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Drainage Protects Irrigation Investments



International Institute for Land Reclamation and Improvement / ILRI

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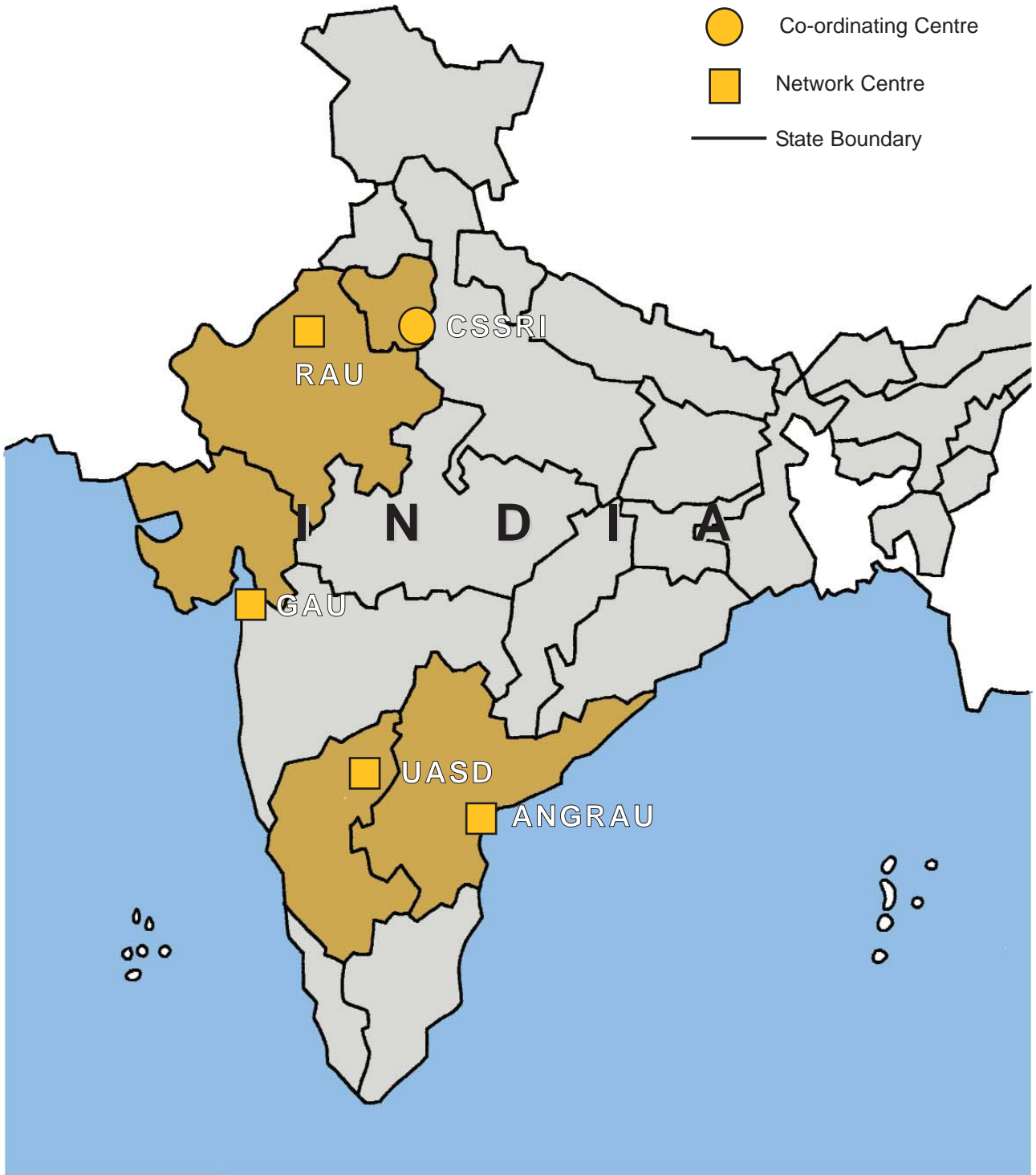
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Map of India showing network centres

BACKGROUND OF THE PROJECT

The Indo-Dutch Network Operational Research Project on Drainage and Water Management for Control of Salinity and Waterlogging in Canal Commands (1995-2002) was implemented jointly by the Government of India through the Indian Council of Agricultural Research (ICAR) and the Government of The Netherlands through the Royal Netherlands Embassy (RNE) in India. The Implementing agencies in India were:

- Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana
- Acharya N G Ranga Agricultural University (ANGRAU), Indo-Dutch Network Project, Bapatla, Andhra Pradesh
- Gujarat Agricultural University (GAU), Soil and Water Management Research Institute, Navsari, Gujarat
- University of Agricultural Sciences Dharwad(UASD), Agricultural Research Station, Bheemaranagudi, Karnataka
- Rajasthan Agricultural University (RAU), Agricultural Research Sub-Station, Hanumangarh, Rajasthan

CSSRI, Karnal was the co-ordinating agency and focal point for all the other Network Centres and technical assistance to the project was provided by the International Institute for Land Reclamation and Improvement (Alterra-ILRI), Wageningen, The Netherlands.

