible to irrigate an extent of 32,905 ha.

Lining of canals in the command area has brought down waterlogging significantly, preventing seepage of water and rise of water table in the command area.

The conjunctive use of groundwater and canal water may be started from head reach areas and extended to middle reach areas. Where the rate of utilization is more than 85%, such areas are not taken for conjunctive use in the priority.

Tail-end areas are suffering from non-receipt of canal water. Most of the distribution system is unlined; as a result, seepage contribution to groundwater recharge is considerable (36.808 mcm). In head and middle reaches of canal, at few places, shallow water table conditions are prevailing. The utilization of groundwater through the existing 13,100 wells is about 51.5% of utilizable groundwater resource. About 8300 wells are additionally feasible to tap the groundwater to full level of development, through conjunctive use.

Conjunctive use of surface and groundwaters, wherever feasible, is thus necessary for optimal use of available waters.

Evaluation of agriculture drainage with special emphasis on design variables and criteria (Principal Investigator: Prof. D.T. Shete, Water Resources Engineering and Management Institute (WREMI), Samiala)

Objectives:
To evaluate the efficiency of present drainage system in the command area of Anklav sub-minor of MRBC project and study of irrigation practices, crop yields, groundwater table, water quality etc.

Findings:
The research scheme envisaged evaluation of efficiency of present drainage system in the command area of Anklav sub-minor of Mahi Right Bank Canal project. It consists of present drainage system alongwith irrigation practices crop yields groundwater table, water quality, hydraulic conductivity, deep percolation losses, etc. in the said command.

The rainfall is the major source for the rise in groundwater specially in the monsoon season. This is mainly due to restricted drainage and land use practice. The whole area has drainage density of 0.3 km per sq.km. which is far below the performance level of surface drainage, most of the water remains ponded for couple of days. Regarding the land use, as 50% area is assigned to paddy and perennial crops in the small bunded field, following the USBR practice and Gujarat Practice the drainage coefficient for removal of excess water within the tolerance limit of prevailing cropping pattern comes out to be 2.46 lps/ha.

Looking to the results and observations following points are suggested to keep the groundwater level in dynamic equilibrium from year to year.

A suitable conjunctive use plan for surface water and groundwater resource must be planned and executed with in a limited time frame. As problem of rising water tables is mainly in the head reaches the landowners in the head reaches of canal must practice well irrigation. The equitable distribution and judicious use of canal water must be assured by the authorities.

A farmer cooperative should be formed to solve the internal disputes regarding even distribution of water in the command. The training can be imparted to the users groups for on-field water management activities. Co-operative must also look after the collection of the water charges and ensure better management for satisfaction of the goal of controlling the problem of rising or declining water table.

The infiltration from rainfall is a major source of recharge. The excessive infiltration is due to ponding of rainwater for longer time. New surface drains need to be constructed and older ones are to be remodeled to carry excess water at rate of 2.46 lps/ha.

Impact of different drainage techniques for the problematic soils of Malaprabha Command Area (Principal Investigator: Dr V.S. Doddamani, University of Agricultural Sciences, Dharwad)

Objectives:
1. To find out the percentage area reclaimed by different drainage techniques adapted in study
2. To study the effect of different drainage techniques on the physicochemical properties of soils and crop yields.

3. To compare the cost of comprehensive drainage techniques presently followed with that of suggested techniques.

Findings:
Interceptor drain was said to be cheap and effective in arresting seepage of canal and excess irrigation water from elevated area to a low lying area and prevent Waterlogging of the low lying area.

From the study it is concluded that interceptor drain is not suited to reclaim the waterlogged areas caused by seepage from canal and elevated area of low lying area and having the slope in multi directions and hence may not be feasible for small areas or individual holdings of this nature.

Study regarding effectiveness of drainage schemes (Principal Investigator: Capt. Pandurang Nighot, DIRD, Pune)

Objectives:
1. To study the effectiveness of drainage schemes in different soil types by constructing different types of drains.
2. To verify design assumptions and
3. To decide crop wise drainage requirement by comparing corresponding drainage indices.

Findings:
The study was conducted on three-drainage schemes viz. Naigaon Drainage Scheme, Taluka Haveli, Distt. Pune, Sonar Drainage Scheme, Taluka Newasa Distt. Ahmadnagar & Telur Drainage Scheme, Taluka Kandha Distt. Nanded. Studies in all three drainage schemes were carried out on open drains. The conclusions of the study are:

The drainage discharges found in the three drainage schemes are ï 0.943 cusec per 100 hectare of protected area in case of Naigaon drainage scheme (crop sugarcane), 2.26 cusec per 100 hectare for Sonar drainage scheme (crop sugarcane), 0.285 cusec per 100 hectare for Telur drainage scheme (Rabi crops). Wide variation in the results of the three drainage schemes may be due to different topography, quantity of water applied and water application methods. Average rate of discharge of the three drains works out to 116 cusec per 100 hectare of protected area. So it has been concluded that one cusec drain discharge per 100 hectare of protected area can be safely used for design purpose in case of medium soils, as well as deep soils. Regarding effectiveness of drainage schemes, observations show that in medium soils protected area of drainage schemes can be considered upto 300 to 400 meter, while for deep soil, it can be considered upto 250 meter.

Surface drainage requirement of paddy at different stages of Ontogeny (Principal Investigator: Dr. Kamalam Joseph, Centre for Water Resources Development and Management (CWRDM), Kozhikode Kerala)

Objectives:
- To study the effect of depths of land submergence as affected at various growth stages on growth and yield of paddy varieties.
- To find out the maximum submergence period which will not adversely affect the yield of the different duration paddy varieties which are recommended for the command areas.
- To arrive at the sensitivity index of the growth stages to submergence variety wise.
- To help in the scientific design of drainage channels in the command areas.

Findings: The Study was conducted in the command area of Ichannur Sub-distributory of the Kuttiyadi Irrigation Project with major objective of estimating the effect of flooding on the growth and yield of different varieties of paddy. The results revealed that:

- All the varieties tried were very badly affected by the submergence treatments.
- The plants which were affected by submergence and recovered performed in a better manner.
- Submergence at Stage 1 was found to affect the survival rate of all the paddy varieties.
- The yield of Triveni will be considerably reduced by submergence at any stage of crop growth.
- The reduction in grain yield due to submergence was 64% for Triveni, 72% for Jaya, 65% for Mashuri and 71% for Neeraja.
- Straw yield reduction due to submergence treatments was 33% for Triveni, 48% for Jaya, 39% for Mashuri and 50% for Neeraja.
- Even the submergence of 24 hours in the ontogeny was causing reduction in grain and straw yield of paddy.

Retardation of evaporation from soils using fatty alcohols (Principal Investigator: Dr A.K. Sinha, Water Technology Centre, IARI, Pusa Campus, New Delhi)

Objectives:

1. To study the efficiency of the fatty alcohol in the moisture conservation.
2. There was no significant difference between plastic mulch, cetyl alcohol mulch and mulched condition so far grain yield, biomass yield and 1000 grain weight are concerned.
3. Cetyl alcohol had no modifying effect on soils temperature both at 7.5 and 15 cm depth.
4. Surfaced spread cetyl alcohol mixed with soil at 80^0C proved effective chechking evaporation

Findings:

The irrigation water for crop production is getting scarce day by day. Further efforts are being made through straw and plastics mulches to retain moisture in the soils. Wheat crop, sown in rabi and moong crop sown in summer studied under cetyl alcohol and plastics mulch conditions and available soil moisture condition in experimental fields in Water Technology Centre, Delhi and in Laboratory. In the field, lysimetric techniques (weight type) and field technique (plots) were adopted. In the laboratory, under controlled conditions, experiments were conducted to ascertain the appropriate method of application of cetyl alcohol. Soil temperature was also measured to know the effect on soil temperature on application of cetyl alcohol.

It is observed that fatty alcohol has retarding effect on evaporation from soil. Also cetyl alcohol had modifying effect on soil temperature both at 7.5 cm and 15 cm depth. Under controlled lab conditions, the lowest evaporation rate was achieved in the treatment where a dose of 2 gm/column was mixed with top 1 cm layer of soil. It stood between plastic mulch and no mulch conditions. Experiment also reveals thatther is no effect or grain yield, biomass yield and 1000 grain weight of crop are concerned. Surface spread cetyl alcohol mixed with soils at 80^0c proved effective in checking evaporation.

Evaporation Control Using Monomolecular Films (Principal Investigator: Dr P.S. Harikumar, CWRDM, Kozhikode)

Objectives:

1. To evaluate efficiency of different monomolecular films for evaporation retardation
2. To develop/modify monomolecular films for effective evaporation retardation
3. To investigate the toxicological effect of evaporation retardant on aquatic organisms like fish.
4. To extend the investigations on large water bodies like Pookot Lake.

Findings:

Different materials like cetyl, alcohol, stearyl alcohol, ceto stearyl alcohol, thermocol, poly styrene anchored cetyl alcohol, nylon 6,6 *salvania molesta*, saw dust were tried as water evaporetardants. The toxicity and water quality tests were conducted before and after the application of the materials. The following conclusions were made from the experiments:

- The percentage evaporation reduction of various materials used after three days of the laboratory experiments (meteorological yard) are: cetyl alcohol (69.9), stearyl alcohol (69.9), ceto stearyl alcohol (58.8), poly styrene anchored cetyl alcohol (73.92), nylon 6,6(100), thermocol (76.5) and salvania molesta (42.8).

- The water quality experiments indicated that, the mono-layer formed by cetyl alcohol, stearyl alcohol and ceto stearyl alcohol were permeable to oxygen and there was no appreciable water quality changes after the application of the mono player. The materials were also found to be not toxic to fish.
- Even though the material nylon 6,6 gave good evaporation control results; the concentration of dissolved oxygen was reduced to 52%, which affected the life of fish also.
- The physical process using thermocol, saw dust etc. can control evaporation loss to a certain extent, but cannot be applied to water bodies where aquatic life is also important, since there material do not allow the passage of oxygen and carbon dioxide freely.

Development of mono-molecular film act as evaporation retardation and prevent water from evaporating from large water bodies economically (Principal Investigator: Prof. G.S. Parthasarathy, Water Resources Engineering and management Institute (WREMI), Samiala)

Objectives:

To evolve a cost effective strategy to prevent evaporation from large/small water bodies by the development of mono-molecular film economically.

Findings:

The rate of evaporation of control was compared with the firm forming material. Some of the compounds exhibited encouraging results. As described in the earlier section dipalmilate of polyethylene glycol and triethylene glycol were synthesized and evaluated for their capacity to retard the rate of evaporation of water. The mono and diesters of fatty acids seems to be highly promising compounds over existing compounds. They are non toxic and contain many ether linkages so permeation of oxygen is facilitated. The strength of firm formed over water will have greater strength as many ether linkage (hydrophic) is present in the molecules. Moreover a perfluoro derivative also was tried. Fluoro surfactants are highly promising class of compounds but they are at present expensive. In future identified compounds can be quantified on a pilot plant level and based on these results they can be evaluated on large scale. Polyethylene glycol and fat acids are easily available raw materials at a very reasonable cost.

Irrigation system management towards crop diversification in two different ecological regions of Tamil Nadu (Principal Investigator: Dr N.V. Pundarikanthan, Centre for Water Resources, Annamalai University, Chennai)

Objectives:

1. What are the factors that factor diversification in these systems?
2. What are the reasons for not diversifying the crops in certain parts of the system?
3. How does the changing cropping scenario (diversification) affect the irrigation system?
4. How to manage the irrigation under rice and non-rice crops?
5. What kind of support services are provided by the government relevant to crops diversification?
6. How do the farmers respond and react under diversifying situation?

Findings:

1. Reliable yield, conventional crops, unreliable water supply, social obligations, official apathy, inability to cope-up with the infrastructure were the motivating factors for crop diversification.

2. Ready marketing facilities, dependable groundwater yield soaring infrastructure costs drove them for diversification of crops.

3. Soaring cost of labour, maintenance free growth, ready market, advance availability of funds and undependable water supply were the motivating factors for crop diversifying.

Evaluation of field irrigation application efficiency in canal command areas using radioactive tracer techniques (Principal Investigator: Dr D.C. Sharma, Uttar Pradesh Irrigation Research Institute, Roorkee)

Objectives:

1. Determination of infiltration rate, percolation losses, field capacity and wilting point and thereafter field application efficiency under different crops by observing the downward movement of soil moisture using radioactive tracer technique.
2. Determination of available water capacity (AWC) for field application desired quantity of water at right time to root zone of plants for proper irrigation scheduling.
3. Collection of data regarding agricultural productivity, water use in relation to the crop requirement and the loss that occur in the system and equity of supplies to evaluate efficiency of measures to be taken to improve water management.
4. Assessment of participation of farmers to improve better water management techniques.

Findings:

1. The rate of infiltration as determined in both the canal command areas is as below-
   - (a) Eastern Yamuna Canal System — 0.032 cm/hour
   - (b) Jaunpur Branch Canal System — 0.030 cm/hour
2. The percolation losses as determined in both the command areas under paddy, sugarcane, wheat and maize crops varies as below-
   - (a) Eastern Yamuna Canal System — 115.92 to 540.44 mm/crop period
   - (b) Jaunpur Branch Canal System — 94.43 to 236.72 mm/crop period
3. The field irrigation application efficiency (Ea) as determined on the basis of field experiments and soil plant relationship worked out in Eastern Yamuna Canal and Jaunpur Branch Canal Command Areas.

4. The field irrigation application efficiency thus worked out indicates that approximately 45% to 63% in case of Paddy crop, 24% to 50% in case of sugarcane, 26% to 44% in case of wheat crop was wasted during application of irrigation management by IRI staff and cultivators while in case of maize crop approximately 84% to 92% irrigation water was drained out being the land already saturated due to rainy season.
5. The study carried out in both the command areas indicates that there is considerable scope for future improvement in water use management on farm development in field managed by cultivators.
6. The study also indicates that the water distribution of an irrigation system is very important aspect as it has to respond to not only physical system condition but even the farmerôs expectations and crop needs which vary in accordance with agro-climatic conditions

Automation of on-farm irrigation water management systems using baffle sluice irrigation modules (Principal Investigator: Dr T.V. Satyanarayana, Principal Scientist, College of Agricultural Engineering, Bapatla)

Objectives:
1. To develop few standard models of baffle sluice models with different design variables to give constant discharge in the range of 20 to 30 litres/sec. Design variables: spacing of baffles; size of opening below the baffles; number of baffles in sequence; method of construction, etc.
2. To test them in the field channels for their ability to give constant discharge irrespective of water level fluctuations (with in 10 cm to 15 cm)
3. To recommended suitable design of baffle sluice irrigation modules for different discharges based on the results of the study for use in field channels in the command areas.

Findings:
The design of three baffles sluice irrigation models have been developed to work in the discharge range of 2 to 25 lit/sec. within the modular range of 15 to 25 cm. Two and four baffle sluice modules are not recommended for use in the field channels. Baffle sluice modules made of Plexi glass have been found to be more effective than the modules made from Teak wood or G.I. sheet. For a large number of small farm holdings, it is advisable to employ low discharge portable irrigation modules to reduce the cost of construction. The models are found to deliver discharges within +5% deviation. This accuracy is normally accepted in measurement and regulation of irrigation water. The turnouts (outlets of field channels) in command areas can be automated by providing irrigation modules to take care of the possible fluctuations in the water levels in the irrigation channels.

These modules have been effectively tested and used in the NSP Right Canal command areas of Andhra Pradesh. The models of baffle sluice irrigation modules developed during the project would be used for demonstration to the students and farmers. These models could also be given to WUAs of certain commands for popularization of models.

Evaluation of on-farm water management works at Cauvery Delta, Thanjavur, Distt. (Principal Investigator: Dr P.K. Selvaraj, Water Technology Centre, Tamil nadu Agricultural University, Coimbatore)

Objectives:
1. To study the on-farm development works that have been installed and their utilization by the farmers.
2. To study the effect of on-farm development works on water distribution and utilization.

3. To study the effect of on-farm development works on the cultivation pattern and yield.

Findings:
Two sites viz. Udhagmandalam and Avalivanallur Village is Vennar system were selected for study where on-farm water management works (OFD areas) had done. For comparison two other adjoining sites were also selected where the on-farm water management works were not done (non-OFD areas). The data on the dates of sowing of nursery, planting weeding, field water levels. In selected fields, inflow into the site, out flow from the site, harvest and yield details etc. were collected in both OFD and non-OFD areas. Socio economic aspects of both OFD and non- OFD areas were also studied. The important information generated from the study are summarised below:

1. The sizes of fields range widely from 5 cents to more than 120 cents. Hence there is a need for optimization of field sizes to 50-70 cents for efficient application of water and to make the cultivation operation easy.
2. More time is taken in field to held irrigation in non-OFD area compared to individual field irrigation in OFD area with the same quantity of flow for the same area.
3. There is reduction in loss of water due to individual field irrigation.
4. Water production function is higher in OFD areas compared to non-OFD areas and there is a general tendency for higher productivity.
5. In non-OFD areas due to field to field irrigation there is nutrients loss and there is considerable loss of NH nitrogen and NO nitrogen. But in OFD areas since individual field irrigation was there. There is no possibility of loss of nutrients through the irrigation water.
6. In OFD areas since the bed dam with sliding shutters were provided under OFD works there was no necessity for formation earthen bunds for irrigation across the channel. But in non-OFD areas, the earthen bunds are to be formed for heading up water which is labour consuming and also causes channel widening near the bunds and silt deposition beyond the bunds in the irrigation channel which in turn reduces the capacity of irrigation channels.
7. In OFD areas, during heavy rainfall, since individual irrigation and drainage channels are provided under OFD works for each and every field the drainage was easy and quick compared to non-OFD areas where there are no individual irrigation and drainage channels. The erosion and silt deposition in channels was also very meager in OFD areas compared to non-OFD areas during drainage.
8. In both OFD and non-OFD areas in the curves of the main irrigation channels, there was a problem of erosion, channel widening channel was not lined throughout itôs length.
9. Investigator has recommended that the utility and benefits of the OFD works should be taught to the farmers.

Application and evaluation of some interventions on irrigation system of deep tube well command area of new alluvial agro climatic zone of West Bengal (Principal Investigator: Prof. R.K. Biswas, Deptt of Soil and Water Engg., Faculty of Agril. Engg., Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur)

Objectives:
To evaluate the individual and overall impacts of interventions viz. tile lining, water application methods and soil amendments on irrigation efficiencies in the commands of shallow and deep tubewells in Nadia Distt. of West Bengal

Findings:
After three years of observations, the major findings are:

a. Burnt Clay tiles as lining material

Performance of clay tiles in controlling seepage loss, is encouraging. The excess seepage loss, Manningôs óNô and Conveyance losses for 100m of this kind of lining may be considered as 5.42cm^3/day, 0-2232 and 0.29% respectively after stabilization of the channel. The cost of channel (30 & 33 cm dia) is Rs.70 per metre (including cost of earth work, transportation etc.)

b. Water application methods

Cross bunds provided for better distribution of water for border irrigation resulted in increase of irrigation efficiencies. The application and distribution efficiencies on an average for borders provided with cross bunds were found to be as 88 & 91%, 91 & 92% and 93 & 94% during the years 1997-98, 98-99, 1999-2000 respectively.

c. Soil amendments

With treatment of mud, water hyacinth, cowdung, etc. bulk densities of soils decreased, the maximum water holding capacity of soils, increased, percentage of clay particles increased and infiltration characteristics changed.

Thus technology developed under the study has ample scope for adoption by farmers and Government and Non-Governmental Organisations working in irrigation management in the country.

Evaluating equity in water distribution from Kuhl (gravity stream) through small polylined water harvesting auxiliary tanks for diversification in agriculture in hills of North-West India (Principal Investigator:- Dr. S.S.Masand, Soil Scientist, Deptt. of Soil Science, HPKV, Palampur, (HP))

Objectives:

The main objective of this research project costing Rs.8.61 lakhs was to find out the deficiencies in the command of Kuhl and to improve productivity by supplementing water stored in auxiliary polylined tanks.