The Project was carried out with the following four long-term, overall objectives:

1. Increase of agricultural production from water logged and salt affected areas through application of proper soil and water management practices along with other agro-techniques
2. Prevention of deterioration of productive lands through adoption of appropriate soil and water management practices
3. Improvement of socio-economic conditions of small and marginal farmers of these lands
4. Development of expertise for handling reclamation projects in India.

From these two Project Objectives were derived:

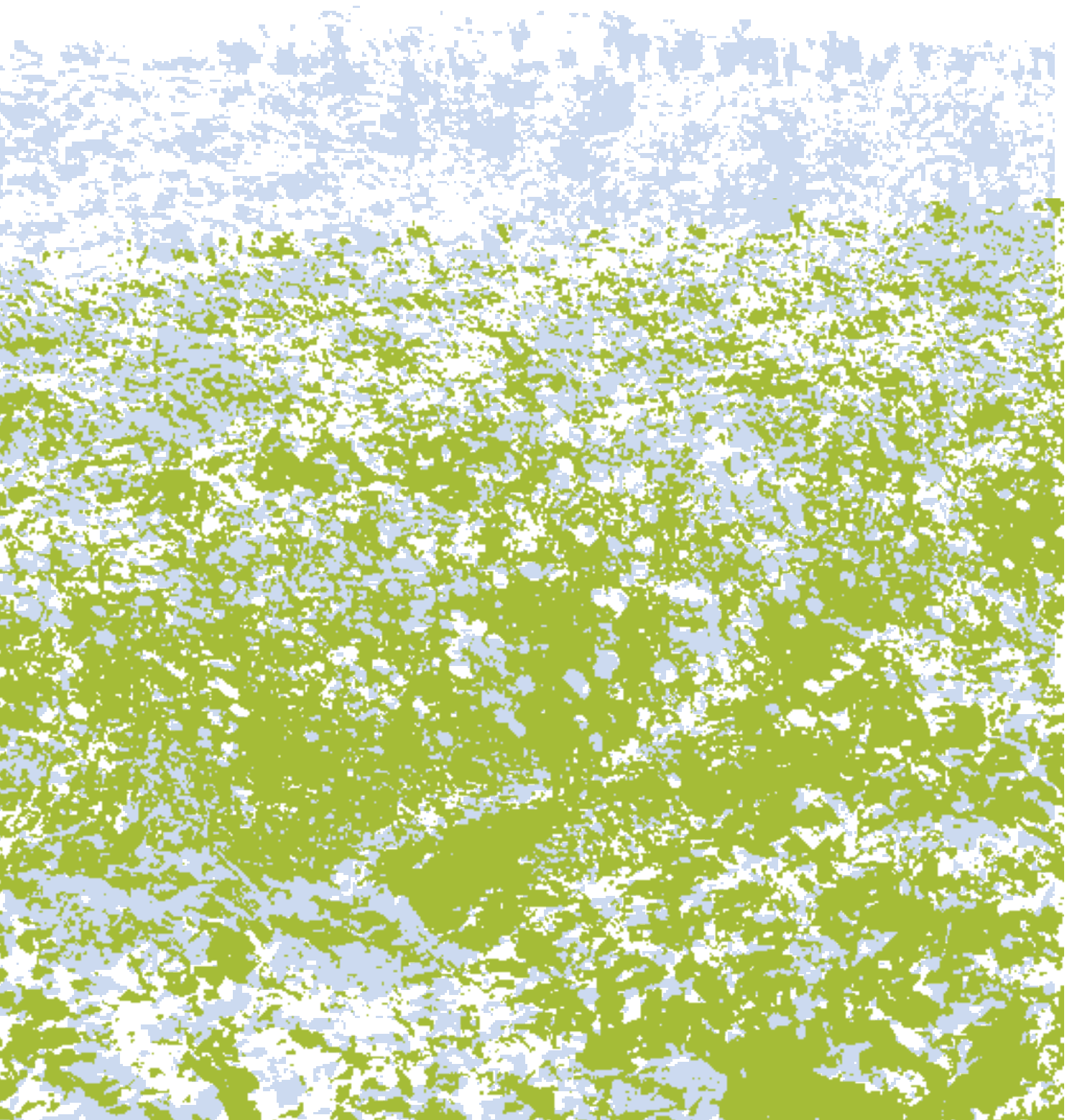
- Strengthened research capacity of CSSRI and the four State Centres, especially in the field of water logging and salinity control;
- Enhanced awareness on drainage and related water management for the control of water logging and soil salinity at State and Central level.

The overall and project objectives were translated in eight project results:

1. A methodology for identification of waterlogging and soil salinity conditions by remote sensing
2. Recommendations on waterlogging and salinity control based on drainage pilot area research
3. Appraisal of irrigation and drainage practices by computer simulations
4. Improved human resources at CSSRI and the four State Agricultural Universities through training
5. Operational Training Centre at CSSRI to conduct national training programmes
6. Enhanced awareness at State and Central Level on the necessity of an agricultural drainage policy
7. Enhanced awareness at farmers' level on improved irrigation and drainage for control of waterlogging and salinity
8. Advice on drainage and related water management

With the intention of developing location-specific drainage technologies for reclamation of salt affected and waterlogged agricultural lands in different agro-climatic zones in the country, eight pilot areas were selected. The drainage strategies developed on the basis of the results of the investigations are presented in this document.

The technical and financial assistance, encouragement and co-operation extended by various organizations and personnel are gratefully acknowledged.



1 INTRODUCTION

Agriculture is a key sector in India's economy, contributing about 35% of the Gross Domestic Product and employing 65% of its adult population. Of the total population of over 1000 million, more than 30% live below the poverty line and about 75% lives in rural areas, depending directly or indirectly on agriculture. One-third of the agricultural labour force are women and agriculture is the main source of employment for women in rural areas. Annual agricultural growth has been modest at 2.6% per annum over the last 25 years. Development plans of the Government of India and State Governments give priority to alleviating poverty and creating employment, particularly in rural areas. Considerable irrigation potential has been created in India to sustain agricultural production against the vagaries of rainfall that is scarce and unevenly distributed in space and time.

The introduction of irrigated agriculture in arid and semi-arid regions of the country has resulted in the development of the twin problem of waterlogging and soil salinization, with considerable areas either going out of production or experiencing reduced yield. It is estimated that an area of nearly 8.4 million ha is affected by soil salinity and alkalinity, of which about 5.5 million ha also waterlogged, mainly in the irrigation canal commands and 2.5 million ha in the coastal areas.

The problem of increasing salinity caused by the rise of water table due to lack of drainage is considered as a major environmental problem that threatens the capital investment in irrigated agriculture and its sustainability. Drainage has not been given importance as much as irrigation by the individuals as well as the governmental agencies. Sporadic research attempts like All India Co-ordinated Research Projects on Agricultural Drainage were made in the past for combatting the land degradation; however, wide spread adoption of appropriate drainage measures has not been taken. The situation demands concerted Research and Development efforts to bring all the affected areas back to profitable farming with increased agricultural production. This document addresses the following three issues:

- Why Subsurface Drainage is needed?
- How Subsurface Drainage works?
- What Challenges make Subsurface Drainage work?

The recommendations and strategies presented in this document are based on research conducted in eight pilot areas and one large-scale monitoring programme in 5 agro-ecological subregions of India. Basic features of these pilot areas are given below.

Introduction of large scale irrigation



Gohana and Sampla

The Gohana monitoring site is located in the Western Jamuna Canal command in Haryana. The climate is semi-arid, monsoon with a mean annual rainfall of 550 mm and an evapotranspiration of 1650 m. The main crops include rice, sorghum, pearl millet and sugarcane during kharif (monsoon season) and wheat, mustard, barley and berseem during Rabi (dry season). The Gohana monitoring site is part of the Haryana Operational Pilot Project, a project to install a subsurface drainage system in saline and waterlogged soils of two 1,000 ha pilot sites. The main problems in the area are saline groundwater, high water tables and surface water stagnation during kharif.

Sampla pilot area is also located in the Western Jamuna Canal Command in Haryana, just south of Gohana. The pilot area that was constructed in 1984 was used to study the long-term effects of subsurface drainage.

Islampur and Devapur

Islampur and Devapur pilot areas are located in the Upper Krishna Project (UKP) in Karnataka. The climate is semi-arid tropical monsoon with a mean annual rainfall of 768 mm and a potential evapotranspiration of 2176 mm. The area is irrigated with good quality canal water and the main crops are paddy, cotton, chillies, wheat and Rabi

Islampur pilot area



sorghum. Most farmers are illiterate and poor, land holding varying between 1 and 2 ha. The various causes of water logging and salinity are poorly drainable black soils, seepage from the canal network, lack of land development, inefficient irrigation practices and inadequate drainage.

Konanki and Uppugunduru

Konanki and Uppugunduru are located in respectively the Nagarjunasagar Project Right Canal Command and the Krishna Western Delta in Andhra Pradesh. The climate is predominantly semi-arid to arid with a mean annual rainfall of 768 to 844 mm and an evapotranspiration of 1600 mm. The main crop in the area is rice. Soils are sandy clay to clay loam. The average farm size is about 0.5 ha; the majority of the farmers are illiterate or have only primary education and are relatively poor. Yields are low due to water logging and salinity problems.

Lakhuwali

Lakhuwali pilot area is located in the Indira Gandhi Nahar Pariyojana Command in north-west Rajasthan. The climate is arid to semi-arid with a mean annual rainfall of 297 mm and evaporation of 1560 mm. The area irrigated with good quality irrigation water from the Indira Gandhi Main Canal, the main crops are cotton and wheat. The soil is a coarse textured sandy soil; a calcareous layer at shallow depth results in the formation of a perched water table.

Uppugunduru pilot area



The area has no natural drainage outlet. After the introduction of irrigation to the area, the groundwater table rose at a rate of about 1 m/year, resulting in complete waterlogged conditions. The farmers are poor and illiterate with an average farm size of 2.3 ha.