Findings:

For the study, Kirpal Chand Kuhl (small gravity stream) located in Palampur Tehsil of Kangra district situated at an altitude of 1214m above mean sea level was selected. Farmers in command experienced the scarcity of irrigation water during the period April-May and October-December, resulting in inadequate yields and crop failures also. Through this research project, flow in Kuhl during lean period (when requirement of crops is minimal) was stored in 11 auxiliary tanks constructed alongside the Kuhl and recycled. These storage tanks were also supplemented through harvesting of rainwater. By resorting to pisciculture and diversification of agriculture, farmers income also got enhanced.

Efficient Water Management through drip and sprinkler Irrigation methods (Principal Investigator: Dr. C.GopalaRao, NG Ranga Agricultural University, Rajendra Nagar, Hyderabad)

Objectives

1. Studies on water requirement of vegetable crops at different ET rates by using drip system of irrigation with and without application of crop mulch.
2. Studies on crop geometry with varied lateral spacing to optimise the cost of drip system.
3. Studies on response of capsicum with application of mulch to drip system of irrigation under different operation pressures.
4. Studies on the effect of wind velocity on sprinkler method of irrigation for groundnut crop.
5. Studies on effect of different methods of irrigation on active root distribution and yield of the groundnut crop.

Findings

i) For Bhindi, the drip irrigation at ET= 0.6 coupled with plastic mulch has shown the highest yield of 9.56 t/ha which was higher by 52/5 % over furrow method of irrigation. The water use efficiency (WUE), was also highest at the same level of water application.

ii) The crop yield and WUE were also found to be highest in drip irrigation coupled with plastic mulch application in case of tomatoes and chillies.

iii) For tomatoes, the crop geometry at lateral spacing of 1.5 meters with plant spacing of 20x72 cm recorded the highest yield of 46.5 t/ha and maximum water use efficiency.

iv) For chillies, the highest yield was obtained in drip lateral spacing of 1.5 meters with plant spacing of 20x72 cm

v) For capsicum (California Wonder), the drip system of operating pressure of 1.0 kg/cm^2 with plastic mulch gave the highest yield and water use efficiency.

vi) For groundnut, it was found that sprinkler system operated at pressure range of 1 to 1.5 kg./cm at wind velocities ranging from 5-7 .5 km/hr resulted in higher yields

vii) The highest active root distribution (ARD) of 43.7 % was obtained at 10 cm depth and 5 cm lateral spacing for groundnut in surface method of irrigation. With sprinkler irrigation ARD was high at 20 cm depth and at 10 cm lateral spacing. However, the crop yield was found to be highest with drip method of irrigation.

Comparative evaluation and economic appraisal of different modes of application of drip system (Principal Investigator: Er. I. Muthuchamy, Water Technology Centre, Tamil nadu Agricultural University, Coimbatore)

Objectives:

1. To design and evaluate different scheme of application through drip system for orchard.
2. To evaluate these schemes of application in actual field condition for their hydraulic behaviour and crop response.
3. To conduct an economic evaluation of comparing the cost and benefits of different schemes of application.
4. To device an appropriate relationship for predicting the most efficient and economic application scheme for a given situation.

Findings:

1. The water requirement drip and conventional method for coconut is in the ratio 1:3.

2. Water saving of nearly 50-60% can be achieved in drip irrigation when compared to conventional system.
3. Labour can be saved in drip irrigation in the range of 40-50% when compared to conventional irrigation.
4. Nearly 250-300% extra area can be brought under cultivation with the same available irrigation water if we switch over from conventional irrigation to drip irrigation.
5. The following modes can be followed in drip irrigation system
   (a) Micro Tube; (b) Tap type; (c) Pressure compensating drippers (Pc); (d) Built in drippers.
6. For getting low discharge for larger duration, four points can be selected for fixing drippers around the root zone area of the coconut.
7. In the overhead system Grapes discharge of 48 lit/day/vine registered the maximum yield, the ambient temperature inside yard is less by 2 to 3 c and relative humidity is more by 2 to 3%.
8. For clogging prone area micro tube (6mm OD) and Tap 0-50 1/h can be used to avoid clogging.
9. To get 95% uniformity and uniform wetting soil volume, high pressure compensating and low pressure compensating drippers can be used.

Optimisation of drip irrigation system layout and design for row crops and orchards (Principal Investigator: Prof. D.T. Shete, Water Resources Engineering and Management Institute (WREMI), Samiala)

Objectives:
To determine the optimum layout and design of a drip irrigation system for row crops and orchards. If the drip irrigation system would be economically viable to the farmers and if the cost of laying and operating the system would be made minimal per unit area for a given crop, the system would be popular within no time and about double the area can be irrigated with the same amount of available water. The cost of the system per unit area for a given crop demands upon number of emitters, diameter and length of lateral, manifold, sub-main and main to be laid per unit area and the pumping head required to operate the system. The capital and the operating costs per unit area of the system varies with different layout designs which can be used for a given crop. Therefore, it is necessary to determine the optimum layout and design of a drip irrigation system for row crops and orchards. The optimum layout and design is the one having the least total cost consisting of capital coast and the operating cost, and giving the maximum water application efficiency, field water use efficiency and crop water use efficiency. The optimum layout and the design of the system can also be defined as the one which gives the maximum net return over the total expenditure of the highest benefit cost ratio.

Findings:
This study has been developed to improve upon the present design with help of computer programming on sloping and non sloping ground. This methodology can be used to analyse other important aspects like lateral diameter and emitter spacing. The results of the study on different crops are given below:
1. Drip irrigation system for lemon on rectangular fields ï Market price is the most sensitive factor in determining the net benefit.
2. Cotton crop ï Crop spacing of 60cm, row spacing of 90cm and operation time of 10 minutes give the highest total yield of 2276.91 kg/ha.. This combination gives the highest net return of Rs.42,750 per ha. Drip irrigation system is economically viable for cotton crop in Kutch region, Gujarat.
3. Design for laterals for row crops and orchards ï It is often difficult to judge the dimension of set for drip irrigation layout for row crops and orchards as it involves lot of trial and error before a solution is found out. Eventhough its optimality is not sure.

Design development and testing of sub-surface drip irrigation system (Principal Investigator: Prof. S.B. Wodatkar, Punjabrao Deshmukh Krishi Vidyapeeth, Akola)

Objectives:

1. Designing of emitter for operation at sub-surface considering operative pressure size of orifice.
2. Preparing die (mould) for manufacturing the emitter, fabricating and testing of emitter.
3. Collecting and analyzing basic data regarding, cost, growth of crops at different stages and fixing the centroid position.
4. Experimentation of small plot/laboratory level to study the pattern of soil moisture distribution in different crops by using different existing emitter.
5. Testing field trials for judging efficacy of newly designed system and modification if required its performance and economics
6. Giving fool-proof system and other researchers and farmers for its extensive trials.

Findings:

The treatment of crow bar technique with sub-surface drip at 10-% ET was superior in primary root length, number of secondary roots, average width of primary root, average length of primary root spread, primary root diameter, etc. This treatment is superior in bio-metric observation i.e. length of wine area of foliage over all the treatments.

Development of mulch cum Drip Sub-Surface Pad Irrigation system for vegetables - (PI: Dr. U. Jaikumaran, Kerala Agricultural University, Trichur, Kerala)

Objectives

1. Development of ósub-soil pad irrigationô system for vegetables
2. Developing and testing a mulch-cum-drip irrigation system for vegetables
3. Evaluation of crop performance under different ómulch-cum-dripperô, system with special emphasis on óWater balanceô in plants and photosynthetic efficiency under varying moisture regimes.
4. Optimization of moisture regime and final selection of ómulch-cum-dripper.ô

Findings

Sub-surface pad irrigation system (SSPIS) is efficient than surface irrigation system at any levels of irrigation in deep rooted vegetables. This system is adaptable in areas where irrigation water is limited. This method saved 535 and 357 mm water respectively at 30 and 20 mm irrigation levels when compared to surface irrigation in snake gourd with yield advantage over 2 tonnes ha^{-1}. Under surface method of irrigation at 40, 30 and 20 irrigation levels 9952, 722 and 492 mm of water was used by the snake gourd crop. But under surface pad irrigation system, the crop needed only 237, 187 and 135 mm of water at respective levels of irrigation, hence requiring only 25% of water compared to surface irrigation. The water saved in case of cucumber was 658, 681 and 721 mm at 40, 30 and 20 mm irrigation levels respectively when compared to 40 mm surface irrigation with yield advantage at all levels of irrigation. Hence requirement was only 21% in case of cucumber. In nutshell it is recommended that

- Sub-surface pad irrigation offers as an efficient and viable system of irrigation for vegetables under limited water supply.
- When SSPIS is designed, the criteria of 2 pads per plant (pit) and water application rate of 2 lph can be adopted.
- Sawdust can be preferably chosen as organic hydrophilic material for filling the pad. Coir pith as well as potting mixture can also be chosen.

- 400 g LDPE poly bags having the dimensions of 45 cm length and 30 cm width can be used as bags for the pads.
- Pads may be buried at 15 to 30 cm depth.
- The depth of irrigation in case of SSPIS may be limited to 30 mm and surface area for computing irrigation water may be limited to the basin area of the plant. The frequency of irrigation may be daily.
- Soil moisture retention at root zone under SSPIS is for a prolonged period and soil moisture distribution is gradual. Hence the SSPIS offers its potential for adoption where water is scarce.
- It is ideal for corps, which are deep rooted, and sensitive to soil moisture stress and advisable for vegetables like snake gourd, bitter gourd, etc. where irrigation is frequent.

Developing drip irrigation system for field scale implementation for orchard and field crops (Principal Investigator: Dr H.S. Uppal, Professor of Agronomy, Punjab Agricultural University, Ludhiana)

Objectives:
To develop suitable agro-techniques to drip irrigation field adopted and minimize the cost and increase its operational efficiency.

Findings:
Crop: Brassica napus L.
Lesser amount of irrigation water applied subsequently resulted in lesser amount of water use by the crop which reduced the seed yield of *Brassica napus* significantly as compared to higher amount of water use by the crop. Water use efficiency was also reduced where the water use was less. The limiting effect of soil moisture stress was observed from the crop mid season onward with the rise in atmospheric temperature on all the growth characteristics viz. plant height, LAI and yield contributing characters viz. number of branches, number siliquae per plant, number of seeds per siliquae and 1000-seed weight.

As a main effect of nitrogen application seed yield of *Brassica napus* was increased significantly with 150 kg N/ha over o, 50 and 100 kg N/ha. A dose of 200 kg N/ha could not increase the yield further. Almost all the growth and yield contributing characteristics also increased with N application up to 150 kg/ha.

Crop: Brassica carinata A. Br.
The results of one year investigation indicated that lesser amount of irrigation water applied, reduced the seed yield of *Brassica carinata* significantly as compared with the treatment of higher amount of irrigation water applied. Similar was the trend for growth characters of plant height, periodic dry matter production, LAI, number of siliquae per plant and number of siliquae bearing branches. Volume-weight relationship of seed was not affected by the treatments of irrigation.

With little advantage in seed yield of *Brassica carinata* can be sown preferably in the month of October, however, the crop can be sown as late as on December 1.

Crop: Wheat
Reduced total amount of irrigation water applied and consequently reduced amount of water use reduced the grain and straw yield, plant height, ear bearing number of tillers. LAI, dry matter accumulation, ear head length, number of grains per ear, grain weight per ear and 1000-grain

weight in both the species of wheat i.e. *Triticum durum* and *Triticum aestivum*. As a main effect 60 kg P_2O_5/ha was found to be optimum for *T. durum* spp. of wheat.

Studies on *Brassica napus, Brassica carinata, Triticum durum* and *Triticum aestivum* spp. of wheat suggest lesser amount of irrigation application may be applied through any irrigation method viz. surface irrigation or drip irrigation, prove deleterious to growth and yield of these crops.

To study the performance of bamboo main and lateral for gravity drip irrigation in hybrid tomato and banana cultivation (Principal Investigator: Dr R. K. Biswas, Deptt of Soil and Water Engg., Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur)

Objectives:
1. To assess the cost, durability and effective use of bamboo drip network
2. To examine the practicability of gravity drip.
3. Optimise the irrigation requirement of crops hybrid tomato and banana in drip irrigation method.
4. To optimize the areas of cultivation for unit man-power.

Findings:
(a) The uniformity co-efficient of distribution of water in drip network was found 0.9302 and the water losses 9.925% at its best performances.
(b) The cost of drip network is Rs.3.33/m^3 or Rs.33,300/- ha. It is Rs.43,300/- ha when the cost of water harvesting system is included.
(c) There was a saving of 57.4% of water and average increase in yield by 9.92% in drip irrigation in comparison in conventional method of irrigation. No significant variations in yields were found in different varieties of plants.
(d) The durability of the drip system developed by bamboo pieces may be 3-4 years.

Effect of irrigation schedules and nitrogen levels on the yield of turmeric through drip and surface methods of irrigation (Principal Investigator: Dr P.K. Selvaraj, Agricultural Research Station, TNAU, Bhavanisagar)

Objectives:
1. To study the effect of irrigation scheduling through drip on the yield of turmeric.
2. To study the yield response of turmeric to different levels of Nitrogen applied and
3. To work out the economics of different treatments

Findings:
Based on three experiments conducted during 1995-96, 1996-97 and 1997-98 for four irrigation levels i.e. one surface and three drip at 80%, 60% and 40% of surface irrigation and three nitrogen levels viz. 100%, 75% and 60% of the recommended (125 kg/ha).

The net returns in all the drip irrigation treatments were higher as compared to surface irrigation. The B.C. ratios were comparable in all the treatments, since an extra amount of Rs.15,400/- per ha was included in the cost of cultivation for drip irrigation.

Drip irrigation daily at 40% of surface irrigation with 75% of recommended level of nitrogen was found to be most economical treatment, resulting in yield increase of over 25% as compared to surface irrigation method.

Effect of irrigation schedules and nitrogen levels on the yield of quality of sugarcane through drip and surface methods of irrigation (Principal Investigator: Dr P.K. Selvaraj, Agricultural Research Station, TNAU, Bhavanisagar)

Objectives:

2. To study the effect of irrigation scheduling through drip on the yield of sugarcane.
3. To study the yield response of sugarcane to different levels of nitrogen applied through drip
4. To study the effect of irrigation and nitrogen levels on the quality of sugarcane

4. To work out the economics

Findings:

The experiment was formulated for two experiments of one plant and one ratoon crop each (totally three plant crops and two ratoon crops). The 1st plant crop was raised during September, 95 after laying out drip system and subsequently ratoon crop was completed in September, 97. The second plant crop was raised during October, 1997 and harvested during September, 98 and the next ratoon crop harvested in October, 99. Four irrigation levels viz. one surface and three drip at 80%, 60% and 40% of surface irrigation and three nitrogen levels viz. 275, 225 and 175 kg/ha were given.

In moderately water scarce areas, drip irrigation at 80% or 60% of surface irrigation with 225 kg. of nitrogen per ha recommended.

In water scarce areas, drip irrigation daily @50% of surface irrigation with 225 kg of nitrogen per ha would yield 5 to 20T/ha extra sugarcane over conventional surface method.

There was no significant variation in the quality aspects such as brix pol and purity among different levels of irrigation and nitrogen.

Comparative study of sprinkler and drip irrigation methods with conventional surface methods (Principal Investigator: Tamil Nadu Agricultural University, Bhavanisagar)

Objectives:

1. To study the sprinkler, drip and surface irrigation with respect to climatic soil and crops.
2. To study design, parameters in respect of sprinkler and drip systems. (This could not be carried out for want of Lab facilities)
3. Study of different systems on water saving crop productivity quality and other aspects including pest.
4. Study the economic feasibility of the improved irrigation system.
5. Comparative study of water use efficiency of different methods.

Findings:

Sprinkler irrigation of 2.5 cm. depth of water at 0.5 IW/CPE ration recorded the higher germination percentage and greater water use efficiency. Comparing the sprinkler irrigation with conventional surface irrigation 55% of water was saved in sprinkler receiving 2.5 cm depth at 0.5 IW/CPE ratio. The net profit in surface irrigation per ha for unit quantity of water was Rs.4488/- whereas it was Rs.8305/- for sprinkler irrigation. In case of drip irrigation the main advantage is water saving which is 35% in case of banana crop and 75% in case of one main crop + ratoon crop.

Solar Power Trickle Irrigation System for Sandy Tracts of Coastal Andhra Pradesh (Principal Investigator: Dr K. Yellareddy, Senior Scientist, Andhra Pradesh Water Management Project, College of Home Science Campus, Bapatla-522101)

Objectives:

1. Installation of solar pumping unit in a shallow well and study of its performance.
2. Installation if trickle irrigation system and study of hydraulic performance of micro sprinklers and inline drip/biwall tube (Design variables; spacing pressure, discharge, size of micro sprinklers)
3. To test the unit performance on nursery and vegetable crops in farmers field.

Findings:

1. The SPV pump discharge was in the range of 1.31 to 1.82 lps during the experimentation. Average pumping volume of water per day was about 52.4 m^3.
2. The water table depths remained shallow in the range of 0.55 to 2.16 m and use of shallow well SPV pumpset is justifiable for pumping water in coastal areas around Bapatla.
3. The experimental field has a basic infiltration rate of 12.9 cm/h. Infiltration constant have been derived to estimate accumulated infiltration as $y=1.-1.54t^{0.757} + 0.086$. The infiltration rate values indicate that the soil was highly sandy in nature.
4. The sieve analysis gave uniformity coefficient 3 and coefficient of the curvature as 0.67. Since the effective diameter (D_{10}) was 0.7 mm and as it lies between 0.1 mm and 1 mm, the soil is classified as fine sand according to ASTM standards.
5. The uniformity coefficients of online emitters were found to be greater than 99% at an operating pressure of 0.681 kg/cm^2. This indicates that even under low operating pressures the online emitters give higher emission uniformity.
6. The moisture front advance in horizontal direction increased to 40 cm with in 2 hours of water application under point source with an average discharge rate of 2.82 lph. In vertical direction the depth of penetration increased from 0 to 45 cm during 120 minutes period of water application through emitting device.
7. In evaluation of hydraulic performance of micro sprinklers, the discharge and diameter of spread were found to be lower than the rated values because the operating pressures were recorded in the range of 0.51 to 0.61 kg/cm^2.
8. At operating pressure of 0.515 kg/cm^2 the droplet sizes of micro sprinkler was in the range of 0.56 to 0.70 mm. This indicates that the droplet sizes are comparatively finer and hence micro sprinklers can be used for raising nursery and vegetable crops, as the impact will not cause damage to tender leaves.
9. At operating pressure of 0.415 kg/cm^2 the droplet sizes of micro sprinkler was in the range of 0.56 to 0.70 mm. This indicates that the droplet sizes are comparatively finer and hence micro sprinklers can be used for raising nursery and vegetable crops, as the impact will not cause damage to tender leaves.
10. The SPV pumping system is capable of irrigating a tomato crop in an area of 4800 sq.m. with the requirement of 12 mm lateral of 3200 m length, 36 mm sub-main and main of 120 m and 42 m lengths respectively and 4 flow control valves are required.
11. Banana crop in area of 7200 sq.m. can be grown under the existing SPV pumping system with the requirement of 12 mm lateral of 3600 m length, 40 mm sub main and main pipes of 160 m and 47 m lengths respectively and 4 flow control valves are required.
12. The economic analysis indicated that the daily cost of owning 900 watt SPV pumping system comes to Rs.17.70 only.

Performance Studies of Sprinkler and Drip Irrigation and Surface Irrigation Methods (Principal Investigator: Dr N.K. Narda, Punjab Agricultural University, Ludhiana, Punjab)

Objectives:

1. To study the influence of design variables on water distribution pattern and other performance parameters under different operating conditions for sprinkler and drip irrigation systems.
2. To quantify the various water losses occurring during sprinkler and drip irrigation and correlate them with prevailing weather conditions.
3. To study the effect of quality of irrigation water on salt distribution in soil profile and crop yields using drip irrigation system.
4. To evaluate and compare the water use efficiency, water economy and yield using sprinkler, drip and surface irrigation systems.