Sisodra pilot area



Lakhuwali pilot area



Segwa and Sisodra

Segwa and Sisodra pilot areas are located in the Ukai-Kakrapar Command in south Gujarat. Segwa situated in the middle branch of the command has a mean annual rainfall of 1500 mm and an evaporation of 1765 mm; Sisodra situated in the lower part of the command receives less rainfall (850 mm/year) but has approximately the same evaporation (1670 mm/year). Segwa is partly irrigated with good quality canal water and partly with poor quality groundwater. Sisodra completely depends on canal water, which is in short supply so that part of the drainage water is reused. Soils are heavy (black cotton, clay content > 45%); the main crops are sugarcane and rice. Farmers in Segwa are relatively well-educated and with an average farmer size of 3.6 ha well-to-do. In Sisodra, farmers are poorer, have a lower education level and smaller farmer size (2.1 ha). Both areas have good outlet conditions, but suffer from waterlogging and salinity, partly because of heavy rainfall during monsoon and inefficient irrigation methods.

In all these pilot areas, subsurface drainage systems, consisting of open and pipe drains with different depth/spacing combinations were installed in farmer's fields. The design was based on the results of comprehensive diagnostic surveys and soil reclamation criteria. For the construction, whenever possible, indigenous materials (pipes and envelopes) and equipment were used.

Segwa pilot area



Through a monitoring programme, the quality and effectiveness of the drainage systems were evaluated. The research programme was conducted in close co-operation with the farmers; farmers were also advised and supported on the optimum agricultural practices during reclamation.

Summary of the various drainage systems in the pilot areas				
Pilot Area	State	Size (ha)	Type of Drainage System	Outfall conditions
Konanki	Andhra Pradesh	20	<ul style="list-style-type: none"> • Composite pipe drainage • Composite open drainage 	Gravity
Uppugunduru	Andhra Pradesh	21	<ul style="list-style-type: none"> • Composite pipe drainage • Composite open drainage 	Pumped
Segwa	Gujarat	188	<ul style="list-style-type: none"> • Composite pipe drainage • Singular pipe drainage 	Gravity
Sisodra	Gujarat	160	<ul style="list-style-type: none"> • Composite open drainage 	Gravity
Gohana	Haryana	1200	<ul style="list-style-type: none"> • Composite pipe drainage 	Pumped
Sampla	Haryana	100	<ul style="list-style-type: none"> • Composite pipe drainage 	Pumped
Islampur/Devapur	Karnataka	180	<ul style="list-style-type: none"> • Composite pipe drainage • Singular pipe drainage • Composite open drainage 	Gravity
Lakhuwali	Rajasthan	75	<ul style="list-style-type: none"> • Composite pipe drainage 	Pumped

2 WHY DRAINAGE IS NEEDED?

In the monsoon-type climatic conditions in India the control of waterlogging and salinity starts with the removal of excess water from the land surface by surface drainage. Timely removal of this excess water is especially important for non-rice crops. However, surface drainage alone is often not sufficient. It should be integrated with subsurface drainage.

In most canal commands of India, the major share of irrigation water is supplied during the Kharif season (July to Oct) and the remaining part during Rabi (Nov to Jan). During the Kharif season, the average monthly rainfall is more than the average evaporation; as a result, the water table starts rising from July and comes close to the ground surface at the end of monsoon.

As mentioned earlier, in addition to rainfall, large quantities of irrigation water are also applied during July to January. To prevent waterlogging conditions, drainage is needed to remove excess water during the Kharif season and afterwards till the canal supplies are completely stopped; otherwise yield reduction caused by waterlogging will occur.

Import of excess water

With a misconception that more they irrigate, more yields they will get, farmers apply huge quantities of canal water. As the canal irrigation water is heavily subsidised, the withdrawal of ground water for irrigation purpose has almost stopped (as it is costlier than canal water). Added to this, there are losses from canals due to seepage. These factors have disturbed the hydrologic equilibrium of the ground water basin and the water table in these areas has started to rise at an alarming rate.



Waterlogging in Rajasthan

Irrigation studies conducted in the Segwa pilot area

Segwa Pilot area is irrigated from various sources: 40% by canal water through the Segwa Minor, 37% by wells, 14% by conjunctive use, 4 % by re-using drainage water and the remaining part is not irrigated and used as grassland. Irrigation water supply through the Segwa Minor is abundant and of good quality ($EC_i = 0.3 \text{ dS/m}$). It exceeds the crop water requirements of the main crops cultivated in the area: sugarcane (43%), paddy (21%), fallow (12%) and non-irrigated grassland (25%). The quality of the well water is poorer and is around 1.7 dS/m .

Design and actual canal supplies in the Segwa Minor differ greatly and the actual supplies by far exceed the crop water requirements for sugarcane:

	Kharif	Rabi	Summer	Year
Actual supply to fields (mm)	1332	779	814	2924
Effective rainfall		499		
Crop water requirements sugarcane (CWRS)		400		
CWRS with 65% application efficiency (mm)	0	674	1238	1912
Excess/Deficit (= Actual Supply - CWR in mm)	1332	105	-425	1012

Import of salts

The introduction of canal irrigation not only brings the much needed water, but also imports salts as even good quality irrigation water contains considerable amounts of salts. The import of salts is further aggravated because with the introduction of canal irrigation system in dry land areas, the farmers started growing high water demand crops. Subsequently considerable amounts of salts are added to the soil profile.