Findings:

- The studies have revealed that the increase in emitter discharge for a particular salt concentration resulted in spread out salt concentration profiles vertically below the emitter indicating rapid movement as compared to the horizontal movement. The values of the iso-EC lines showed that the salt concentration near the emitter was less and the values of the salt concentration increased with depth. When the experiments were repeated using higher salt concentration, it only increased the salt concentration near the emitter. The increasing trend of salt concentration with respect to depth was again noticeable. It was found that when it emitter discharge was increased the salt concentration near the emitter decreased and so did all the values of salt concentration with respect to depth.
- A comparison of the iso-EC lines for various combinations of salinity levels and emitter discharges indicated that similar results were obtainable for higher salt concentration using higher emitter discharge, as could be obtained for low salt concentration with low discharge.
- The various techniques employed for the estimation of evaporation losses yielded different amounts of evaporation losses for the same operating conditions. The losses ranged from 5-34%; 6-29% and 4-24% for catch-can, polythene sheet and the electrical conductivity methods respectively. The catch-can method was found to be the best of all the techniques since it accounts for spray evaporation as well as drift losses that occur under field conditions.
- Evaporation losses increased with the increase in wind, speed, solar radiation, wetted radius, riser heights and operating pressure and vice versa. The losses were found to decrease with increase in nozzle size, sprinkler discharge. Regression equations of evaporation losses on individual as well as different combinations of meteorological parameters and sprinkler system parameters were computed.
- To minimize operation losses, the sprinkler should be operation at low values of wind speed, air temperature, solar radiation, which implies that the sprinkler should be operated either in the late evenings or early mornings.
- Rectangular pattern of sprinklers, was found to be comparatively better than square and triangular pattern for reduced evaporation losses.
- The drip irrigated tomato plants had higher specific water uptake during the early stages of growth, as compared to furrow irrigated for the 0-15 cm and 15-30 cm soil depths. Later these values tapered off towards the end of the season, to become identical with furrow irrigated ones.
- Rooting density and root dry weight for furrow irrigated irrespective of the water extraction level was greater, as compared to drip irrigation plots for all depths.

- Ascorbic acid, TSS and pH of drip irrigated tomatoes were higher than the furrow irrigated. Ascorbic acid and TSS for the 50% water extraction level was high and for 60% the minimum within the furrow irrigated. The pH value for 55% water extraction level was minimum and maximum for 50% level.
- Ascorbic acid and TSS should be higher for nutritive and processing point of view. This drip irrigation helps to achieve this objective. But high value of pH obtained with drip irrigation is not desirable, which is a negative aspect.
- Quality comparison studies on furrow irrigated tomatoes under three different moisture extraction levels revealed that irrigation scheduling to tomatoes be done at 50% moisture abstraction level for better quality fruit.
- Trickle irrigation resulted in enhanced crop yields (22.26-56.09%) over furrow irrigation schemes. Near potential yield for Punjab Kesri variety of tomatoes can be achieved by placing laterals along the crop row and applying water equivalent to 1.00 (PET).
- Water use efficiency for water application 0.80 (PET), when laterals were placed along the crop row and at distance of 20 cm from the crop row, was highest amongst all the treatments.
- Greater number of fruits per plant (47) and yield per plant (1314g) were recorded for treatment having laterals placed along the crop row and water applied equivalent to 1.00 (PET).
- The shape of wetting zone for all the water application from trickle emitters for tomato crop, has deeper vertical component (wetted depth) and narrower radial component (wetted radius).
- The hemispherical model developed for prediction of wetted radius in the presence of infiltration and water extraction can be used for characterizing emitter spacing under different soil, crop and climatic conditions.

Revision and Updating of Manual on Canal Lining (Principal Investigator: UPIRI, Roorkee)

Objectives:
To revise and update the existing manual on canal lining after collecting data the details of work done on the subject by various states/research stations, so that a comprehensive manual could be available for the use of construction engineers and water management experts.

Findings:
1. Subgrade and water table conditions, climatic conditions, availability of materials size of the canal, service requirements, economy and experience are the factors affecting selection of the type of lining. Adoption of a particular type of lining will require consideration of all these factors and hence it is not possible to recommend any one type of lining suitable for all conditions.
2. In major canals hard surface lining has been provided. Depending on ease of construction, availability of equipment and material, it has consisted of concrete in-situ, c.c. or brick tiles.
3. In small canals LDPE film protected with hard surface lining has widely been used. Use of LDPE film below any hard surface lining has been found effective for canals in silty sandy soils with high ground water table condition. It has proved as one of the low cost method of lining, particularly plastic film overlaid with hard cover for lining old channels.
4. Pressure release valves and under drainage system are very necessary for canals with high groundwater table conditions or in the areas where rise in groundwater table or Waterlogging is expected due to canal operation. The performance of drainage arrangements must be monitored from time to time.
5. Cohesive-Non Swelling (CNS) treatment should be adopted for lining of canals in expansive soils. However, ferrocement lining is also one of the effective methods worth to be tried in such type of soil.

Publishing of Status Report on various subjects concerning irrigation and drainage viz. Drip Irrigation; National Guide on Operation, Maintenance and Management of Irrigation and Drainage Systems and Preparation of Report on Sprinkler Irrigation in India (INCID Sectt.)

Objectives:
National Guide on Operation, Maintenance and Management of Irrigation and Drainage System: ICID and World Bank jointly prepared a ñGuide for the Preparation of Strategies and Manuals on Planning the Management, Operation and Maintenance of Irrigation and Drainage Systemsò (The World Bank, Technical Paper No.99). INCID Sectt circulated the Guide in November, 1991 to various organization for their comments about its suitability for adoption in Indian conditions to be discussed in a National Level Workshop in February, 1992. While adopting the document as a global guide, the workshop recommended that INCID should prepare a National Guide based on the Indian experiences.

The National Guide comprising 13 Chapters aims at giving exhaustive guidelines for adoption taking into account the present practices in India. Many chapters included in the World Bank Guide were enlarged and modified extensively restructuring them to suit Indian conditions. Some new chapters have been added which include Statutory Acts, Rules and Policies; Management Information Systems (MIS); Communication Network; Training and Computerisation which are

vital to make any plan of operation and Maintenance (POM) comprehensive. The report is published in 1994 and widely disseminated which was well appreciated.

Drip Irrigation in India: INCID with the assistance of its Working Group on Micro Irrigation later constituted as Special Committee on Micro and Mechanised Irrigation has brought out a report on Drip Irrigation in India. The advantages of drip irrigation are manifold, the farmers are having some doubts in their inquisitive minds, whether such huge investment is justified, what will be the pay back period, how much water could be saved, whether any improvement in water use efficiency could be achieved and whether at all there will be any increase in yield etc. The report is published in July, 1994 and widely disseminated which was well appreciated.

Sprinkler Irrigation in India: INCID sought the assistance of Dr R.K. Sivanappan, former Dean, Tamil Nadu Agricultural University, Coimbatore for providing the status report. The draft report was widely circulated. Later on the draft report along with compendium of comments/ suggestions was discussed in a National Seminar. As decided in the Seminar, the draft report was then referred for the review and modification to a Working Group consisting of a select group of seven experts.

This document comprising of nine Chapters alongwith informative annexures aims at giving comprehensive details of how to go about the much needed technology. Besides giving the details of technology, design, application and adoption of sprinkler irrigation in India, an attempt has been made to include the need and scope for research and development in this field, benefit cost and economics of sprinkler systems and infrastructure requirements to shoot up the acreage under sprinkler irrigation. The report is published in May, 1998 and widely disseminated which was well appreciated.

Preparation of History of Irrigation in the States of Andhra Pradesh and Tamil Nadu (Principal Investigator: Prof. A. Mohanakrishnan, INCID Sectt.)

Objectives:
To prepare documents bringing out the irrigation practices and management adopted in the different periods from pre-historic times up to late Eighties in the States of Andhra Pradesh and Tamil nadu

Findings:
History of Irrigation Development in Tamil nadu: Initially this work was started by INCID on its own and subsequently entrusted to Dr A. Mohanakrishnan, Former Chief Engineer, Tamil nadu and Chairman, Cauvery Technical Cell. Dr Mohanakrishnan prepared this report based on data collected through various sources. The draft of the report was circulated to various organizations for their comments. The INCID Sub-Committee-I discussed and approved report and comments with minor variations.

The present publication contain seven chapters and covers irrigated agriculture in Sangam age, development of irrigation during pre-British rule, i.e. during the periods of Cheras, Cholas, Pandyas and Pallavas, during British rule and after Indian independence. The report also covers future perspectives of irrigation development in Tamil nadu. The report is published in March, 2001 and widely disseminated which was well appreciated.

History of Irrigation Development in Andhra Pradesh: Dr A. Mohanakrishnan, Former Chief Engineer, Tamil nadu and Chairman, Cauvery Technical Cell prepared this report based on data collected through various sources. The draft of the report was circulated to various organizations

for their comments. The INCID Sub-Committee-II discussed and approved report and comments with minor variations.

The present publication contains seventeen chapters and covering development of irrigated agriculture right from the pre-Mughal period through the British period and the period after independence. The report also covers future perspectives of irrigation development in Andhra Pradesh. The report is published in March, 2004 and widely disseminated which was well appreciated.

Study of morphological and ecological changes occurring d/s of a weir due to its construction (Principal Investigator: Prof. P.M. Modi, Director, Water Resources Engineering and Management Institute (WREMI), Samiala)

Objectives:
To develop storage and retrieval system regarding morphological and ecological changes taking place in a river after the construction of a weir across a perennial river.

Findings:
The scheme envisaged developing storage and retrieval system regarding morphological and ecological changes taking place in a river after, the construction of a weir across a perennial river namely, Wanakbori weir constructed on Mahi river as a pick up weir at Wanakbori, Village of Gujarat State.

The theoretically sound methods of estimating suspended sediment load carried by the stream is to integrate sediment concentration and velocity distribution curves. But it has been observed a cumbersome and lengthy process as well as it involves higher degree of uncertainties. Therefore, an attempt has been made to relate the suspended sediment load directly to the water discharge.

Though it can be seen that sediment concentration changes exponentially with respect to water discharge, more hydraulic as well as hydrological variables are required to be incorporated in the same relationship to develop a unique relation, which may be applicable and reliable to small as well as large catchments.

In this regard, it may suggested to consider more seriously functional parameters like catchment area, annual precipitation, avg. slope of catchment, percentage forest cover, pattern of discharge variation etc. to modify the existing direct equation between water discharge and sediment load.

Water Infiltration as influenced by agro-chemical application and its persistence in oxisol (Principal Investigator: Dr. V.O. Kuruvilla, CWRDM, Kozhikode, Kerala)

Objectives:
1. To study the effect of various concentrations and kinds of chemical amendments applied in the oxisol of Kerala on its infiltration characteristics.
2. To evaluate the relative persistence of the ionic effect of the soil upon infiltration rate.
3. To establish the co-relation between the infiltration process and the soil chemical factors.

Findings
Application of agro-chemicals such as lime, urea, ammonium sulphate, mussoori phosphate and magnesium sulphate in the soil has in general resulted in increasing the soilôs water intake rate.

The maximum effect was seen associated with treatments involving lime and magnesium sulphate at full recommended rate showing a value of 18.2 cm/hr.

Addition of chemicals such as potassium chloride and sodium chloride has caused decrease in infiltration rate of the soil under study. The lowest value was 11.3 cm/hr, when potassium chloride was applied to the soil at full rate.

Between the 2 rates of chemical application, the infiltration values of the soil were higher at the full rates except potassium chloride in which case the trend was reverse.

In general there was a decreasing trend in infiltration values of soil towards the end of the study period of sixteen weeks indicating a decline in the persistence of chemical effect. This was observed in all the treatments except potassium chloride and sodium chloride.

Marked increase in the water intake rates of the soil has been found after nine weeks of the study in treatments involving potassium chloride and sodium chloride.

The Chemical effect was seen to last through out the experimental period through the persistence was diminished with progress of time in several cases.

Study the effects of sea water intrusions and inundation on the soil, plant characteristics. (Principal Investigator: Tamil Nadu Rice Research Institution, Aduthurai, Tamil Nadu).

Objectives:

1. To study and delinease the extent of sea water intrusion in Sirkazhi, Thiruthuraipoondi and Nagapattinam taluka.
2. To assess the damage caused to soil groundwater and crop due to inundation.
3. To study the effect of sea water intrusion on physico-chemical properties of the soil.
4. To select suitable rice variety for coastal saline and alkali soils.
5. To reclaim the soils by cheap amendments.

Findings:

The scheme survey was carried out in the 45 Coastal villages of Sirkazhi, Nagapattinam and Thiruthuraipoondi talukas and fertility status and physical properties of soil were studied. The following results can be exploited by the study:

1. Rice variety CO.43 and rice cultures AD 85002, IET 9276 and IET 8113 are best suited for seawater intruded areas.
2. With leaching of the soil, the treatment of green leaves application or gypsum application with either presumed or coir pith are found to be beneficial for salt affected soils.

The study also recommended construction of shallow ponds upto 4ô depth in coastal belt to tap the good water resources for irrigation, some of the rainwater will be floating over the seepage seawater in the underground.

Study of black soil regions around Adivalli in PAP Command Area with a view to alleviate salt and Waterlogging problems (Principal Investigator: Tamil nadu Agricultural University, Coimbatore)

Objectives:

1. To study the degree and extent of drainage and salinity problem of the area.
2. To evolve possible management practices for salt affected soils and for use of saline water.
3. To work out suitable drainage practices to avoid salt accumulation.
4. To suggest suitable crop rotation for optimum land and water utilization.

Findings:

Initially studies were conducted to develop soil and crop management practices for the marginal groundwaters of the study area. The results indicated that out of 35 wells located in the study area only few wells are found to be suitable for irrigation as per Government recommendations. Results of the experimental trials revealed that it is beneficial to apply Farm Yard manure (FYM) at the rate of 25 t/ha, 25 kg of Zn SO_4/ha and an extra dose of N at 25%. Among the irrigation methods ridges and furrows proved highly superior over other methods.

A comprehensive sub-surface drainage system was designed and laid under actual field conditions. The design was based on several agro-climatological factors. Several types of pies and spacing were experiment. The results revealed that the PVC pipes (perforated) are good means of drainage in the area. Conclusions were drawn with regard to the spacing and diameter of the pipes suited for the area. 15-20 m spacing was found to be most suitable for the study area.

15 wells of the study area were continuously monitored during the study period. General conclusions on the water table movement during the supply and non-supply periods were arrived at. It was observed that the status of system tanks present in the study are influencing the water table position and the salinity as well. However, the interactions between supply periods and the system tanks requires further understanding. It was also observed that in place where the drainage system were laid, water table was lowered by 0.3 to 0.5 m.

In all, the experiments conducted in the study area, have given much insight in developing appropriate strategies for the better water utilization. Since the trials were conducted in farmerôs fields, the efficacy of improved technology were also demonstrated in convince the farmers.

Identification of waterlogged areas arising out of related irrigation projects of Kerala (Principal Investigator: Dr L.C. Kandasamy, CWRDM, Kozhikode)

Objectives:

1. To identify the locations of waterlogged areas under the command are of nine selected major and medium irrigation projects of Kerala viz. Kuttiyadi, Malampuzha, Pashassi, Walayar, Cheerakushi, Gayatri, Mangalam, Pothundy
2. To monitor the changes in Waterlogging and salinity problem.
3. To establish benchmark data for future monitoring of the affected areas
4. To provide reliable base for investigation, planning and development of land and water management projects.

Findings:

1. Out of nine major/medium irrigation projects, three projects viz. Malampuzha, Kuttiyadi and Pazhassi have been identified to be affected by Waterlogging to a limited extent.
2. Apart from design characteristics of the canal network, physical characteristic of the region, especially topography is a major factor in preserving the commands free from Waterlogging.
3. Causes have been identified for rectification and future monitoring.

Control of Waterlogging and salinity of salt affected area of Purna valley under the command of Katepurna and Morna Projects (Principal Investigator: Prof. S.S. Hiwase, Dr Punjabrao Deshmukh Krishi Vidyapeeth, Akola)

Objectives:

1. To carryout survey of waterlogged and salt affected area of Purna valley
2. To diagnose the nature and extent of salt problems, cropping patterns and utilization of irrigation water.
3. To analyse the water and soil for their properties
4. To estimate the leaching requirements for various cropping systems
5. To find out suitable irrigation management practices and
6. To suggest suitable surface and sub-surface drainage systems etc.

Findings:

The extensive survey of salt-affected area of Katepurna and Morna command areas indicated that most of the farmers are having small land holdings and soil is very deep clay, sticky and waterlogged, the canals were covered with layers of salt and area needs proper reclamative measures.

The soil samples shows soils of fine texture, slowly permeable, less drainable porosity and having low infiltration rate resulting in Waterlogging and hampering yields. Study shows that 25% soil have severe soil limitations and 75% soil have moderate soil limitations for sustained use under irrigation. This means that some reclamative measures such as leaching, addition of amendments like gypsum, etc. and drainage network is essential to avoid salt accumulation. Further, mechanical operations can improve the drainage properties of ill-drained salt affected soil. The yield of ñUdidò crop was higher with the treatment of deep ploughing. The experiment shows that increase in electrical conductivity of irrigation water increases the actual water requirement of the crop due to higher leaching requirement.

Studies were also made for suitable irrigation system for salt affected soil, effect of Broad bed furrow planting technique on productivity under saline soil, effect of conjunctive use of fresh and saline water on growth and yield of wheat etc.

Studies for combating salinity problem in the Upper Krishna Project (Principal Investigator: Dr G.R. Naik, Gulbarga University, Gulbarga)

Objectives:

1. To take action to combat salinity problem at the initial stages of irrigation under Upper Krishna Project.
2. The study salt tolerance in local plant species.
3. To bring awareness amongst the farmers on salinity problems
4. To develop Bio-drainage concept for improving productivity of desired crops.
5. To utilize of óVA-Mycorrhizaeô for combating salinity.

Findings:

1. The project area is prone to develop severe salinity and alkalinity problem in case proper water management is not there
2. Strategies to develop salt tolerant crops and bio-drainage and microbial desalinization may have to be followed instead of engineering approach.
3. The variety of crops which can be grown under moderate salinity conditions are ï Groundnut (VRI, S-206, S-230), Banana (Vasai), Sunflower (Jwalamukhi), Soyabean (MACS-124), Mulberry (M-5) and Sugarcane (GS-9)
4. Bio-drainage using óMoringa Oleiferaô (trees species) and desalinizing using VAN, seems good approach for combating salinity problem.

Crop and crop planning for flood and flood prone areas
Objectives

I. To evaluate land suitability for correct matching between cropping pattern and productivity potential for long-term sustainability in crop production.
II. To develop appropriate technologies for improving the productivity and production of pulses, oilseeds and vegetables etc. As pre and post harvest of rice and rice-fish multiple enterprise farming system in flood prone eco-system.
III. To conduct socio economic survey for getting a holistic approach for better linkage of agro-climatic conditions `vis-a-vis farmerôs socio-economic conditions and
IV. To disseminate the information to the stakeholders.

Findings

- The field trials conducted on different varieties of paddy during the pre-flood, during flood and post flood seasons and crops that are feasible to be grown in pre and post flood seasons has led to conceptualize the management strategies for the entire flood prone areas of Assam.

- The Physico-chemical properties of the field plots and its nearby areas located in the flood plain areas reveal the inherent soil status. The results obtained gave enough inside

to fit in the crop, select proper varieties of crops to be grown in the flood plain areas during different periods like pre-flood, flooded, and post flood.

- As a one of the management strategies the most suitable sowing time, variety, extend of areas to be covered under different crops which are based on natural soil moisture regime obtained from multi-locationals investigations are incorporated.

- The prime task was to utilize the flood prone areas for productive use with proper crop planning. During the study, more emphasis was given for evolving management practices to grow crops even in excess water and in water stress situations. From the very beginning, farmers have been involved actively with the activities of the projects, allow to conduct field trials at their own land and manpower. ñLow cost, low input and relevancyò is prime criteria of the evolving methodology.

- The flood affected areas where the studies were conducted, presently having very low agricultural production and the farmers are not aware about the scope of different Cropping and water management technologies. The soil parameters, ground water condition and soil moisture status assessed in the study areas are found to be favourable for cultivation of a large varieties of crops. The field trials conducted on paddy and other crops like in pulse, oilseeds and vegetables indicated optimal but economically viable productivity.

- Water table in most of the areas is shallow and is regularly replenished due to water inundation over a substantial period of time. The field trials were conducted in farmerôs field and thereby the result does not suffer the criticism of control condition in research farm.

- The crop and water management practices were based on the soil moisture content and soil moisture tension observed in the study area. Life saving irrigation during long dry spell is proposed to be provided from STW and dug out ponds. A large area of Brahmaputra valley known worldwide for its flood hazards can be covered under the suggested practices leading to food and social security to the vulnerable section of the inhabitants.

- Characteristics of flood affected areas of Assam for crop production are more or similar in nature. Crop damaged due to concurrent floods, poor cropping intensity and lack of proper cropping pattern, low productivity due to under utilization are common phenomenon in flood affected areas of Assam. Therefore, crop planning able to mitigate or reduce the need and requirements for better utilization of land and water resources

- Based on the results and experiences from the study in the flood prone villages of Sonitpur and Dhemaji districts of Assam, it is strongly recommended to adopt the proposed crop planning envisaging restructured cropping pattern in pre flood, during flood and post flood situations in low lying, medium and upland conditions in other parts or areas having being affected by floods in Assam. Dissemination of the results and achievement among more farmers of other areas of flood prone districts of Assam should be continued and should become a part of extension service. However, to cope with the fragile eco-system of the flood prone areas was found to be very challenging. Considering the need of the farmers to provide them a suitable crop planning, the results of the research hopefully might have led towards development of relevant methodologies for productive use of flood affected areas. It has been expected that the developed system would save land, water, fertilizer, plant nutrients and increase employment and socio-economic status of the farmers. The outcome of the study should be transferred to the similar situations in the different parts of the Assam and other States of NE region. More studies in similar line are yet to be taken to find many unanswered issues which are also required to expand in river basin wise location specific situations.

Standardization of drip irrigation and fertigation schedules with and without mulchin fruit crops (Apple and Apricot) of Himalayan Region.

Objectives

I. To determine the drip irrigation and fertigation schedules with and without mulch for apple and apricot fruit crops.

II. To study the effect of drip irrigation and fertigation on weed incidence, nutrient content of soil and plant and on growth, yield and quality of apple and apricot.

Findings

From the project studies conducted, it is concluded that both in apple and apricot, 18-20% % increase in fruit yield can be achieved under fertigation besides better quality crop. To get a yield level of 13t/ha in apple and 9.9t/ha in apricot, the crops should be drip irrigated at 80% Etc with fertigation @ 80% of the recommended dose of NPK fertilizers (Table 19&21). For that purpose, drip irrigation and fertigation schedules are given in Table 22 & 23. surface (0-30 cm) soil moisture contents under drip irrigation were higher under drip irrigation as compared to surface irrigation and rainfed conditions. Application of black plastic mulch resulted in moderation of soil hydro-thermal regimes and checking of weed growth which proved to be beneficial for plant growth. Soil and leaf nutrient (NPK) values were found to be higher under fertigation than conventional fertilization.

Diversified utilization of harvested farm pond water to augment the water productivity in rainfed alfisols of eastern dry zone of Karnataka.

Objectives

a. To estimate the run-off pattern and to strengthen the farm ponds through lining material being used indigenously at farmersô level.

b. To determine the utilization efficiency of stored water through drip system and to know the potentiality of fish culture through farm ponds besides, working out the economic feasibility and

c. To know the effect of accumulated Sesqui-Oxides on growth and yield of fishes in farm ponds and to develop methods to neutralize their effects.

Findings

Better utilization and conservation of farm resources and yield sustainability of radish could be attained by adopting proper land configuration with recommended dose of fertilizers proved to be better in realizing higher yield in radish. Apart from this, both crop productivity and water productivity could be improved by storing the runoff water in farm ponds and using the same during long dry spells / at critical crop growth stages as protective irrigation during rabi in order to obtain higher root yields.

"Implementation of novel "Root Zone Technology' at the field level to maintain environmental quality of water in river Kshipra and Ujjain."

Objectives

The conventional engineering technologies for treating the domestic and industrial waste waters are expensive and not affordable by most of the municipalities and those public organizations, maintaining the water quality act field scale to keep water bodies clean and aesthetic. The present research will effort to develop and implement the low cost eco-friendly technology to treat the flowing water from nullah in the catchments of riverine system, and treat the stagnant water during the late to summer months in the river by installing, either a free floating reed wetland system in situ, or at the bank of the bathing ghats or at appropriate place by diverting the river water to land based ôReed Bed Systemô, and then conveying the treated water to main river body.

Findings

It can be over viewed that by installing two types of constructed wetlands in combination package: the land based Subsurface flow constructed wetland (SFCW) intercepting the ongoing wastewater stream, and secondly the AFI on the stagnant water body, receiving the wastewater stream are low-coast, nature-based eco technology. The combined package seems to be a long term and sustainable option for overall treatment of sewage-polluted water body.

Rainfall – Runoff modelling and groundwater dynamics of irrigation tank clustered catchment in semi arid region

Objectives

The objective of the study is to estimate the surface water and ground water potential using empirical methods at the basin scale. And to simulate the surface and groundwater dynamic through `physically based integrated modelling approach incorporating tank cascaded catchment at sub-basin level.

Findings

I. Analysis of results shows that MIKE SHE along with MIKE 11 is capable of simulating physical processes in a tank cascaded semiarid sub-basin effectively through modular approach.

II. The study reveals the importance of incorporating the surface water bodies in modelling as it has great influence on water balance analysis of integrated modelling and for appropriate water resources estimation.

III. The scenario analysis with and without inclusion of tank cascaded system indicates the change in overland flow and recharging pattern in the saturated zone when tank cascades were incorporated in the model helps in assessing water resources potential accurately and may lead to optimal and sustained utilization of resources.

Improving water productivity under canal irrigation command through conservation and recycling of runoff, seepage, rainwater and groundwater using tanks and wells

Objectives

I. To study the feasibility of harvesting, storage and conservation of canal, seepage water, runoff and rainwater in storage tanks in a command area for irrigation and fish production.

II. To evaluate the performance of the new system in terms of water availability, change in cropping intensity and agricultural productivity; compare the same with another distributaries in the command of the same canal, which has no such system
III. To study the conjunctive use of canal and groundwater in the command area for enhancing agricultural productivity during lean/dry seasons
IV. To study social, economic and environmental consequences of newly developed irrigation system

Findings

I. As per project activities, study site has been characterized (**Section-II**), soil properties characterized (**Section-III),** detailed analyses of rainfall (**Section-IV**), has been made to assess runoff, rainfall-runoff relationship (**Section-V**), canal water availability, water supply, time schedule and discharge rate (**Section-VI**); constructed rain/runoff water storage tanks and open wells (**Section-VIII**) for irrigation and fish production.
II. Performance evaluated on groundwater fluctuation and groundwater quality (**Section-VII**); cropping pattern, agricultural practices and socio-economic status of the farmers (**Section-IX**); water availability in tanks (**Section-XIII**); appropriate cropping system were developed and economic assessments were made due to pond-based intervention (**Section-XI**); the new system has been compared with water storage tank and without water storage tanks in another distributaries in the command of the same canal, which has no such system (**Section-XII**).
III. Conjunctive use and study on multiple uses of stored water, and development of pond-based integrated farming system has been made (**Section-XII**); appropriate cropping systems were developed in the pond-based sites for enhancing agricultural productivity during lean/ dry seasons (**Section-XI**)
IV. Social and economic assessments has been made (**Section-IX**) groundwater quality (**Section-VII**); soil fertility and water quality (**Section-X**); impact assessment on availability of water, crop and fish production, groundwater dynamics, environmental and other issues (**Section-XIII**)

Conjunctive use planning of water resources considering spatial variation in cropping pattern using remote sensing and GIS
Objectives

I. To study the spatial variation of cropping pattern in command area using Remote sensing data. `
II. To Formulate the Linear Programming Model
III. Evaluation of Optimal Allocation Policies for the Optimal Cropping Pattern

Findings

Crop management at command level requires considerable efforts in terms of crop planning, water management, pest management, etc. When the area encompasses by the command is large the task becomes more difficult for the command area authority for proper planning and decision making. With the arrival of technologies such as remote sensing and geographical information systems, NDVI based crop identification and discrimination in large areas is helping planners in multiple of ways. These techniques support not only in discriminating different crops which are essential for crop yield assessment but also indicates the health of

different crops at different growing stages helping command authority in taking timely measures for maximum crop yield. In the preset study, utility of LISS-III and multi-dates AWIFS images have been demonstrated for identifying and discriminating different crops during Rabi season in the Tawa command. Based on the NDVI profile and sample GPS points taken during field visits, four principal crops viz. wheat (74.68%), chick-pea (14.52%), sugarcane (2.42%), linseeds (2.32%) and others mainly vegetables (6.06%) are identified in the command. Also in the study, demonstration has been made how distributed crop evapotranspiration (ETc map) is prepared based on the relationship between crop coefficient and NDVI. This helps in estimating the demand and supply scenario in the canal command.

"Ensemble modelling of rainfall runoff transformation process"

Objectives

I. To develop multi-model ensembles for studying the rainfall-runoff transformation process
II. To analyse the performance of the developed multi-model ensembles.
III. To determine the optimal size and optimal combination of models for the ensemble modelling of the rainfall-runoff transformation process
IV. To evaluate the reliability of the simulated outputs obtained through multi-model ensembles.

Findings

I. Weighted average based on calibration performance (WAM_k_1.5) and linear programming methods are the best ensemble methods for Kesinga and Salebhata catchment`, respectively.
II. The ensemble of SWAT, TANK, SIMHYD, SACRAMENTO and SMAR is the best ensemble for Kesinga, whereas, the ensemble of SWAT, HEC-HMS, TANK, SIMHYD and SACRAMENTO is the best ensemble for salebhata.
III. The selected ensemble outperform individual model in simulating river discharge for both Kesinga and salebhata.
IV. The Uncertainty level of the selected ensemble is lower than that of individual models.

Vulnerability of North-East India to Climate Change for Hydrological Extremes of Floods and Droughts

Objectives

I. To develop an ArcGIS toolbar using ArcObjects for temporal trend analysis of meteorological parameters,
II. To determine the temporal and spatial trends of meteorological parameters over north-east India, and
III. To assess vulnerability of north-east India to climate change for hydrological extremes of floods and droughts.

Findings:

Based on the above study, the following conclusions were drawn:

I. The two unequal methods, namely, AHP and Iyengar and Sudarshanôs method produced similar results. However, there were some differences in the indices due to difference in the assigned weights to indicators.
II. For Arunachal Pradesh, Papumpare and Dibang Valley were found to be less vulnerable while Changlang, East Kameng, East Siang, Kurung Kumey, Lohit and Tirap were found to be highly vulnerable to flood. This might be because Dibang

Valley had the lowest hazard index and Papumpare had high adaptive capacity index in both the years. On the other hand, Changlang, East Kameng, East Siang, Kurung Kumey, Lohit and Tirap had very high exposure index and low adaptive capacity index.

III. For Assam, Kamrup and N.C. Hills were found to be less vulnerable, whereas, Baksa, Barpeta, Darrang, Dhubri, Dhemaji, Karimganj, Lakhimpur, Hailakandi, Nalbari and Nagaon were found to be highly vulnerable to flood. This might be because Kamrup had highest adaptive capacity index and N.C. Hills had the lowest exposure values in both the years. On the other hand, Baksa, Barpeta, Darrang, Dhubri, Dhemaji, Karimganj, Lakhimpur, Hailakandi, Nalbari and Nagaon had very low adaptive capacity index with high exposure index. Karimganj also had high hazard index in almost all the months

IV. For Manipur, Chandel, Ukhrul, Tamenglong and Senapati were found to be less vulnerable, whereas, Churachandpur was found to be highly vulnerable to flood. This might be due to the highest hazard index for Churachandpur. On the other hand, Chandel, Ukhrul, Tamenglong and Senapati had very low hazard index and low exposure index.

V. For Meghalaya, East Khasi Hills was found to be less vulnerable while South Garo Hills was found to be highly vulnerable to flood compared to other districts. This might be because South Garo Hills had the highest hazard index, whereas, East Khasi Hills had the lowest hazard index in almost all the months.

VI. For Mizoram, Aizawl was found to be less vulnerable and Mamit was found to be highly vulnerable to flood compared to other districts. This might be because Aizawl and Mamit had the lowest and the highest exposure index, respectively, in both the years. Aizawl also had high adaptive capacity index while Mamit had less adaptive capacity index.

VII. For Nagaland, Wokha was found to be less vulnerable while Mon was found to highly vulnerable to flood compared to other districts. This might be because Wokha had low exposure index with very high adaptive capacity index. On the other hand, Mon had the highest exposure index with low adaptive capacity values in both the years.

VIII. For Tripura, West Tripura was found to be less vulnerable to flood while South Tripura was found to be highly vulnerable to flood. This might be because West Tripura had the highest adaptive capacity index in both years. On the other hand, South Tripura had the highest hazard index in many months and also in the yearly average of 2001.

IX. Validation for three selected states (Arunachal Pradesh, Assam and Manipur) done by comparing state Govt. data, a global flood database and compilation of online news reports with results of this study (for both AHP and Iyengar and Sudarshanôs method) proved to be quite matching and hence the results could be considered acceptable. However, since the AHP of assigning unequal weights was a subjective method and the weights were dependent on the decision maker, the Iyengar and Sudarshanôs method was recommended.

X. The aerial maps generated by spatial interpolation of point indices at an interval of approximately 10 years could be used for visual interpretation of vulnerability components and identification of priority area for reducing the vulnerability to flood.

XI. For Arunachal Pradesh, during 2004ï2013, the vulnerability had no significant change in major portion (central and western portion) in all the months except in June and also in the yearly average. However, the entire eastern portion was seen with decreased VI in almost all the months. This might be because there were no significant differences in the interpolated indices and for the eastern portion, the exposure index had decreased.

XII. For Assam, during 2000ï2010, the vulnerability had decreased in major portion in many months (seven) and had no significant changes in some months (five). This might be because, in major portion of the state, there was no significant change in

the adaptive capacity but the hazard indices for the major portion of the state had decreased in many months.

XIII. For Manipur, during 1998ï 2009, major portion of the region was found to have no significant change in majority of the months (nine), while in the month of June and December the vulnerability was increased and decreased respectively in the major portion. This might be because the hazard had increased in the major portion of the state in June and also the exposure index had increased while in the other months there were no significant changes in hazard index.

XIV. In Meghalaya, during 2000ï 2010, there was decreased in VI in almost all of the state in some months (eight) and in some months the VIs had showed no significant change. This might be because major portion of the region had hazard decreased hazard index with some of the portion having no significant change.

XV. For Mizoram, during 2000ï 2010, there was decreased VI in almost all of the state in all the months except some parts of the state (northern portion) where vulnerability had not changed significantly. The decrease in VI was due to decrease in the hazard indices.

XVI. For Nagaland, during 2001ï 2011, most districts of the state had no significant change in maximum number of the months. However, vulnerability had decreased in some part in almost all the months and increased in some districts in the months of June and December only. In major portion of the region there was no significant change in vulnerability because the exposure and adaptive capacity did not change.

XVII. In Tripura, during 2001ï 2011, no significant change in vulnerability was noticed over most districts in majority of the months and also decreased VI was seen over some districts in few months. Major portion of the state was seen having increased VI in the month of December and little portion of Dhalai in June

Identification & Mapping of Palaeo-Channels in the Eastern Fringe of the Indian Thar Desert for Water Resources Augmentation Plan

Objectives

The objectives of the study are oriented towards the identification and precise mapping of palaeo channels and behavior of ground water in palaeo drainage in terms of quantity, quality, recharge capabilities etc. The major objectives are as below:

I. Identification and mapping of palaeo-channels in Jhunjhunun, Sikar, Churu, Nagaur, Pali, Jalore and parts of Barmer district of Rajasthan.

II. Verification of palaeo channels by Geophysical survey and field Hydro-geological studies coupled with remote sensing studies.

III. Location of suitable areas for artificial recharge.

Findings

Analysis of satellite images of various seasons of years shows strong signature of Palaeochannels in to scattered form in various parts of the study area in the form of long elongated valleys, coarse to medium grained fluvial deposits at various stock, fluvial clay deposits in sub surface vegetation patterns, availability of good quality groundwater at comparatively shallow depth, series of playas in the direction of the of palaeo drainages, field investigations and interviews also strengthen the availability of palaeochannels through disjointed drainages, availability of river sand and concrete in the subsurface area, spill way, and culverts on the road which are constructed long back, series of ponds,

comparatively higher yield of wells in the area, long runoff, and sheet wash areas, natural depressions of the fluvial deposits etc. During field investigations interviews of local people confirms the occurrence of water flows during rainy season in the identified palaeochannels area especially in Kantli river basin, drainages along Nawalgarh, Mukundgarh, Mandawa, Dundlod, Kuharu village, Sanchor and in the Pachpadra.

Looking to the direction of flows, size, depth and interconnectivity of playas, field observations clearly indicates availability of two good network of palaeochannels- one is associated to Kantli river basin where number of palaeochannels, rivulets, valleys are available and which are collectively flowing towards the Ghaggar river bed. Kantli River is now flowing up to Sulkhania village during high rainy season and there is clear visibility of track of flow towards Ghaggar with other evidences of alluvial deposits. Another network is associated with Luni river system which encompasses the inland drainage system of Sambhar, Didwana, Nawa, Ranauli, Pachpadra, extending up to Rann of Kutch. These playas in the form of salt lakes are probably the remnants of old drain network which are getting inflow from the waters from the channels flowing from north east and east directions which was the direction of Palaeo drainage which are associated to the Vedic Saraswati River. This shows the area was sometime drained by large network of river associated with Saraswati river system. Some of the areas have very prominent signatures of the palaeo drainage like from Samod to Sambhar as Anokhi buried channel, drainage from hill in the north of Sikar district at Ranauli. Starting from hills near Nawa, a channel merges in Jojri River flowing through Jodhpur district which ultimately merges in ñLuni Riverò near Balotra. There are numerous evidences around Degana, Merta area in Nagaur district in form of disorganised flow, natural depressions and presence of clay soils. It seems that this area was the part of large river system which has deposited the large amount of sediments in this area. Even now in this area water accumulates during rainy season which supports good agriculture. Only before 50 years or more this area was having very good ground water potential and the area was known for cash crops. In North and North East of Balotra there are many number of channels coming and merging with Luni River, it seems that these channels are the part of Ancient River flowing from Sikar, Nagaur, Jodhpur districts and now dried up due to increase in aridity in the area.

In Pali district a network of small channel basins emerges and flow for long distance and merges in to Luni river right at the town. There are numerous channels, inter dunal flats visible in Southern most part of Jalore and Barmer districts which ultimately merges into Rann of Kutch. In ancient times this area may be a low lying land converging in to sea after making a delta like structure. Water is still flowing in some of the sandy rivulets during rainy season and going into Rann of Kutch. Due to the dynamic nature of this area

it is difficult to identify the individual channels-whether it is Palaeo or recent drainage.