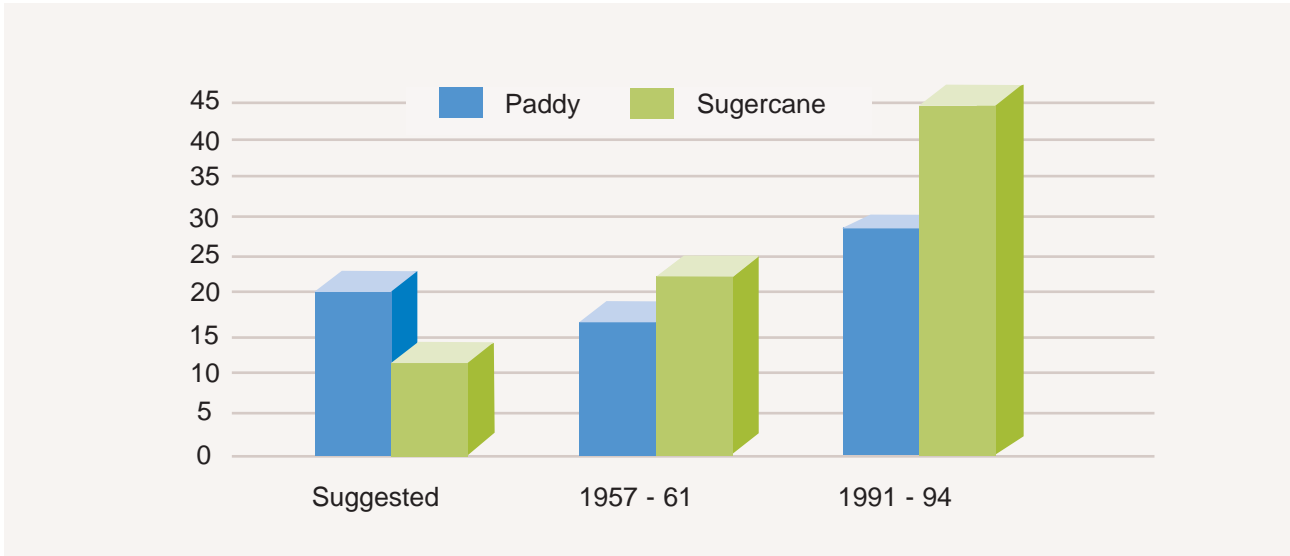
Year after year salts are accumulated in the profile and ultimately affecting crop yields. The rise in water table and build up of salinity reduces crop yields by causing poor establishment of the crop and damaging the root system. Yields are reduced in proportion to the increase in the salt build up in the profile.

Salts added to soil profile through irrigation per season.

Crop	Irrigation mm/season	Canal water EC =0.3 dS/m	Salts imported (t/ha)	
			Groundwater EC =1.0 dS/m	Groundwater EC =2.0 dS/m
Banana	1920	3.6	11.9	23.8
Cabbage	480	0.9	3.0	6.1
Cotton	280	0.5	1.8	3.6
Okra	780	1.5	5.0	10.0
Paddy	1200	2.3	7.7	15.4
Sugarcane	1500	2.9	9.6	19.2
Sorghum	240	0.5	1.6	3.2

Salt build-up in Rajasthan





Change in Cropping Pattern

In the canal command areas, where the imported surface water is made available at a highly subsidized price, the farmers have not followed the cropping pattern as suggested by the project authorities and started growing water loving crops like paddy. Before the introduction of canal irrigation mainly rainfed crops like cotton, chillies, groundnut, coriander, bajra and jowar were grown during southwest monsoon (Kharif) and lands were kept fallow during Rabi and summer. Once the good quality irrigation water became available by the introduction of canal irrigation, farmers were able to grow paddy besides the above crops. Farmers, however, did not follow the recommended cropping pattern, and ceased to cultivate water-saving crops like sorghum in favour of water-loving crop like paddy. The high yielding water-loving rice also replaces rainfed varieties of rice. Subsequently, the import, including the dissolved salts, has considerably increased.

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Although the benefits of the introduction of canal irrigation are without dispute, it is clear that the two major site-effects (waterlogging and salinization) are serious threats to the sustainability of irrigated agriculture. For example, in the Surat Branch of the Ukai-Kakrapar Command (36 000 ha) the above mentioned site-effects have seriously increased the area affected by high water tables and the areas affected by salinity is about 33% of the total command area.

Combine harvesting rice crop



The rising trend of the groundwater and the increase in soil salinity clearly indicates that drainage is needed to sustain agriculture in irrigated lands. Besides sustaining agriculture, drainage will also improve health conditions for the rural population as it will increase food security, reduce flooding (and thus improve access to fields and farmhouses) and reduce the occurrence of vector-borne diseases through the elimination of standing-water. Even more than irrigation, drainage is a communal activity and can not be effective as long as farmers do not co-operate. Furthermore, the drainage infrastructure especially the main drainage system will not only act for the disposal of excess water from the farmers fields but also serves rural residents as well as industry: drains and drainage water can be used as a source of water, not only in the area itself but also downstream. Drains also serve to dispose wastewater from rural settlements, cities and industries, thus should be considered as public goods.