The investigating team has identified some of the concrete Palaeo drainage network as below

1. From Sulkhania Bara of Jhunjhunun near Rajgarh, Bhadra, Nohar to Ghaggar River bed.
2. Promising area found near Mandawa in Kuharu village flowing from Nawalgarh-Dundlod-Mukungarh-Mandawa-Kuharu village which is associated with elongated, narrow, deep valleys, sand dunes and is a high moisture and high vegetated area.
3. Singhana near Khetri originating from Udaipurwati hills and flowing through Nawalgarh to Mukungarh
4. East to West flowing channels emanating from nearby Bhakra hills flowing from Hadater-Kamalpura-Palri-Harecha and ultimately meets Luni River.
5. One more palaeo-drainage passing through Sanchor, Dantiya, Bhika Nai ki Dhani and meets merges into Rann of Kutch.
6. Another drain flowing from village Hadater through Dhamana village near Palri where intermittent surface ponding is observed.

As per the project proposal geophysical survey was to be conducted in the identified Palaeo channels after doing the investigations and analysis it id found that palaeochannels are very much scattered in large area and so it is difficult to verify the presence of palaeochannels by 10, 20 or 30 number of geophysical points. At the same time project is delayed due to administrative difficulties. Therefore the idea of going for geophysical survey looks impractical. What was possible in Remote Sensing and field investigation is which is present in the report.

Bed form characteristics with varying discharge intensities and depth of flow.

Objectives

The objective is to study the bed form characteristics and consequently the effective resistance to flow while an unsteady discharge representing a run-off event is passed over the movable bed. The change in flow resistance due to bed form is reflected by a change in depth and velocity and consequently in depth discharge relationship of a stream. The depth discharge relationship for the lower flow regime in particular is to be studied in order to investigate the effect of varying rate of change of discharge with time for a run-off event.

Findings

a. Resistance to flow in alluvial channels can be expressed as a unique function of modified relative roughness i.e. $r_b L / H_2$

b. For a given depth, the maximum resistance to flow is offered by a rippled bed when the flow conditions are such that the ripples are in the most developed state. The resistance to flow will be less if flow conditions are such that either the ripples are not formed to their maximum dimensions or they are partly degenerated due to rearrangement in the process of forming dunes.
c. The points of maximum ripple resistance are reference points for comparison of flows of different depths over the same bed material.
d. The resistance equation $1/\sqrt{f_b''} = 34.33 (r_b L / H_2)^{0.6309}$ obtained from the flume data would predict the bed friction factor for natural streams for lower flow regime with reasonably good accuracy.
e. The equation $U = 0.0096 / (r_b^{0.628} S^{0.314})$ obtained from the flume study has been validated with respect to prototype canal and river data for lower flow regime.
f. Observations on rivers and flume studies have shown us that the presence of suspended load tends to decrease the resistance in an alluvial stream. However, present experiments also revealed that with ripples on the bed, the effect of suspended load on the resistance to flow is of secondary importance.
g. The ripple beds generated in the present experiments were hydro-dynamically rough and therefore the friction factors of the beds investigated were independent of Reynolds number.
h. The Froude number of the flow had to be less than one. However the absolute magnitude of the Froude number in different flow regimes depends on the scale of the system and is only quantitatively significant for the system under consideration.
i. The parameters modified relative roughness ($r_b L / H_2$) and $r_b / e H$ are indices of the amount of resistance from ripple beds.

Experimental study on labyrinth / piano key spillway
Objectives

Keeping in view the relatively reported better performance of Piano Key Weirs in comparison to linear and Labyrinth weirs, following objectives are considered for the present study.

I. Investigation of Piano Key Weir behaviour covering h/p ratio values in the higher ranges of h/p.
II. Hydraulic performance of different shapes and dimensions from the stand point of Piano Key Weir effect.
III. Study of jet interaction and its effect on labyrinth behaviour at higher h/p ratios.
IV. Study of length magnification ratio (L/W) vis-à-vis (h/p) ratio on Piano Key Weir effect.
V. Preparation of standardized design covering higher ranges of h/p ratio above 0.5.
VI. Investigation into hydraulic and structural effects of Piano Key Weir by different degree of cement mortar filling.
VII. Investigation of energy loss behaviour in the flow domain around different models of Piano Key Weir.

With the above objectives in view, the relevant details of the experimental programme have been done.

Findings

Based on this study, the following conclusions can be inferred:

I. Different phase of experiments (phase -I to IV) which were planned with different configurations of Piano Key Weir, i.e. with or without ramp and one or two side overhanging (u/s & d/s) indicate that Piano Key Weir with presence of ramp and two sides overhanging provides a higher discharge under same head when compared with other Piano Key Weir configurations with lesser number of ramps and/or over-hangings. Different phase of experiments (phase -I to IV) which were planned with different configurations of Piano Key Weir, i.e. with or without ramp and one or two side overhanging (u/s & d/s) indicate that discharge through Piano Key Weir gets increased with increasing h/p upto unity

II. The hydraulic effect of P. K. Weir on discharge passing capacity at higher value of head over crest to crest height ratio h/p may depend upon height of model only and not the L/W ratio. Because at higher value of h/p, the net discharge increment for the best model seems to coincide at constant model height, and variable L/W ratio does not coincide at variable values of model height and constant value of L/W ratio.

III. At higher range of h/p, nappe formation occurs due to hydraulic effect triggered by upstream Piano Key shape between two elements. At medium range of h/p, depths of nappe formation that occur from upstream direction of elements are smaller than higher discharge due to effect of Piano key shape. Two more nappe formation between each element occurs sideways from the element, resulting in collision of lateral jets at the brink of each wall. At lower ranges of h/p, nappe formation phenomenon is less pronounced due to combined effect of (i) upstream piano key shape and (ii) two nappes plunging from the sideways of each element, which are more than that of medium range discharges and no occurrence of jet collision is observed at the brink of each wall.

IV. The discharge magnification ratio of ór ô value is increasing with the length magnification L/W ratio for different h/p values. But as can be discerned from the plot, at higher h/p values (i..e 0.75), the ór ô value does not display any significant increase with L/W ratio. Also, it is seen from graphs of different phase experiments that the discharge magnification ratio (r) was found to increase with magnification ratio L/W. However, at larger value of L/W, the ratio (r) was observed to tend to approach a limiting value in the proximity of four.

V. From graphical plot of Phases I-IV, it is seen that at lower h/p value the sensitivity of crest height parameter ó p ô is clearly discernible. The lower value of ó p ô gives higher magnitude of ór ô in the lower range of h/p ratio.

VI. In phase-V experiments, fillings were introduced in the ramps but these were not found to increase the discharge. Thus, ramps with no planar discontinuity were found to be best performing. In phase-V experiments, modifications were introduced into inlet limb of Piano Key Weir but it was again observed (experiment set P5M1 & P5M2) that such inlet modification was of no practical significance as it did not lead to any increase in the discharge.

VII. Comprehensive model study of Piano Key Weir for Sawara Kuddu HEP as an adopted case study shows very interesting result that energy loss behaviour in downstream of Piano Key Weir is sufficient with providing steps in downstream of Piano Key Weir and it is also shown in Plate No. 5.8.

Water Harvesting and Water Conservation in Imphal East I Block, Imphal East District, Manipur

Objectives

I. To identify surface and ground water resources.
II. To investigate ground water potentiality.
III. To assess the quality of surface and ground water for domestic and irrigation purposes.
IV. To carry out the management practises for deterioted water.
V. To construct suitable water harvesting and water conservation structures.

Findings

The ground water exploration 1s an ancient task as revealed from the excavations of Mohenjodaro during the Indus Valley Civilisation. The need of dug wells came into the systematic hydrogeological task was taken during 1970 by Central Groundwater Board and concerned state agencies in the country to tackle the need of drinking water supply. Besides, National Project on ñTechnology Mission on Drinking Water and Related Water Managementò was launched during 1986-88 to provide the potable water supply to the villagers.State Public Health Engineering Department, Govt. of Manipur is a leading agency to tackle the task of drinking water supply in urban and rural areas in the state. Due to lack of hydrogeological knowledge, availability of gas pockets during drilling, high iron content in the groundwater and slow recharge in the alluvial aquifer, occurrence of drought and flood during lean and monsoon ,the state agency is far behin to achieve the task. ôTherefore, Imphal Last 1 Block has been selected for present studies for both surface and subsurface investigation to provide a scientific source of finding at village level to help state lead agency. Imphal East I Block is situated in northern part of the city (Imphal) fall under meridian N 24 ° 45ô to N 25° 7ô and parallels E 93° 54ô to E 94° 9ô 30ò. It comprises an area of about 280 sq.km. The average height is 780msl in the valley. The area received an annual rainfall for the last 24 years is 1400 mm. Surface water of the area falls within the Manipur River basin which account for 0.5192hectare metre annual run off against a total catchments area of 6332 sq.km. General trending of all drainage in the areais N-S direction. Three major river crossed the area i.e., Imphal, Iril and Kongba rivers. Iril |river is one of the largest river in the area.. State PHED had installed pipe line in many villages of the area but water supply through the pipe is very very less because water availability, harvesting and conservation problems. The actual source of water supply in the area is from surface (more than 95%).However, Drought and flood are frequently occurred in the:study area during lean and monsoon seasons. The villages in the block suffer scarcity of water for drinking, domestic and irrigation purposes in most of the season except during peak monsoon month due to lack of proper water conservation and management practices. : Seismotectonically, the region is an active one and requires the attention. Therefore, the construction of tube wells/ hand pumps are more recommended than theconstruction of large reservoir to avoid the future reservoir induced seismicity.Water harvesting and Water Conservation in Imphal East I, Block, Manipur Stratigraphically, two distinct groups of rocks constitute the area, viz Disang Group (Tertiary), and Alluvium (Quaternary). The Disangs found as the structural and isolated hills in central part of the area. They are highly weathered. Shale and sandstone constitute the structural hills where shale is dominant. Major part of the area belongs to Alluvium, which is further divided into Older Alluvium and Younger Alluvium due to - change in lithology. Based on lithology and structure, the region is broadly divided into two types of aquifers viz. weathered rock aquifer and alluvial aquifers. Geomorphologially, the area is divided into several land form units. The structural hills are the oldest members and constitute the run off regions. The coalescing alluvial fan zone and piedmont zone constitute a prospective aquifer region due to high recharge. A number of hand pumps are installed to feed the domestic consumption. Thea alluvial

plains constitute the large part of the area. The aquifer is found in the form of sand lenses. The thickness of the alluvial plains varies from few metres to few hundred metres. The gas pockets are available which frequently disrupt the drilling operations at places. The alluvial plains provide a prospective region. The various land use patterns are identified in the area. The agriculture lands constitutes a large part which 1s followed by settlement, degraded forest, forest plantations etc. Ground water occurs both under confined and unconfined conditions. Water table is met Within a depth of about | to 4 metres below ground level as measured in tube well in depth from 0.33m to 15.03metres.The water table is in conformity with topography. The water table rises during rainy season and lowers gradually, being the minimum in. May with fluctuation of about 1-3 metres. Th shallow alluvial aquifer consists of ill-sorted pebbles and cobbles, below the depth of 1.5mts. The aquifer in central part of the district is coarse grained sand, dark grey in the form of sand lenses. |The confined conditions occur within a depth of about 60mts.below the ground level as indicated by the flowing tube wells in western side and occurrence of springs |along the foot hill zone of structural hills in Yaingangpokpi area in eastern side of the study area. Most of the springs occur in silty shale which suggests the combined lithological and structural control.

The source of the ground water recharge varies for shallow and deeper aquifers.It may be inferred that it is mainly from the top soil cover in the weathered rock aquifer while in alluvial plains the top soil 1s clayey, therefore infiltration and recharge are relatively less. The general slope of the area is from north to south, hence the gradient is 2.2meter/km. Water harvesting and Water Conservation in Imphal East 1, Block, Manipur Results of geophysical electricity sounding indicate the H-type and K-type curve .at various locations. All the success tube wells are observed carefully and its lithology is found to be consisting of top soil, hard shale, clay, sand and sandy gravel. The curve of success tube wells are of H-type. Unsuccess tubewell are due to thick formation of top clayey soil with loose shingles. Unsuccess tubewell are correlated with K-type.Weathered shale is the aquifer, however it is essential to determine the depth of the formation. This is manifested by the sharp increase in resistivities of the formation (H-type curve). The highest yield in the shale at Wari (Sawombung) is 375 I/m. All the aquifers of sand (sandy gravel) yield very low as 10 1/m approximately, except in some cases of Awang Potsangbam, Nilakuthi, and Sangsabi etc. After considering with the result obtained from electrical survey and correlation with the existing lithologs, the following points are given below: :

i. K-type section should be avoided for groundwater exploration, chancesof gas problem Is very high.

ii. Western side of Imphal river and eastern side of the Ini river such as Pangei, Kundrakpham, etc are not recommended for drilling, due to gas pockets.|

ili. H-type curves are favourable for further groundwater exploration in Imphal East District.

The analysis of water quality indicates that the water sample is within the permissible limits for use in domestic, irrigation and industrial purpose.

Village level data on drinking water amenities has been analysed and mapped with reference from State PHED, Census hand Book of 1991, 2001 and field survey.In the project area 5(five) structures for surface and sub-surface water harvesting and water conservation have been constructed.

Reservoir performance analysis using stochastic stream flow models.

Objectives

I. Development of a versatile user-friendly software for periodic stochastic modelling of river flows, with built-in decision-aids at various stages of modelling.
II. Using the stochastic model fitted, large number of similar flow sequences would be generated, which would be useful in : (a) fixing the required capacity of a reservoir being planned; (b) evaluating the performance of any existing reservoir system, for various existing and projected target demands and different operating policies.
III. Establishing trade-off relationships amongst the performance indicators such as reliability, resilience and vulnerability for a few existing systems, for standard operating policy and a few selected hedging policies.
IV. Construction of reservoir storage-performance-yield (S-P-Y) relationships and isoperformance lines for selected operating policies for reservoir systems.
V. Demonstration of the practical usefulness of these tradeoff relationships developed in making decisions regarding reservoir planning, design and operation.

Findings

A multi-objective optimization framework has been developed to evaluate optimal hedging rules. This employs NSGA-II, an efficient multi-objective genetic algorithm technique that can handle constrained formulations. The evaluation of the non- dominant solutions on the trade-off surface between the conflicting objectives of minimization of vulnerability and minimization of shortage ratio helps us to compare the performance of the different hedging rules under water shortage conditions.

A new hedging rule has been proposed in the present study which is more generic than the discrete hedging rule and the modified two-point hedging rule. From the results of the optimal hedging studies done using the Dhorai reservoir data, the proposed hedging rule is shown to produce efficient non-dominant fronts containing well-distributed non-dominant solutions. The compromising hedging policies obtained using the proposed rule is shown to yield a number of trade-off solutions that exhibit good performance with regard to the different reservoir storage performance indicators.

Assessment of water resources under climate change scenarios at river basin scale

Objectives

I. To analyze long-term rainfall and runoff processes, water demands and extreme hydrological events in Mahanadi and Krishna river basins of India.
II. To identify a set of climate variables affecting the magnitude, temporal and spatial variability of streamflow and evapotranspiration
III. To develop stochastic/ statistical relationships between the climate variables and the two hydrologic variables (streamflow and evapotranspiration) for the two river basins.
IV. To construct long term future hydrologic scenarios by downscaling GCM outputs to hydrologic variables at basin scale for a diverse range of climate change scenarios.
V. To study the implications of climate change on water resources in the two river basins in terms of changes in water availability, water demands, and magnitude and frequency of hydrologic extremes.
VI. To suggest measures for sustainable management of surface water resources in the selected river basins, based on key findings, and
VII. To provide guidelines to the policy makers regarding adaptation of water resource projects to mitigate the impact of climate change.

Findings

Methodologies are developed in this project work to assess the impact of climate change on rainfall and stream flow at river basin scales, and to address the uncertainties involved in such assessment. Results are provided with an aim to help the policy makers in developing adaptive responses to climate change. Specifically the following problems have been dealt with in this project:
a. Impact of climate change on Mahanadi streamflow,
b. Impact of climate change on rainfall and meteorological droughts in Orissa
Meteorological subdivision,
c. Impact of climate change on streamflow of Malaprabha river, in the Krishna- riverbasin, and
d. Uncertainties associated with the future projections.
The following conclusions are drawn from the studies:
1. The methodologies for downscaling and addressing uncertainties developed in this project, does not limit their applicability only for the specific regions and specific variables. They are adaptable and can be used to model any other hydrologic variable also and in any other region in the country (and elsewhere) to assess the impact of climate change on hydrology.

2. The downscaling model developed based on the RVM is capable of producing a satisfactory value of goodness of fit in terms of R value and Nash-Sutcliffe coefficient. However, it is observed that the model is not able to reproduce the extreme stream flow observed in the record. Possibly this could be because regression based statistical downscaling models often cannot explain entire variance of the downscaled variable.
3. The GCM CCSR/NIES with B2 scenario projects a decreasing trend in future monsoon streamflow of Mahanadi, under climate change. This observation is consistent with an earlier study reported by Rao (1995). Such a decrease in streamflow may cause a critical situation for Hirakud dam in meeting the future irrigation and power demand.
4. The streamflow in Malaprabha river is projected to increase on an annual scale during 2021-2100 for A1B, A2, and B1 scenarios, and during 2061-2100 for COMMIT scenario by the SWAT model. In the case of SBEM model, the streamflow is projected to increase during 2041-2100 for AIB scenario, and during 2061-2100 for A2 and B1 scenarios. In the case of DDSM model, the streamflow is projected to increase during 2061-2100 for A2 scenario, and during 2081-2100 for A1B scenario and no trend was discerned with Bl and COMMIT scenarios. Thus, with all the models and most scenarios considered, the streamflow is projected to increase in Malaprabha river, although the extent of increase differs from projections of one model to another.
5. A large number of uncertainties exist in climate change impact assessments. These

uncertainties stem from various GCMs available and future plausible climate scenarios used. The downscaling relationships themselves introduce another source of uncertainty. To address such uncertainties, results are provided through possible changes in the probability distributions of the meteorological drought and the streamflow.

6. The results indicate an increasing trend in the probability of severe and extreme drought for Orissa meteorological subdivision with a decrease in the probability of near normal condition. It may be concluded from the results that the region will be more drought prone due to the effect ofclimate change.

7. The results show that the CDF of Mahanadi streamflow downscaled from one GCM is entirely different from that of another and also that dissimilarity exists among two scenarios of any particular GCM although all scenarios project a reduction in monsoon flow.

8. An increased dissimilarity between the GCMs with time, is observed in projecting Mahanadi streamflow. The amount of uncertainty in 2080s 1s higher than those of the other time slices. This may point to different climate sensitivity among the models due to ignorance about the underlying geophysical processes. Such ignorance is addressed here with possibility theory.

9. For water resources management it is important to know the effectiveness of the GCMs in modelling climate change and which of the scenarios best represent the present situation under global warming. Possibilities are assigned to GCMs and scenarios based on their system performance measure in predicting the stream flow during years 1991-2005, when signals of climate forcing are visible. A decreasing trend in future monsoon stream flow is projected for the Mahanadi even with a possibility weighted CDF.

10. A limitation of the work presented here is that the methodologies do not consider the uncertainty due to the use of multiple downscaling models. Another limitation of the work is that the Third Assessment Report (TAR) data have been used in most models developed in the present study, except the ones used for Malaprabha stream flow, which use the recently released Assessment Report 4 (AR4) data.

Fuzzy-stochastic modelling for stream water quality management

Objectives

(a) Objectives (Reproduced from the sanctioned proposal):

i) To develop a fuzzy-stochastic multi- objective optimization model for the water quality management of a stream. The model would specify, - for known hydraulic characteristics, BOD levels of the industrial and municipal effluents and the environmental constraints on the allowable DO deficits - the optimal treatment levels for the effluents, considering the random variation of the streamflow and conflicting objectives of the industry and the environmental agencies. The research in the project would aim to enhance the current state of the art in modeling by incorporating the following features:

(a) Use of a sophisticated pollutant transport model (such as the QUAL2E-UNCAS, developed by Environmental Protection Agency, US) in the optimization model, and

(b) Inclusion of randomness of streamflows in the model, thus addressing simultaneously uncertainties due to randomness and fuzziness both in the same modeling framework.

ii) To demonstrate the applicability of the model through a case study in Karnataka state. Interpretation of results, discussion on the implications for industry and the environmental agencies would be provided for the case study.

iii) To document, for the case study application, a step by step procedure for using QUAL2E-UNCAS, including the uncertainty analysis details. This document would act as a user manual for adaptation to any other river system in India. Details of usage of QUAL2E-UNCAS for water quality predictions will also be provided, along with a procedure for estimation of parameters, details of data modules etc., so as to provide guidelines for applications to other river systems.