Rice crop after introduction of subsurface drainage

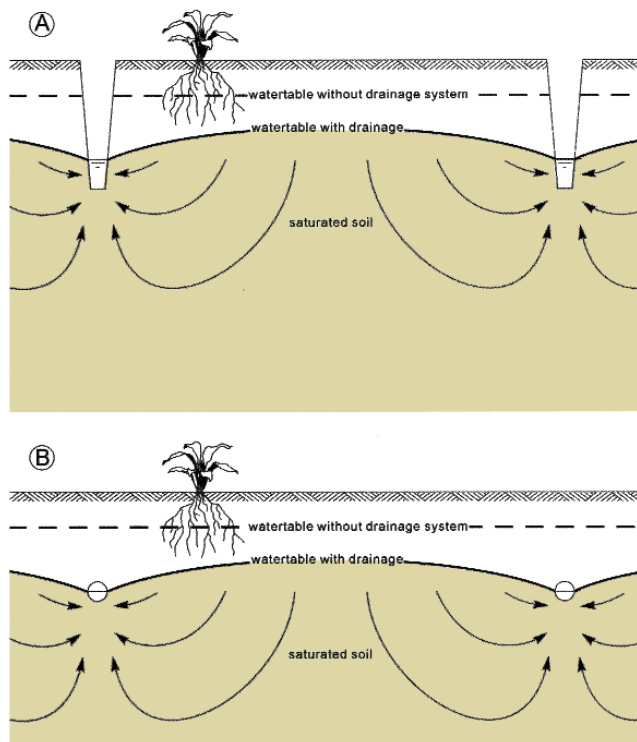


3 HOW DRAINAGE WORKS ?

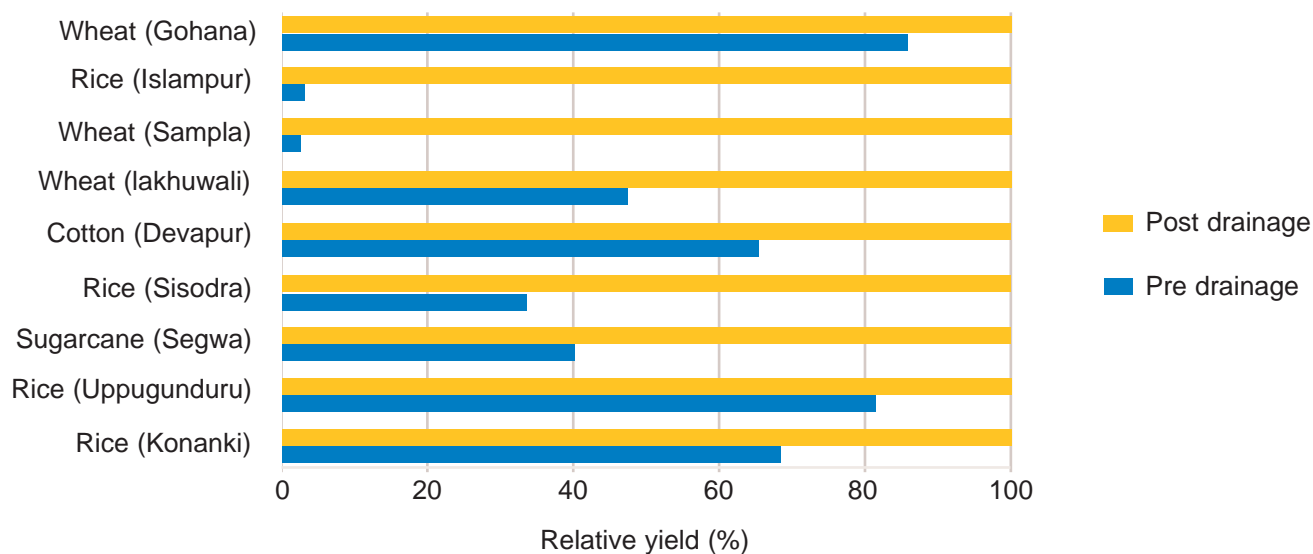
Subsurface Drainage as a Measure to Combat Waterlogging and Salinity

The studies conducted at the various pilot areas clearly proved that, under the prevailing soils, agro-climatic conditions and social settings found in the project areas, subsurface drainage, either by pipe or open drains, is a technically feasible, cost-effective and socially acceptable technology to reclaim water logged and saline lands and to sustain agriculture in irrigation commands. Significant increases in crop yield were obtained within one or two seasons after the installation of the subsurface drainage system.

The significant increase in crop production can be attributed to the direct effects of the introduction of subsurface drainage, i.e. the control of the water table and a decrease in soil salinity. Monitoring the performance of subsurface drainage systems clearly showed that the system effectively controls the water table and the soil salinity in the root zone. The water tables can be controlled at a relatively shallow depth: 0.5 - 1.5 m (depending on the crop) or even shallower in paddy fields. These shallow water tables avoid excessive drainage while at the same time harmful salts that are brought in by the irrigation water are effectively removed.



Open drain (A) or pipe drain (B) can effectively control waterlogging and salinity





Brinjal introduced as new crop (Segwa pilot area)

Apart from the increase in yields of the traditionally grown crops like wheat, sugarcane and rice, the introduction of subsurface drainage has also led to increasing cropping intensity: highly remunerative crops were introduced like brinjal, blackgram, chillies, greengram as a second crop.

Subsurface drainage is also an eco-friendly technology. The pilot area studies revealed that:

- Drainage effluent does not contain excessive amounts of nitrate or other toxic elements;
- Drainage water can be re-used for irrigation either directly or in conjunction with good quality irrigation water;
- During Rabi and summer, drainage water has a high salt concentration, making it often unsuitable for re-use. In such cases, the option to temporarily stop the discharge for disposal at a later stage should be considered;
- During the monsoon (Kharif) season, drainage water quality is much better, because of the dilution effect of the rains. At this time the water is not required for irrigation in many cases. In such circumstances, excess water can be disposed off in the natural drainage system.

It should be realised, however, that subsurface drainage systems can only be successful in controlling salinity, if sufficient good quality irrigation

water or monsoon rainfall is available for leaching and that supplementary measures in soil & water management like application gypsum, salt-resistance varieties, irrigation efficiency improvement, etc. will enhance the positive effects of horizontal subsurface drainage.



Chillies introduced as new crop (Devapur pilot area)

Design specifications for subsurface drainage systems

Horizontal subsurface drainage systems can be installed with either open or pipe drains with drain spacing between 45 and 150 m and drain depths between 0.90 and 1.50 m. The agro-climatic and soil conditions determine the most appropriate combination of drain depth and spacing. To avoid costs for pumping the drainage effluent, gravity outlets should be preferred by reducing the drain depth and narrowing the spacing.

Singular subsurface drainage systems, with (pipe or open) field drains directly discharging in an open main drain or natural stream (Nala) proved to be more cost-effective than a composite system. If such outlet conditions are not available, a composite system, consisting of field and collector pipe drains, is required. If gravity drainage is not an option, pumping the drainage effluent should be considered.

Horizontal subsurface drainage can be made still more effective by introducing controlled systems to halt the drainage flow in times of water scarcity and to prevent excessive leaching of valuable nutrients. This will also avoid excessive loss of irrigation water in rice fields.

Subsurface drainage systems consisting of open drains (depth up to 1.0 m) proved to be the most cost-effective method. Adverse soil conditions, operation and maintenance requirements, loss of land, and social settings, however, restrict their use. Alternatively, corrugated, perforated, plastic (PVC) pipes with a diameter of 100 mm or more can be used.



Manual installation of open drains

For the heavy soils, there is no need for an envelope material. Pipe drains with and without envelopes performed equally effectively in these soils and excavation programmes, conducted in the various pilot areas one and two years after installation, showed only traces of sedimentation. For the lighter soils, field tests are recommended to select the most appropriate envelope material. Non-woven polypropylene filter material performed best, although it is rather expensive.

Summary of design specifications based on pilot area research

Pilot Area	State	Type	Spacing (m)	Depth (m)	Costs (Rs/ha)
Konanki/Uppugunduru	Andhra Pradesh	• Composite pipe	60	1.0	18,500
		• Composite open	75	1.0-1.2	4,500
Segwa/Sisodra	Gujarat	• Composite pipe	45	0.9-1.2	20,400
		• Singular pipe			17,400
Gohana/Sampla	Haryana	• Composite open	67	1.6	8,300
		• Composite pipe			18,000
Islampur/Devapur	Karnataka	• Composite pipe	50	1.2-1.5	22,300
		• Singular pipe	50	1.0-1.2	24,000
Lakhuwali	Rajasthan	• Singular pipe	150	1.2	19,500
		• Composite pipe			8,600
					21,000

Two methods for the construction of subsurface drainage system are available: manual and mechanical installation. The project has developed and successfully tested a combination of these two methods using conventional machinery. Under Indian conditions, with its abundant labour force, this combined method is most promising and needs to be tried at more places. The presently available guidelines on the need and selection of an envelope material seem appropriate. The only exception is the coefficient of uniformity, that as a criterion for deciding on the need of an envelope, should not be used for the Indian conditions.

The installation cost of subsurface drainage system with different spacing and envelope material were recorded for economic viability assessment. Horizontal subsurface drainage systems are extremely beneficial. For the most expensive (composite pipe drainage) systems, cost benefit ratios are in the range from 1.1 to 3.6, internal rates of return in the range from 18 to 58%, and pay back periods in the range from 3 to 10 years.



Manual installation of pipe drains

Cost and Benefit Studies conducted in Segwa and Sisodra Pilot Areas.

For assessing the economic viability of the subsurface drainage systems, the crop yield and cost of implementation and cultivation were recorded.