Findings

In this project, methodologies are developed for addressing uncertainties due to (a) randomness of variables (such as stream temperature, streamflow, friction resistance to flow, effluent flow and concentration, reaction coefficients etc) that influence the water quality in a stream, and (b) fuzziness associated with management goals and imprecision arising out of lack of adequate data. The methodologies are demonstrated with the case study of the Tunga-Bhadra river system in Karnataka, India. In addition, a user manual is prepared for use of the water quality simulation

model QUAL2K, the latest model available as a free download in the HEC web page (http://www.epa.gov/athens/wwatsc/html/qual2k.html). This manual, along with other case study details provided in this report, will be useful for analyising the water quality in a river system in the country.

Hydrological investigations of lake pichhola Udaipur (Rajasthan) for its rejuvenation

Objectives

I. To assess the water availability in the lake through systematic investigations of the lake water balance
II. To study the evaporation from the lake
III. To evaluate the water quality and trophic status of the lake
IV. To evaluate the suitability of the lake water for various purpose
V. To estimate the sedimentation rate of the lake
VI. To identify the causes of quantitative & qualitative degradation of the lake
VII. To suggest remedial measures for the rejuvenation of the lake

Findings

Based on the studies conducted so far and analysis of the data collected, various problems of the lakes have been identified along with their causes. Based on these findings following recommendations are made to rejuvenate, conserve and manage the lake:

1. Trend analysis does not indicate any falling trend in rainfall for the region. Thus, the possible causes of drying of the lake appear to be: (i) reduced inflows due to surface abstraction because of construction of anicuts and checkdams etc, (ii) heavy evaporation losses, (iii) seepage losses from the lake to the downstream of the dam and (iv) higher withdrawis than availability of water in the lake. More scientific investigations on impact of anicuts on the inflow regime of the inflowing stream to the lake need to be carried out. Since water is also required by the villages in the catchment, an optimum volume may be decided for retention by the anicuts. Moreover, since there are heavy evaporation losses from the anicuts due to the shallow nature of the anicuts, other structures with lower exposed surface area may be planned instead of the anicuts.

2. The bathymetry survey of the lake is about a quarter century old. Due to sedimentation over the years there is a possibility that the volume of water available in the lake at any specific water level may not be equal to the storage volume as was at the time of the carrying out bathymetry survey. This may lead to wrong assessment of availability of water which may subsequently lead to over exploitation or mismanagement of water. So fresh bathymetry survey should be carried out to derive the depthð area-capacity relationships for the lake for better management of the lake water.

3. From the preliminary studies on the groundwater-ð lake interaction, it is observed that the water is being lost through the downstream end of the lake through seepage (particularly in the Jawahar nagar side). Exploitation of groundwater in this area through the tube well may be regulated to ensure that the overexploitation does not cause considerable reduction of the lake water.

4. From the comparative study of the catchment water balance and the inflow regime of the Sisarama river, it is apparent that a significant amount of water that falls in the catchment does not reach the lake. It is either retained as surface retention or is lost through to the ground. A major portion is also lost through the ET in the catchment. The water that goes to the ground does not enter the lake till the Bujhra village. Further detailed investigations on these aspects are needed.

5, Detailed scientific field investigations may be carried out on the ET losses from various land uses/crops/ forests in the catchment and, efforts be made to minimize these losses and maximize the runoff to the lake.

6. A considerable amount of water is being lost through evaporation from lakes. The present depth of water is very shallow. So the lake is vulnerable to heavy evaporation losses. Dredging of the lake may be carried out especially at the dam end to increase the depth so that surface area of the lake gets reduced. This will reduce the evaporation losses. The soil may be deposited in the pits created upstream of lake bed. Presence of thick mats of water hyacinth causes additional evaporation losses, so these need to be removed from time to time.

7. The lake is already in an advanced stage of hypertrophic condition. A comprehensive action

plan for control, reversal and management of the eutrophication problem needs to be undertaken. For this purpose, various point and non-point sources of nutrients (phosphorous) need to be controlled and treated before they reach the lake. In-lake nutrient control techniques such as bio-manipulation (using fish and faunal introductions etc) may be employed. Scrapping of the upper layer of sediment containing nutrients as cleansing of the lake to control eutrophication may be taken up whenever the lake bed is exposed due to drying or reduced inflows. A wetland may be developed at the mouth of the lake where the river water enters the lake. This will settle the nutrients and other pollutants in the wetland and prevent their progression to the lake.

8. Considerable deforestation in the lake catchment has been reported. Extensive aforestation may be undertaken to curb the sedimentation in the lake. The present cover of about 20% dense forest is not adequate for the hilly catchment. The reported sedimentation rate of the lake is 0.48 cm/yearand with this rate, the expected life of the lake is about 160 yrs.

9. Improvement in present sanitary conditions is required to prevent people from directly using the lake banks for open defecation. Similarly activities like washing, bathing, socio-cultural rituals which add detergents and other organic pollution should be strictly controlled.

10. Creation of a Lake Development Authority to undertake all the works & related to the conservation and management of lakes along with a high power supervising committee to review the work and to suggest measures as and when needed. It should also have a research wing to undertake research and generate data on various aspects as needed from time to time.

11. There is a need to create an eco-friendly buffer zone along the periphery of the lake in the catchment wherein activities which damage the & lake ecosystem through generation of pollutants etc, need to be banned. The distance from the lake to Bujhra village may be taken as an approximate radius for this buffer zone.

12. A number of Central and State goverment organizations, N.G.O., Academic Institutions are at present involved in research and management of different aspects of the lake. At present most of these agencies are working in & isolation and there is no coordination between the various organizations. A & close interaction between these organizations, particularly between the limnologists and hydrologists is highly recommended.

13. Excessive human interference in the lake catchment and increasing socio-cultural and religious activities in the lake area are Causing threat to the lakeôs health and life. An effective mass awareness Campaign should be undertaken to sensitize the people about their role in conserving the lake. Without the people participation, no lake conservation programme would yield the desired results

Identification of vulnerable areas in Himalayan watersheds

Objectives

I. To investigate the process of rainfall-runoff sediment yield in Himalayan watershed viz.,Ramganga catchment and its sub catchments
II. To investigate the available process based models and suggest suitable model for Himalayan watershed viz.,Ramganga catchment and its sub catchments
III. To develop a simple physically based mathematics model for rainfall-runoff ï sediment yield simulation
IV. To identify vulnerable zones in degraded Himalayan watershed
V. To develop a computer software for identification of vulnerable areas

Findings

Identification of vulnerable areas and proper understanding of the complex phenomenon of rainfall-runoff-sediment yield within a drainage basin facilitate improvements in planning and management of soil conservation and water resources and systems. Such identification basically involves quantification of erosion and sediment deposition and its spatial distribution within the water shed .more over in spatially distributed domain, these processed can be effectively addressed with the help of remote sensing(RS) and Geographical Information System (GIS) techniques.

Notably, only a limited number of studies have been reported in literature applicable on

steep Himalayan catchments.Thses studies indicate that the area of soil erosion from these catchments in increasing at an alarming rate due to heavy deforestation, urbanization and other developmental activities, and the lack of proper conservation measures. Therefore, a systematic study for quantification of rainfall-geminated runoff, soil erosion, sediment yield, areas vulnerable to soil erosion from such catchments was carried out in this project work. Using different newly developed methodologies/techniques/models were also tested /investigated for their applicability to Himalayan watersheds. This chapter first summarizes the research outcomes and finally identification of vulnerable areas which forms to be part of applied reseacrh.Mainly, the Ramganga a Himalayan /hilly watersheds and sub catchments namely Chaukhutia, Naula, and Gagas are considered for various studies carried out under this project.

Efficient use of water for increasing cropping intensity through conjunctive use planning in costal tract of Orissa

Objectives

I. To assess the existing available water resources for planning the best use of surface water during kharif reason
II. To exploit groundwater during rabi and summer season for increasing cropping intensity through high value cash crop
III. To monitor the changes in groundwater quality, drawdown due to three hundred percent cropping intensity
IV. To optimize the best use of water and to analyze water productivity through multiple use of water in the developed system

Findings

I. During kharif cropping season (June to November), on an average, the canal running period was125 dasy and water availability was 1805.4 ha-m against crop water demand of 555.6 ha-m. Besides, the release of excess water along with rainfall caused water logged situation in the canal command area.
II. During Rabi and summer season (up to May) , on an average of 36days canal running period, the water availability was 405.9 ha-m against crop water demand of 532.1 ha-m. As there is a good amount of water deficit during Rabi and summer season, the ground water was exploited to irrigate field crops.
III. The conjunctive use study shows that during dry spell period in kharif season and non availability of canal water at tail end the farmers used ground water upto 20% of the crop water demand with enhancement of crop yield up to 21%.
IV. During Rabi and summer season,, due to non availability of canal water at tail end, the farmers utilized groundwater to irrigate vegetable and oil seed crops)brinjal, potato, tomato, onion, chill , ladies finger, radish, cucumber, ground nut) the water requirement was also worked out after considering the effective rainfall and it varied from 290mm for cucumber to the highest value of 716.2 mm for brinjal. The water requirement of summer crop (bitter groud) was 508mm.
V. Studies were also carried out utilizing open well water for irrigation and its command

area for three crops (short duration rice- potato/ radish- bitter gourd) in a year an recorded net return of Rs 87368/ha. Under two crops in year (rice - brinjal), the net return was_ Rs 90,031/ha. The reason for getting more return in two Crops in a year was due to pruning and continuing the same crop with best management practices till onset of monsoon. In rest of the six crop combinations (rice- tomato, rice ð onion, rice-chilli, rice-bhendi, rice-french bean, and rice-groundnut) the net returns were

comparatively lower than the above combinations.

VI. The periodic study on fluctuation of groundwater table were carried out during the project period which varied during pre-monsoon in the range of 2.0 m to 3.18 m,during post monsoon period it ranged from 2.0 m to 3.2 m and it remained about 2 m during monsoon season. Due to presence of groundwater at shallow depth throughout the year, it could be exploited with minimum expenditure.

VII. Studies on groundwater quality and soil quality were carried out and it was observed that the quality of both groundwater and soil were consistent throughout the year. The values of EC and pH were within the prescribed norms.

VIII. Further, the aquifer properties were also studied through recuperation study and it was

observed that this value varied in the range of 2.6 cm/hr to 3.5 cm/hr for pre-monsoon to post monsoon period, respectively which shows the good prospect of groundwater Utilization in the study area.

IX. Studies were also conducted to optimize the water use, enhancement of water productivity through multiple use and it was observed that the combination of paddy,

Vegetables and fish resulted the water productivity (in terms of net return) Rs. 30.1 per m3 of water whereas the water productivity of the suggested cropping pattern (rice brinjal) with conjunctive use was 22.8 per m3 of water and farmers practices was 6.0 per m3 of water.

To assessment the impact of presence of septic tank on groundwater and spread of water borne diseases and to identify means to solve the problems created by the waste water in Balrampur district in Uttar Pradesh

Objectives

I. Detailed characterization of hydro geological framework of the study area through analysis of available information and detailed field inventory.
II. To study the impact of wastewater originating from septic tanks on the quality of ground water.
III. To ascertain the kind of water borne diseases in the locality and its spatial distribution.
IV. To perform hydro geological and geophysical study to identify potential contamination sites.
V. Assessment of ambient status of contamination and identification of potential sources and pathways of migration of pollutants.
VI. Periodic ground water regime monitoring in terms of quality and quantity in selected observation wells and making ground water models to identify the geochemical behavior and migration pathways of contamination in ground water and its future predictions.
VII. To assess the above issues and evolve techniques of effective wastewater treatment and design of septic tanks to improve quality of ground water.
VIII. To propose a ground water management cum monitoring programme for future.

Findings

The major portion of water supply in villages comes from ground water. From the depth to water level data the occurrence of shallow aquifers is confirmed in the region. The quality of ground water is a very important issues in villages. the quality of ground water is not taken as a serious issues in these areas as a a result the untreated ground water is the root cause for some of the major health hazards in the villages .The present study area

Balrampur is a case of urbanization of village due to betterment of socio-economic condition of the masses. People opted for improperly designed septic tanks and soak pits over a very small area. the septic tanks are not always constructed in the downstream area of the flow of water, as a result when water is withdrawn there is a chance of contamination of ground water and sewer materials. This has a direct impact on the ground water quality. Contamination is accelerated during monsoon .this is the main source of nitrate contamination in the area. The older septic tanks are not cleaned regularly and they are let to over flow. The concentration of nitrate in ground water is higher than permissible limit.Methomoglobinaemia in infants and cancer in adults re the effects of this concentration.

To keep the ground water free from nitrate contamination the following recommendations are made :

- Since long, waste disposal system appears to be inadequate /improper resulting in nitrate contamination on ground water. This is now high time to take special attention to rectify the mistake and to develop proper sewerage system immediately. The position of latrines should be well planned. The sepic tanks should be constructed in the downstream side of the water flow to avoid contamination when the water is withdrawn.
- The water quality should be monitored on regular basis so as to prevent the growing crisis
- Unlined drains carrying sewerage/effluents are the potentials sources of contamination of ground water therefore should be lined urgently.
- Rainwater during monsoon period can be fruitfully utilized for recharging ground water by various techniques. This will not only augment the ground water resources but also dilute and flush the polluted area gradually.
- Available technologies for the treatment of water for nitrates should be evaluated and cost effective and eco-friendly technologies adopt. Root zone treatment system can be adopted to treat sludge water with RZTS treatment of wastewater is easily possible & affordable beauacse it involves low capital operation & maintenance cost.
- Awareness among the public and other NGOs about the adverse effects of the chemical contaminations should be encouraged.

Water quality assessment and characterization in Pondicherry region

Objectives

I. Assess the spatial and temporal variation of major and trace elements in the ground water and surface water of Pondicherry region and to understand the process controlling the seasonal variation of these elements.
II. Determine the spatial variation of the various forms of inorganic nutrients (NO3; NO2; NH4 and PO4) in ground water to evaluate the impacts of agriculture activity in this region
III. Evaluate the residue levels of organ chlorine pesticides in surface and ground waters of this region.
IV. Predict the dispersion and migration patterns of the metals and to establish the geochemical pattern and hydro chemical facies of ground water of this region
V. Study the pattern and extant of salt-water intrusion into the fresh water aquifer system using solute ï transport modelling
VI. Propose the possible water management practices limiting seawater intrusion and to create a comprehensive assessment of pollution with a scientific database.

Findings

In this study an effort has been taken to identify the pathways and contamination of major and trace elements, nutrients and pesticide residues in the ground water of Pondicherry region, a coastal plain in south India. Overexploitation of groundwater and improper management of natural resources, led to the unequal distribution of major and trace elements in nature. Also it can be seen that the major element concentrations are predominantly influenced by natural agencies than anthropogenic activities. On the other hand the trace metal concentrations, nutrients and pesticide residues in ground water indicate that the polluted over lying environment due to manmade activities, is influencing the quality of ground water in Pondicherry region. It is also evident from the numerical analysis that the overexploitation of ground water led to the seawater intrusion in this area.

The problem of pesticides and other agricultural impacts on the ground water and the environment requires a new focus for research and farm management. More integrated farm management and more complete research into integrated farming system is needed, with a focus on efficiency and off-site impacts rather than just maximizing yields. Pesticides and fertilizers will remain as a tool for agricultural production but clearly less toxic compounds can be adopted; greater efficiencies and more judicious use can clearly be employed. To resolve agricultural non point source problems fully, policies for production must be integrated with policies for conservation and environmental protection, if we are to effect a satisfactory balance between efficient and economic agricultural production and protection of our water resources. Thin study suggests that the fresh water resources in this region need to be widened and have to be protected against unwarranted mining and over exploitation of groundwater to meet the ever-increasing demands. If the aquifers e stressed further, the quality of water may deteriorate, making unfit for various needs of the society.

Rengali multi-purpose project: A boon for Odisha

Objectives

Construction of Rengali Multi Purpose Project.

Findings

I. As the proposed tunnel alignment passes through a topographic saddle, rock is weathered up to and beyond tunnel bed level, adequate fresh rock cover above the crown of the tunnel is not available and tunnelling is to be done below the water table, the present alignment is not considered as favorable for tunnelling.
II. Weathered khondalite will from the tunnelling medium. This is not considered as a good medium for tunnelling.
III. As deeply weathered khondalite sometimes form lithomergic clay along shear zones or discontinuity place in association with water and since the tunnel will be driven below the water table, the possibility of occurrences of flowing ground condition and formation of deep cavities cannot be ruled out.
IV. As rock cover is very low, tunnelling by conventional blasting may give rise to cavity or chimney formation. Heading and benching method of tunnelling is to be followed.
V. Due to the absence of 2D rock cover above the crown of the tunnel, good arch action to sustain rockland may not develop causing tunnel, good arch action to sustain rockload may not develop causing tunnel collapse even before installation of support.

VI. The poor RQD and rock quality (Q) of the weathered khondalic possibly indicates its how stand-up time. Hence, support is to be provided even before mucking operation.
VII. These details were placed before the technical advisory committee (TAC) on 10.12.99for taking a decision.

Ecophysiology of tree species to evaluate bio-drainage potential for waterlogged soils of Haryana.

Objectives

I. To understand perspective of trees in providing drainage under given agro ecological conditions and identify potential trees for biodrainage in irrigated semi-arid region context.
II. Provide useful data and parameters that can guide planning and design of biodrainage schemes and their management in locational context
III. Build database that can be used for modelling the water use as well as salt and water regime dynamics.

Findings

- The Fabrication of sol-embedded PVC lysimeter design is a simple and cheap innovation that can be issued by other workers especially for tree water use studies here the tree to tree space can be extended as per requirement without any additional expenditure. Tree water use quantification using lysimeter of different architectures for specific objectives continue to be a contemporary scientific priority.
- Our findings that average consumptive water use of trees may vary from 16 L d^{-1} to 47 L d^{-1} are in agreement with values quoted international literature using different techniques. As a matter of fact, information obtained from lysimetric studies are more exact as compared to many such values arrived at using energy balance equations, sap flow or stomata conductance, where scope of error is much more. the dependence n various means to compute such values are situation specific a per objectives of the experimental worker. in any case our results also show a positive correlation of physiological micro-traits like stomatal density , stomatal; conductance and potometric water loss with tree water use or biodraingae potential.
- Our results on the effect of various meteorological factors on biodrainge are an important confirmation othe known findings, but we assest that for real time bio drainage (evapo-transpiration) trends instead of depending on parameters like relative humidity it is better to focus on vapour pressure deficit.firther factors like overall incident radiation or temperature may have an over diving role over water was from leaves instead of physiological micro-factors like stomatal conductance and meteorological factors like sunshine hours at a particular area location.
- Our findings reaffirm the fact that in a shallow water landscape a ócone of depressionô is formed below the tree plantations (see Heupermann et al., 2002). However, our investigations are first or their own kind in literature where the comparative bio drainage potential of different tree species in demonstrated by comparing the percent magnitude of the water table depression under ten strips planted with different tree species vis-a-vis a fallow control strip.
- The fact that bio drainage plantations lower water table is known from the work of Australian scientists and the Indira Gandhi Naher Project (Heuperman et al. 2002). However, bulk of these studies involves óblock plantationsô. Block plantations are very effective but these do not fit into the agro ecological

landscape of south-west Haryana where water logging occurs in several large but randomly distributed pockets, land holdings are small and fragmented and space for effective block plantations may be out of question. In this region the farmerôs field raised bund strip plantation model suggested by our collaborations (Dr. Jeet Ram, Haryana forest department) and co-investigator (Dr. O.P. Toky) (See Ram et al. 2007, 2011) is a win-win option for the farmers. This model has been validated by our studies using tree species other than *Eucalyptus* as well.

- In semi arid south west Haryana where the ground water is saline and liberal canal irrigation is practiced there is problem of rising saline water tables. The identification of water logging tolerant fast bio drainers like *Eucalyptus* clones, Tamarix aphylla and prosopis juliflora shall be a boon. In north-eastern Haryana on the other hand the ground water aquifers are sweet and have been subjected to indiscriminate exploitation for irrigation, industrial and urban use. Here there is a serious problem declining sweet water tables and development of vast pockets of ñdark zonesò (Angrish et al. 2006). The plantation of fast bio drainage like *Eucalyptus* in these areas, which can strike ñsinker rootsò down 20 m to access deep water tables, may prove to be an ecological disaster. Here plantation of slow bio drainers, as also identified in present studies, should be considered. In this connection the identification of slow bio draining species like terminalia Arjuna is significant. Their slow biodrainage potential can also be correlated to their summer deciduous nature. These have low leaves area values and biodraingae values when the evapotanspiration demand is at its peak in end April and May. These are several other summer deciduous trees like Cassia Fistula that also follows such cycle. Exploitation of such species and their utilisation should be a matter of interest and investigation.

Energy dissipation on block ramps

Objectives

I. To examine the manifold hydraulic parameters characterizing energy dissipation on blocks ramps with an experimental model.
II. To simulate the effect of various permutations and combinations of boulder concentration, size and spacing with respect to relative energy dissipation on the ramp. The present study is focused on finding optimum configuration of boulders in staggered pattern.
III. To study the effect of slope with different configuration of boulders on the ramp, and the variation in resultant energy dissipation.
IV. Test the applicability of the existing relationship for the estimation of energy dissipation on the block ramp with various arrangements of the macroroughness elements. The relationship for the evaluation of energy dissipation on smooth ramp, ramp with base material and ramp with boulders in staggered arrangements of boulders of different sizes on base material is to be validated with the experimental database derived in the present study
V. To develop relationship for the energy dissipation incorporating ramp & boulder physical parameters and flow parameters.
VI. To develop design rules and recommendations to protect water resources and hydraulic structures using ramps.
VII. To study of air concentration and stability of the block ramps.

Findings

- In general, it was found that relative energy dissipation increases with the steeper slopes in various conditions of block ramps in the tested conditions . while , there is no significant variation with slope.

- The Reynolds number was found to range from $2.55*10^4$ $10.68*10^4$ with a distinct association for each tested slope with the respect o the relative dissipation in the tested conditions. The froud number was found to range from 1.64 to 3.98 and had low corleation with the relative enrgy dissipation in the tested conditions.

- On the smooth ramp, it wasa found that relative energy dissipation on the teasted ramp slopes : for 1V:5H in the range of 54 to 71% , for 1V:7H in the range of 30 to 49% and for 1V:9H in the range of 12 to 35 %. When the relative energy dissipation was evaluated using the Pagliara and Chiavacinni (2006a) equation with the observed dataset, it was inferred that the computed relative energy dissipation was in parity with observed values for 1V:5H sloped ramp. However, the same relation estimates the relative energy dissipation for the other two slopes i.e. 1V:7H and 1V:9H, by more than 10%.

- On the block ramps with base material, intermediate roughness conditions were found to mainly prevail for the tested range of base material with $1.95 < h,/dsp < 5.81$. The rate of energy dissipation was found to gradually decrease with increase in h,/H and with descent of the ramp slope. Few indications were found that the block ramp with $S < 0.14$ can dissipate more energy than at steeper slopes within $0.10 < h,/H < 0.26$. :

- No significant effect between the angular and round base material (for the same ds size) was being found ascribing the relative energy dissipation function on block ramps with base material in the tested conditions ($0.07 < h,/H < 0.26$).

- For block ramps with base material, the relative energy dissipation AE, on the teste dramp slopes found were: for 1V:5H in the range of 67 to 82 %, for 1V:7H in the range of 61 to 73 % and for 1V:9H in the range of 48 to 63 %. When compared with the mooth ramp for each respective slope, a significant increase in the relative energy dissipation was found with base material. The difference increased as the ramp slope gets flatter ($S' < 0.20$).

- When the observed relative energy dissipation on block ramps with base material was compared with that evaluated using the Pagliara and Chiavacinni (2006a) relation, an overestimation by more than 5% of the AE, values were noted for $0.07 < h,./H < 0.26$.

- The values of the two roughness parameters FE and F (functions of arrangement and roughness of boulders), which was postulated by Pagliara and Chiavacinni (2006b) : were found to be 0.23 and 11.6 respectively, for boulders in rows arrangement and rounded (smooth) condition in the present study. The new values of these two parameters can be considered more suitable for larger boulder sizes ($Dg > 0.042$ m) from that adopted by the authors in their study.

- It was found that the boulder block ramps with staggered configuration yielded higher energy dissipation than the rows configuration, for same longitudinal spacing of : boulders of same size and test conditions ($T = 0.10$ ð 0.12 and $0.07 < h,/H < 0.26$).This is in congruence with the findings of Ahmad et al. (2009).

- On the 1V:5H slopedð boulder block ramp, closer spacing with S,/Dgz < 1.5 and certain non-uniform configurations exhibited higher dissipation of energy than the uniform : distribution on the boulder block ramp with staggered configuration.

- For larger boulders with W/D z < 3.0 on the 1V:5H ramp slope, it was found that there : is negligible effect of the boulder spacing and distribution on the relative

energy dissipation AE,g as depicted by the 0.10 m diameter boulders in the tested conditions : (0.05 <h,/H < 0.12).

- For the 1V:5H slopedð boulder block ramp, the relative energy dissipation observed was between 73 ð 92 % for the range of various boulder concentration using five boulder sizes in the flow parameter range 0.05 < h,/H < 0.12, and it was found that AE;gz decreases appreciably as the flow parameter h,/H increases.

- On the 1V:7H slopedð boulder block ramp, intermingling trends of the relative energy dissipation were observed. For the smaller-sized boulders (Dg < 0.055 m), larger spacing exhibited slightly higher dissipation of energy than that ascribed by the closer spacing (S,/Dg < 1.5).

- The non-uniform distribution in the staggered configuration of boulders on the 1V:7H slopedð boulder block ramp exhibited higher dissipation of energy than the uniform distribution especially in the case with bigger boulders for Dg > 0.080 m.

- For the 1V:7H slopedð boulder block ramp, the relative energy dissipation observed was between 74 ð 83 % for a boulder concentration range of T = 0.14 ð 0.29 and flow parameter range 0.14 <h,/H < 0.29.

- No significant effect of the boulder spacing or distribution was found for the smaller boulder size tested (Dg = 0.042 m and 0.055 m) on the 1V:9H slopedð boulder block ramp. This condition was also found on the 1V:7H slopedð boulder block ramp. Hence: it can be affirmed that at slopes S < 0.11 for W/Dg > 5.5, the boulder spacing and distribution is not significant in describing the relative energy dissipation within the test conditions. "

- The non-uniform (NU-4) configuration exhibited higher dissipation of energy than the other tested configurations in the case of biggerð sized boulders (for Dz = 0.065 m and 0.080 m) on the 1V:9H slopedð boulder block ramp.

- For the 1V:9H slopedð boulder block ramp, the relative energy dissipation observed was in the range of 67 to 77 % for the flow parameter range 0.18 < h,/H < 0.26, and AE,g decreases considerably as the flow submergence increases, for the range T° = 0.19 ð 0.29.

- It was found that there was a rise in the relative energy dissipation trend with increase of boulder concentration upto a certain range of T beyond which further increase of boulder density led either to decay of the AE,/AE, function or it remained constant. This threshold boulder concentration was found to be in the range 0.22 ð 0.25 for the tested boulder sizes and configurations (0.08 < I< 0.32).

- The analogy of flow resistance with the relative energy dissipation on boulder block ramps have been examined in terms of the resistance function (8/fy" * and it was found that this function varied inversely with the relative energy dissipation function, asserting that higher flow resistance described by the friction factor f, showed increase in the energy dissipation on boulder block ramps.

- A modified relation based on the Sayre and Albertsonôs (1961) relation has been 7 presented to evaluate the longitudinal and transverse spacing of boulders on block ramps with staggered boulders. The relation Eq (4.7) may be satisfactorily used for block ramp applications for the range T = 5 to 35 %.

- A relation (Eq. 4.13) has been formulated for computation of relative energy dissipation on block ramps with staggered configuration of boulders. The relation can be used satisfactorily within + 5% error limits for the range [= 0.17 ð 0.30 and 0.05 < h./H < 0.29. The same relation has been also presented in terms of coefficients which are specific for particular boulder ranges as given by Eq. (4.14) to provide more accurate estimation of AE,;g in practical applications of boulder block ramps. Design recommendations and guidelines for practical application of boulder block ramps have been formulated based on the findings of the present study.

- The critical discharge for the stability of the block ramp increases with non-dimensional parameter d*5) while decreases with chute slope. The critical discharge also increases exponentially with the increase in uniformity coefficient of the boulders.

- The data of Robinson et al. (1997) and present study are used to arrive at a specific relationship, i.e. Eq. (4.16) for critical discharge estimation at local failure. The pro- a posed relationship satisfactorily estimates the critical discharge at local failure with 30% error.

- Due to scale effect, aeration in flow was not noticed downstream of the block ramp for all the range of data.

Water laws in India: An Assessment and way forward

Objectives

I. To provide a brief analysis of the constitutional provisions related to development and management of water resources in India.
II. To provide a consolidated picture of both central and state water laws in India at one place. This would include laws dealing with not only canal irrigation but also ground water, flood management, environmental and inter-state aspects. An attempt is also made to ascertain and examine the well established local practices having force of law with respect to water sector.
III. To examine the present legal status with respect to privatization and public-private partnership in the water resources sector.
IV. To make a critical review of the water laws including local practices having force of law, with respect to (i) attaining such national objectives as water use efficiency , equity , environmental sustainability and inter-state harmony specially in the light of future challenges facing the water resources sector in India(ii) their implementation at the grass root level
V. To find out extent of implementation of 73rd & 74th constitutional amendments brought about in 1992 with respect to water in different states of India and reasons for slow progress, if any.
VI. To analyse the present status with respect to ownership of and rights to water in India with particular reference to the new challenges and new developments in water sector.
VII. To provide suggestion for improvements and indicate action points so as to facilitate better managements of water resepources.

Findings

1. Water Laws and the Three Es

- Efficiency, Equity and Environmental sustainability (the three Es) are now regarded

as the basic objectives of water resource management. But the legal system for water resources in India is weak in facilitating attainment of these three objectives.

- Efficiency in canal irrigation is marred by lack of accountability of the canal irrigation bureaucracy for its inability to provide adequate and timely supply of water because of the protection provided to canal officers in the laws. Even the enactment of PIM legislation has not made much change in this respect. This deficiency is aggravated further by the, legal provision whereby determination of water rates is left to the complete discretion of the government which, guided by political considerations, has made canal irrigation highly subsidised or even free in some states. As a result, farmers too have little incentive to save water and to be demanding for a more efficient delivery system. Provision for assured supply of water to farmers at least during years when rainfall is normal or above normal should be made in the law. In case of dispute, failure to supply water should be looked into by an independent legal authority.
- Proper maintenance and upkeep of canals, which is necessary for their efficient operation, requires finances and this inevitably raises the question of water charges.Even the existing water charges, which are not paid in many circumstances, are far less than the expenditure needed for proper operation and maintenance of the system. In this context, the fact that the Irrigation Acts themselves do not lay down any criteria or rationale for determination of these rates represents a glaring omission in these laws. Maharashtra seems to have taken some lead on this aspect by putting a regulatory mechanism in place that other States could use to their advantage.
- Suitable legal measures are needed to break the vicious circle of low water rates, lowrecovery, inadequate funds for maintenance, poor maintenance, poor delivery system, little accountability, low recovery and so on. For this, it is necessary to provide for accountability of irrigation department and ensure its compliance by instituting an independent,transparent and speedy dispute resolution and grievance redressal machinery on the other or assigning this responsibility to an independent agency as envisaged in the new law on water regulatory authority as in Maharashra

2. Water Rights @

- e The Right to ópollution free waterô and the right of access to ósafe drinking waterô have been included as part of óRight to Lifeô under Article 21 of the Constitution of India through a liberal and activist interpretation of the fundamental right to life both the by the Supreme Court and the High Courts of the country in a series of cases.
- Mere right to water is not enough if people do not have water, which is safe to drink. In India, there are no legislated standards to define clean water, unlike other parts of the world. The right to water should inspire a simultaneous movement towards laying down a framework of laws/regulations that would support such a right e.g. the minimum quantum of water needed per person and the quality of water defined in easily measurable terms.
- The water rights regime needs to evolve conditions under which a group entity can e also become a right holder so that an entity like a legally constituted Village Water yo and Sanitation Committee (VWSC) or a Water Users Association (WUA) can @ exercise such rights to its advantage.

- The VWSC needs to be given legal footing and for this necessary amendments should be made in existing Panchayat laws. Some States provide for ñStanding/ Subject Committeesò for water supplies with the Panchayats but others donôt. There is no reason why there cannot be a uniform approach on this institutional aspect in all State laws.
- When it comes to planning and management of rural water bodies, a review of the legal provisions show that they are not clear and categorical on the question of vesting rights with people including right of ownership over local water sources and structures. The legal regime needs to respond to a growing feeling that without a sense of ownership, villagers including farmers will not participate in the maintenance of the structures. This ósense of ownershipô should not be an illusion but grounded on peopleôs right to water and their ownership over local water harvesting structures.

3. Water Righ

- A Striking aspect of Indiaôs Participatory Irrigation Management (PIM) programme is the little attention that is given to water rights. It has meant that the governments rights to water are unchallenged, while its obligations to deliver water to WUAs are rarely legally binding.
- The laws giving effect to PIM do not make it clear that if the right to receive water in bulk from the irrigation department is not honoured what remedies might lay with the (An exception can be made for the years when rainfall is much below normal).In other words, whilst there is a generally worded right, there is no accountability of the department.
- A problem from a rights based perspective of the State laws is that even while these laws require that the Distributary Committee and the Project Committee need to be constituted as farmer bodies, they have not been constituted in most of the States. This has meant that powers that were required to have been vested with these bodies under the law have not been realized. These bodies should be established by making it mandatory for the states to do so within a specified period of time

Study of characteristic features pertaining to bio-drainage potential of some selected tree species

Objectives

I. To understand the perspective of trees in providing drainage under given agro-ecological conditions and identify potential tree species for bio-drainage in the region/area.
II. To evaluate transpiration and aboveground plant characteristics of some selected trees species having bio-drainage potential in relation to varying surroundings.
III. To assess stomatal behaviour and rooting characteristics of tree plants under study.
IV. To evaluate the capacity of plants to tolerate waterlogging and soil salinity and understand their adaptability mechanism.
V. To determine the relationship of plant water use and biomass characteristics.
VI. To assess the one-site impact in terms of soil salinity and salt harvest by plants.
VII. To provide useful data and parameters that can guide planning and design of bio-drainage schemes and their management at region level.

Findings

The growth behaviour, biomass accumulation by the plants and physiological parameters suggests that E. rudis has high potential to be used as an efficient bio-drainage species in IGNP area. Apart from the planted species, prosopis juliflora, Tamarix dioca and Saccharum munja also have come up in the area with recession of ground water table as natural succession and contributed significantly for further lowering of ground water table and increasing productivity. Which suggests that along with tree species shrubs and bushes can also play a major role in increasing productivity of waterlogged area. Soil working may be a viable option in assisting regeneration of local species growing nearby.

Under simulated condition of waterlogging and salinity growth, physiological parameters, biomass, root behaviour and water use characteristics OF A. Nilotica, E. camaldulensis and T. Aphylla indicated that salinity significantly ($p<0.01$) reduced all the parameters in all the three species under test, compared to non saline treatment. Water logging alone affected only few growth parameters significantly. Eucalyptus camaldulensis plants in W3 S3 treatment started wilting permanently at the age of two year (22 months after the water logging and salinity treatments initiated). Native species, Acacia nilotica and tamarix aphylla showed higher tolerance towards salinity compared to E. Camaldulensis and may be a better option for planting in waterlogged areas with higher salinity (opto 10 dSm-1). Though above ground dry biomass was high in A. Nilotica followed by E. Camaldulensis and T. Aphylla, below ground dry biomass was high in E. Camaldulensis followed by A. Nilotica, and T. Aphylla total dry biomass was however, high in E. Camaldulensis followed by A. Nilotica and T. Aphylla. Hence for biodrainage point of view A. Nilotica may be batter choice over E. Camaldulensis and T. Aphylla by virtue of greater water use and above ground biomass. However, E. Camaldulensis may be better option considering carbon sequestration aspect because of high total biomass under non saline waterlogging condition.

Extension of some low cost lining materials for increasing the area of irrigation commands

Objectives

I. To examine the hydraulic characteristics of the channels made of identified low cost lining materials
II. To demonstrate the performance of the lined channels in farmersô fields
III. To educate and train the farmers/users towards selection and use of lining materials
IV. To evaluate overall impact of interventions on irrigation commands

Findings

I. The costs of conventional lining materials, viz. bricks, steel reinforced concrete, stone, etc. keep away the average Indian farmers in lining their irrigation channels by using these materials. The bamboo-reinforced precast concrete of appropriate diameter can be suitably used in irrigation & drainage channels. The channel sections are suggested to be fabricated at close as possible to the channel site to avoid the chances of breakage during transportation. The maximum diameter section of 50cm can be constructed by using the moulds used here and these sections can permit the discharge of 40l/s at 0.35% slope. However, in DTW & STW commands 36.4cm (14 inches) diameter sections are of sufficient capacity. The farmers have preference to bamboo-reinforced concrete channels over other channels made of non-conventional materials.

II. The burnt clay tiles (half round) of 35cm diameter and trapezoidal section made of 45cm length, 25cm breadth and 2cm thick flat earthen roof tiles are of sufficient capacity for carrying the water for average condition in DTW & STW commands. The seepage loss of these channels improves with the passage of time due to fill up of the pore spaces in it by finer particles. It is less costly & easily can be made by the

local artisans; however, farmers donâ t have the preference unless their fields are protected against cattle traffic or other disturbances.

III. The utility and economy of these lining materials need to be more focused to the concerned departments of the Govt. associated with financial & technical assistance to the irrigation or drainage channels. Unless it is accepted in principle and incorporated in regular works schedule of the departments it is difficult to get wider acceptance. The CWC may take initiative to this.

IV. On an average the 15-20% of area or cropping intensity or both have increased in irrigation commands where the project works are implemented.

V. CWC may undertake more & more such extension activities towards saving of scarce irrigation water**.**

Identification of suitable tree species and other vegetation for biodrainage in Bargi command area (Jabalpur, M.P.)

Objectives

I. To drain out excess water of the soil in water logged/canal seepage areas through vegetative means.
II. To reduce or prevent salt concentration in the root zone.
III. To enhance the site productivity through (a) and (B) above.

Findings

The present study was proposed to identify suitable tree species to drain out excess water of the soil in waterlogged sites of canal command areas through biodrainage and to enhance the site productivity in Bargi command area (Jabalpur, M.P.). To achieve the objectives, two sets of experiments were conducted under the project. First set of experiments were conducted along left bank canal of Bargi command area, where a plantation of 10 ha area including 7 tropical forest tree species viz. Acacia nilotica, Albizia lebbek, Albizia procera, Dalbergia sissoo, Eucalyptus hybrid, Pongamia pinnata and Jerminalia arjuna was raised. Strip plantations were raised along the canal and the effect of each tree species on underground water table was observed by installing 10 feet size observation wells in each plantation at different distances from the canal. Out of the seven tropical forest tree species planted along left bank canal of Barg command area, F. hybrid, followed by P. pinnata and T. arjuna was found to have significant effect on lowering down the water table in the canal command area, although average water use by A. procera and A. lebbek was found more than 7: arjuna under lysimetric experiments. This could be attributed to slight variation in climatic conditions between lysimetric tanks (Tropical Forest Research Institute) and plantation sites (canal command areas) because monthly variation in water table due to tree plantations was found directly related to temperature, humidity and rainfall. Depth of water table in plantations of all the tree species gradually increased from January to mid June, with the increase in maximum and minimum temperature. After this period, water table suddenly
increased due to decrease in temperature and onset of rainfall in the second half of June. In July, August and September the water table continued increasing in all the plantations due to high rainfall. Maximum decline in water table in £. hybrid plantation was observed at 14.00 ð 16.00 hours in summer. Maximuin height was attaitied by E. hybrid, followed by P. pinnata and A. nilotica, while maximum girth was found in D. sissoo, followed by P. pinnata and E. hybrid in the plantations raised along left bank canal in June 2011. The results partially corroborate the growth characteristics of similar tree species planted in lysimetric tanks, where during this period maximum increase in height was found in E. hybrid, followed by A. procera and A. nilotica under 0 ð 0.25 m water regime. Four and half years old trees of £. hybrid annually accumulated maximum biomass, which was followed by P. pinnata and D. sissoo planted along canal command sites.

In the experiments simulated in lysimeters, most of the selected species performed better under water logged conditions compared to control, which could be due to their high water requirement. Eucalyptus hybrid, Pongamia pinnata, Albizia procera and Terminalia arjuna

exhibited their maximum growth values under 0-0.25 m water regime.

Maximum water use on per day basis was found in Excalyptus hybrid, followed by Pongamia pinnata under different depths of water logging in lysimeters. Water use by the species decreased with increase in depth of water logging, which could be due to more surface area of roots in contact with soil water. Significant monthly variation in water use was observed in the species under test, which was directly related to the climatic conditions.

The transpiration rate was found maximum in E. hybrid, followed by P. Pinnata and 7. arjuna in control or non-waterlogged conditions, but under water table maintained at 0 - 0.25 mi, 0.25 - 0.50 mi atid 0.50 - 0.75 m peak transpiration rate was observed iti P. pinnata, E. hybrid and D. sissoo respectively. The results showed that with the increase in : water logging, transpiration rate increased in all seven species. Peak transpiration was observed at 12 hour during the period for most of the species, but for some species the peak period shifted to 11 hour or 13 hour.

E. hybrid and P. pinnata showed the best performance regarding growth and biomass accumulation. Higher biomass in £. hybrid and P. pinnata and proportionately higher allocation to leaves and branches in P. pinnata might have resulted the higher transpiration rate by these species. Moreover, higher water use by these tree species support the fact that these species exhibited steady rate of transpiration throughout the year in comparison to other species. If rate of transpiration is the indicator of plant water use, it was found maximum for £. hybrid and P. pinnata. :

Waterlogged areas in India cover about 2% of the irrigation command areas due to which land is degraded and growth of trees is adversely affected by deficiency of oxygen causing reduction in site productivity. Biodrainage is the vertical drainage of soil water through evapotranspiration by vegetation and is the eco-friendly approach to manage ground water table. In the present study, £. hybrid and P. pinnata were found to have steady rate of transpiration, more water use and higher biomass, hence these species have high potential to be used as efficient bio-drainage in Bargi command area and can be used for plantation purpose for reclaiming water logged areas. The strip plantation including these species can be done along the canal in rows and the number of rows can be decreased with increasing distance from the canal. The suitable gap between the group; of rows can be maintained to facilitate the agricultural operations. This way, the waterlogged sites in canal command areas can be managed and site productivity can be enhanced to certain extent

Capacity building of women for natural resources management in command areas

Objectives

I. To propagate the management strategy developed by CWRDM for mainstreaming women in irrigated agriculture through grass root level organisation and thus to strengthen the existing Water User Associations.
II. To empower selected women and grass root level organizations in the mainstreaming process through appropriate front line demonstrations and thus to capacitate women for taking up location specific activities of natural resources conservation and management in a scientifically sustainable manner

Findings

The training and demonstrations which were undertaken in the project had great impact on empowering the women in various aspects of natural resource management. The activities were centering around the scientific management of land, water and biomass. It could be understood that the project could make considerable impact on the target women.

The knowledge gaps could be bridged in various aspects like mechanical and

biological measures of soil and water conservation, organic farming, organic manure production, vegetable farming, fodder production, water conserving irrigation methods, vegetable farming, water resource development and management, team building and leadership skills, accounting and book keeping etc through demonstrations, practical training, field visits, lecture sessions etc.

The front line demonstrations were useful for empowering the selected women groups and also for technology transfer to the farmers of the nearby panchayaths, school children as well as to their neighbours. Moreover, they had transferred the experiences and knowledge gained to others when they had group meetings in the associations in which they are members eg. kudumbasree etc.

As a result of the project, the perception and attitude of the target women towards natural resource management changed and they became confident to be ambassadors of the activity to other areas as well.

There had been considerable social empowerment since the women could express their problems, needs, priorities, ideas etc.

The experiences in the project had considerably empowered the project officials to study the problems and prospects of such an initiative. Based on the experiences, some of the replicable strategies are presented below.

- Women must be educated and motivated properly and sufficiently to overcome their shyness, recognize their capabilities, understand their own needs and desires and limitations and develop a strong will to achieve their goals.
- It is advisable to include lady extension workers in the project aimed to empower women in any activity.
- Activities generating income directly will have to be included in the project, since this will attract participation at the initial level.
- Efficient communication with the grass root level women should be ensured by being with them, being friendly to them, working with them and understanding their life and explaining the things in multiple ways in their local dialect.
- it is advisable to formulate unbiased laws and administrative practices to ensure womenôs equal rights to natural resources, credit and social status.
- Training, awareness and demonstrations on alternate livelihoods will have an everlasting impact on the minds of women; it will lead them to adopt new income generating activities, health care and other technologies to which they were hitherto averse. Commitment of responsibility and positive community participation.

Development of integrated irrigation information system (IIIS) for a part of nagarjuna sagar command area, Andhra Pradesh using Remote Sensing, GIS, GPS and field studies.

Objectives

I. The land use map will be utilized as a basic database, which provides the information for allocating new land use practices.
II. It will incorporate demographic, economic and environmental impact, which has occurred in an area.
III. Not only will the information indicate where intensive development has already taken place and where there is open land suitable for future expansion, but it will also make it possible to determine special areas, such as prime agricultural lands.

IV. Land use/ land cover map will serve as a basis for monitoring land use change.
V. The land use map will serve as a base in the integrated overall planning of agricultural and industrial development of the region.

Findings

- Irrigation units in developing countries have an enormous range ð from several thousand hectares in the case of Government-sponsored commercial farms, to less than a hectare in the case of small family units. For instance, high-pressure sprinkle systems are cost effective in the case of large farms, whereas microsprayer or bubbler systems may turn out to be more suitable for family units.
- It is not possible to design a universally applicable system of efficient use of water in irrigation because of the complexity of the variables with regard to soil, water, climate, crop and people, and because of the need to be compatible with other inputs such as seed varieties, fertilizers, tillage, pest control, etc.
- Advances in information technology have made it possible to optimize the various system variables. Efficiency of water delivery needs to be optimized in terms of conveyance of water with minimal losses (say, in closed conduits), capability to provide measured amounts of water calibrated to meet the needs of crops in time and space, while preventing wastage, salinity, and rise in the water table.
- Efficiency of water utilization is to be optimized to low-volume, low-pressure, high-frequency, partial-area irrigation to achieve high crop yields (Hillel, 1987, p. 99).

Action research on-farm water management for paddy through farmer's participation

Objectives

I. To study water use efficiency in irrigated rice under channel to field method compared to the traditional practice of field method of water distribution.
II. To identify factors which would help to promote adoption, and constraints in adoption of this improved OFWM practice among farmers.
III. Extension of improved/scientific OFWM practice among farmers through conducting seminar on OFWM practice among farme.

Findings

The results of the studies carried out under this project reveal that majority of the farmers are not aware of scientific irrigation scheduling for paddy, even though: many of them are aware of channel to field method of irrigation. A good proportion of them also agree that it is better than field to field method. However, they cite genuine constraints in adopting it such as cost involved, lack of group action in paddy farming (which will be necessary to implement the irrigation method in a large proportion of the command area), availability of excess water etc. Only 12.2 % of farmers are aware of scientific irrigation scheduling for paddy, and 38.8% about the quantity of water applied to the crop. 34.9 % reported uncertainty in water availability as the most important reason why they are not interested in being aware of scientific water management.

96.2% of the farmers, who express good opinion about channel to field method mention better water management as the reason for it, while 46.2% report full utilization of fertilizers through this irrigation method as the reason for preferring the method. Of the farmers preferring field-to-field method, 7.8% report convenience in water management as the reason, while, 17.3% were not sure about the benefit of channel to field method.

Ranking of constraints in adoption of channel to field method reveals that the most important constraint is non-conviction about the method. This may probably be due to small landholdings and low income from paddy, which act as a de-motivation for farmers to adopt improved practices. The next important constraint reported is excess water availability, which makes it difficult to adopt channel to field method. Lack of group action in paddy cultivation is the third constraint. The experience of group farming in rice cultivation, implemented by the Agriculture Department in Kerala, was not promising. Group approach is required to implement channel to field method in a good proportion of the command area. Cost involved is cited only as the fourth constraint in adoption of channel to field irrigation, implying that if water supply can be

controlled, and there is group approach in rice farming, cost will not be a problem. Some more constraints were mentioned such as land occupied by channels, fear of loosing land ownership etc.

Infrastructure assessment carried out in Ichannur sub distributory, which conveys water to the study area, shows that the problems include visible siltation, cracks in canal lining and embankment and unlined portions of the distributory. 37.1 % of the distributory Is unlined, causing considerable seepage loss. Of the lined portion, 83.3% is damaged with cracks, which promote leakage and water loss through weed growth. Visible siltation of about 1 cm is observed on the distributory. In all the control structures, gates are missing or in a damaged condition, implying that the distributory and control structures are ill maintained. Hence, water seeps down, causing water logging and without supplying sufficient water to the tail end farmers. Normal value of seepage loss for different soils in Kerala is reported to vary from 0.8 I/sec/1000m^2 to 6.4 I/sec/1000m^2 . However, the average seepage loss in the distributory in the study area is found to be very high, of the order of 86 I/sec/1000m? in the head reach, and 72 I/sec/1000m^2 in the middle reach. This indicates the need for lining the canal with appropriate measures to improve the water conveyance efficiency, which will ensure adequate and timely water availability, a condition necessary for motivating farmers to adopt improved on-farm methods like channel to field irrigation.

In the study on water use efficiency, the quantity of water used under the channel to field trial plot is 1505 mm/ha, while for the field to field irrigation plot, it is 1879 mm/ha. During the first year of the trial, yield obtained under channel to field irrigation is 2087 Kg/ha and 2252 Kg/ha under field to field irrigation, while the water use efficiency under the former method is 1.4 Kg /mm of water applied, and 1.2 Kg/mm under the field to field method. During the second year of the trial, yield of rice obtained is 2500 Kg/ha and 2600 Kg/ha under channel to field and field to field method respectively. Water use efficiency during this irrigation season is found to be 1.7 Kg /mm in the channel to field irrigation plot, and 1.4 Kg/mm under field to field irrigated plot. Similar to the first year of trial, a water saving equivalent to 37,40,000 litres/ha has been achieved through adoption of channel to field irrigation during the second year also, maintaining more than 90% of the yield obtained under farmer's practice of field to field irrigation, in both. The years of study.

From the seminar on improved organized on improved On-farm water management for rice, it is observed that farmers, in general, do not have much interest to adopt channel to field irrigation for their rice crop. The main reasons Cited for non-adoption of the irrigation method include the following namely, lack of interest since they are used to the traditional method of field to field irrigation, non-cooperation of farmers to spare land for the field channels, problem of cattle damage to channels laid out in the fields, absence of group farming, mainly due to lack of sufficient labour and the individualistic nature of cultivation by many farmers, fear of loss of ownership of land where the channels have to be laid out, water stagnation in the field through leakage/seepage of canal and poor drainage facilities in the field, water scarcity existing in the tail reaches of canal, non- availability of water at the proper time etc.

Analysis of the data collected on preferences of farmers towards various water distribution methods shows that there is a significant shift in preferences from Ferro cement channel to earthen channel, when subsidy is reduced from 100% for the former method. However, the rate of reduction in number of farmers preferring earthen channel is comparatively very less, when subsidy is reduced. This is a promising indication for possible change from the traditional method of a field to field having low irrigation efficiency to this relatively efficient water distribution method. With respect to farmers, who give first preference for field to field method, all of them continue their preferences for the same method under all the lower levels of subsidy, Including no subsidy. This indicates that farmers do not necessarily require financial assistance for adopting their traditional method of water distribution. From the above discussion, it may be inferred that, for effecting a significant change over from the traditional, wasteful practice of field to field water distribution for rice to improved OFWM methods like channel to field, it may be required for the irrigation/agriculture department to subsidise the cost of construction/layout of the methods considerably. Even though this may not appear to be a very feasible option under the present scenario, where the emphasis of Governments, including that of donor agencies, is to reduce such type of financial assistance in order to instil a sense of ñownershipò for farmers in their development activities, and accordingly, make them more sustainable, it will be in the good interests of irrigation projects to find out ways and means to finance such improved water management practices tn the command areas. If irrigation efficiency has to improve.

Further, in order to make more farmers properly aware, as well as convinced about improved OFWM practices, it will be required to have suitable extension methods like training,

seminars/workshops, demonstration plots on the practices etc. in various parts of Kerala state. Group approaches to farming should also be undertaken as action research cum demonstration units by the agriculture/water resources departments. in different ôPadashekharamsô through peopleôs Participation, in order to ensure collective adoption of various agricultural practices, including improved OFVVM methods by farmers. These units can serve as successful models of not only group farming, but also better water management methods. This appears to be a necessity in the days to come for Kerala state, when the Governments of other states in the country have already started implementing irrigation management transfer to farmers through Participatory Irrigation Management (PIM). Implementation of PIM in the state, with demand based volumetric water supply to farmers, will ultimately require adoption of efficient water distribution methods in the command areas in order to make the programme self sustainable. Also, once it becomes inevitable for the farmers under PIM programme to adopt water distribution methods like channel to field for efficient, equitable distribution of the measured, volumetric supply of water received from the department, this can also instil a better sense of cooperation among then, which can also help in motivating them to adopt group farming In the long run. PIM programme will then be able to achieve the purpose of economic rice cultivation in Kerala, which, at present, is facing problems due to factors such as high labour cost, labour un-availability, high cost of production, low yield/income, lack of suitable marketing mechanism for farmers etc.

Testing and development of devices for reduction of scour around bridge piers.

Objectives

I. Assess the applicability of collars in reducing the live bed scour when there is sediment supply from the upstream as is mostly the case during flood flows.
II.
III. Quantify the flow pattern around a pier.
IV.
V. To investigate the process of scour around compound piers and to develop a method for computation of temporal variation of scour around circular compound piers.
VI.
VII. Quantify the scale effects through a study of scour around bridge piers on proto type scale pier and validate the effectiveness of the scour reduction devices.

Findings

The scour prediction methods developed in the laboratories and the scour equations based on laboratory data does not always produce reasonable results for field conditions. Scale effect also becomes evident when one considers the similitude requirements for hydraulic modeling of pier scour. Therefore a detailed experimentation on prototype were planned to understand the controlling parameters which influence the scouring around pier. In present project however it was proposed that the field studies (proto type pier) would be carried out by Railway Design Standards Organisation (RDSO) - Ministry of Railways, Lucknow. An abandoned railway bridge located in Moradabad-Ambala route on river Ganga at Balawali in U.P. was selected by the railways earlier for this purpose. However after the approval of present project by ministry of water resources, the investigations on proto type pier by RDSO were not made. Also the facility developed in IIT Roorkee to study the scour around bridge piers on proto type scale did not yield any decisive results. Whereas the flow discharge upto 0.5 m3/s could be generated in laboratory flows under available facilities a rate of flow more than 3 m3/s however would be required to minimise the scale effects in the scour experiments.

Seepage effects on the hydraulics, stability and sediment transport of alluvial channels.

Objectives

I. It is to find experimentally the effects of seepage (injection and suction) on the various parameters like flow depth, energy or friction slope, bed resistance/shear, stability, mobility and incipient motion of bed particles, sediment transport rates of an alluvial channel in non-cohesive (sand) material.
II. Based on the experimental data it is aimed to develop relationships in quantitative terms about the seepage effects on the various parameters as mentioned above.
III. It is also aimed to develop laboratory regime equations by considering the seepage as an explicit variable.

Findings

I. Hydrodynamic effects of both seepages of suction (in downward direction) and injection (in up-ward direction), through alluvial channel bed on several aspects like: (i). Bed resistance; (ii). Stability, mobility and incipient motion of bed particles; (iii). Channel hydraulics, velocity profiles and turbulence; (iv) Stream power concept and its application (v) Design of stable alluvial channels affected by seepage and (vi). The alluvial channel regime with seepage are extensively studied by conducting laboratory experiment.
II. The other investigations leading to the basic understanding on incipient motion without seepage on aspects like (i) Incipient motion of over-riding spheres; (ii) A new incipient motion criterion independent of particle size; (iii) influence of aspect ratio on incipient motion; and (iv) Design of stable alluvial channels without seepage are also studied.

Development of drought vulnerability indices for preparedness and mitigation.

Objectives

I. Identify and characterize drought indicative parameters.
II. Prepare drought vulnerability scenario under different conditions for macro and micro-level units.
III. Capacity building in understandings / realizing the preparedness and vulnerability indices.

Findings

I. The Problems related to drought can be current or could have occurred in the pasta and are expected to could possibly occur sometimes in the future. Hence, an attempt has been made in defining the status quo required creating an inventory of resources that could be used to, make prediction of the future.
II. Geo-spatial data base has been created using the information available from their existing observations units.
III. A shared information approach adopted in this study can be used by people and water resources planners in establishing the status quo, assess the impacts of the status quo and other alternatives. It facilitates the plan implementation, and maintains plan effectiveness in the future. This approach is more flexible and interactive than that of the existing one.
IV. This approach allows way for alternative methods taking into confidence of the peopleôs observation and simplified methods, in reducing the impacts of water

shortage by way of watershed based strategic (long-term in fine-tuning alternatives through sensitivity analysis and also new alternatives) or tactical (short-term in reducing village level vulnerability to drought, or emergency (set emergency plan can minimize severe impact from drought when the anticipated weekly rainfall is reduced)) responses.

V. Timely, effective actions using science ï based drought indicators can be achieved by developing drought preparedness information for producers; assessing water demands and water resources; and monitoring drought-related parameters and creating a spatial data base.

VI. Drought alert actions need proper communications that can be understood and be followed by the affected administrative officers and people in responding to various existing approved drought related programs.

VII. Effective decision making is possible provided, reporting information is based on scientific methods by conducting monitoring, evaluating and reporting on drought-related conditions.

VIII. Drought indicators (physical and bio-physical) need to be monitored continuously. The drought status could be determined according to drought stage (four) ï yearly, monthly and weekly. Color coding could be used in conveying the forthcoming stress conditions (Table 10).

IX. Drought intensity information can be presented by the parameters such as 1) Current rainfall data along with long term average rainfall, 2) monthly totals of rainfall along with decadal rainfall and deviation, 3) the current monsoon cloud pattern could be used and 4) based on the previous (within 5years) drought occurrences and the impacts, rainfall deficiency with reference to certain thresholds could be used and updated.

X. Orbital Satellite images could be effectively used in irrigation water demand and status of water spread areas.

XI. Owing to climate change and the impact on rainfall, meteorological data along with other information could portray the drought intensity (reduced water availability) for preparedness and management.