	Cost of subsurface drainage					
	30 m spacing		45 m spacing		60 m spacing	
	Rs/m	Rs/ha	Rs/m	Rs/ha	Rs/m	Rs/ha
Singular open drains	22 - 33	7,200 - 10,800	38	8,300	30 - 35	4,800 - 5,800
Composite open drains	31	10,200	43	9,500	55	8,800
Singular pipe drains	77	25,700	78	17,400	80	13,300
Composite pipe drains	85	28,300	92	20,400	98	16,400

Economic returns of subsurface drainage systems in the drainage pilot areas were also calculated. The recommended drain spacing (45 m) has, even for the most costly package (the composite pipe drainage system), positive economic returns:

	Control plots	Drained plots
Cost of installation (Rs/ha)	-	20,400
Cost of cultivation* (Rs/ha)	31,286	41,143
Yield (t/ha)	78	105
Gross income (Rs/ha)	63,555	85,500
Net Present Value (Rs/ha)		75,000
Benefit/cost ratio (-)		1.7
Internal Rate of Return (%)		58
Pay-back period (years)		3

Supplementary activities in soil and water management

A shallow water table can help to meet part of the irrigation water requirements of crops. Under these conditions, irrigation water requirements can be reduced by 20-25%. This can be achieved either by reducing the depth of irrigation water application or by reducing irrigation frequency.

Reduction in canal water supply is commonly advocated as a mitigate measure to control water logging. Although technically sound, the studies revealed that:

- So far technical and management measures to improve irrigation water management have not percolated to the farming community in the pilot areas constructed by the project. Therefore, more systematic efforts need to be made to generate awareness on irrigation water management among the farming community;
- In one command, the water supply on an annual basis is more than the demand. However, in spite of the efforts made so far at all levels, it has not been possible to reduce water allowance;
- The well-known supply gap between the head-end and tail end farmers is yet unsolved. Tail-end farmers will never agree to a reduction in the overall water supply, since they are already short of water and any reduction in water allowances would accentuate this gap.

The role of farmers

The farmers' role in adoption of drainage technology is very important in command areas as it is a collective effort of the farmers and their spouses who have to take the responsibility of operation and maintenance of the subsurface system. In the pilot areas, there were generally no problems in persuading the farmers to adopt drainage technology as the farmers were involved in the design, construction, operation and maintenance of subsurface drainage system.

The farmers' confidence in the drainage technology had to be sought before implementation of the project and continuous interaction with the farmers and also with their family members is also important element for success of the transfer of the technology. At the pilot areas, farmers' confidence was first obtained by enlightening the probable future benefits the farm families may derive with the installation of a subsurface drainage system in their fields. At some pilot areas, like Uppugunduru, the structural co-operation of the farmers was relatively easy from the very beginning, as there was already a co-operative society functioning for the last 75 years.

Project staff meeting pilot area farmers



Farmers attitude to Drainage as a tool to combat Water logging and Salinity

The attitude of the farmers and farm women was analyzed by conducting base line survey on socio-economic and gender aspects at both the Konanki and Uppugunduru pilot areas. All pilot area farmers and their spouses participate in the survey. This survey helped very much to understand the attitude of the farmers and farm women towards new technology.

The main observations of the base line survey are:

- 90% of farmer's farm holdings were less than one hectare in both pilot areas;
- Farmer's literacy was 65%;
- Farmers fully agreed that their land needs to be addressed to overcome water logging and Salinity problems.

And after the installation of the subsurface drainage systems:

- Farmers were fully convinced that drainage technology brings prosperity as technology has increased the yields considerably after system installation;
- The improvement in land quality was felt by the farmers;
- The land problems such as poor land quality, low yields, less quality of fodder and low cropping intensity due to waterlogging and salinity conditions were reduced;
- Asset values increased by 175 %;
- Farmers understood fully the operational and maintenance issues such as maintenance of pipe drain and open drainage systems, pumping of drainage effluent and that drainage is not an individual responsibility but a collective activity in which they have to cooperate among each other.

Gender issues also indicated the following:

- Women perception towards technology has changed positively;
- Knowledge on waterlogging and salinity consequences like effects on yield, farm income and standard of living has increased among women;
- The drudgery of women in agricultural operations was considerably reduced;
- The farm women preferred more and more interactions with scientists as it helped to address some of their farm and home management problems;
- Both farmers and their wives are fully convinced that drainage gives both direct and indirect benefits that give prosperity in the long run.

4 WHAT CHALLENGES MAKE DRAINAGE WORK?

Institutional and policy issues

The role of the State Government is crucial since drainage requires a regional infrastructure and affects generally more than one farmer. To reverse the rising trend of land being affected by waterlogging and salinity the State Government should take the lead and prepare a Drainage Policy emphasizing on a time bound action plan to reclaim these waterlogged and salt-affected lands and to safeguard other irrigated lands against these twin problems.

Implementation of subsurface drainage should graduate from the pilot areas to full-fledged drainage programs under the relevant Departments. The benefits often go beyond the direct interest of the concerned farmers, therefore the Government should also (pre)finance complete or part of the costs. Government support is recommended to overcome constraints such as:

- Limited knowledge on drainage as a tool to combat waterlogging and salinity within the existing (government & private) organizations involved in irrigated agriculture;
- Limited capacity to implement drainage projects;
- Limited financial resources especially for those farmers whose land has been gone out of cultivation due to waterlogging and salinity.
- Reclamation of waterlogged and salt-affected soils although cost effective seems to be beyond the reach of the small and marginal farmers as far as the initial investments are concerned. Funding of such programmes should come from the government which can be recovered in interest free instalments along with the land revenue and irrigation water charges.



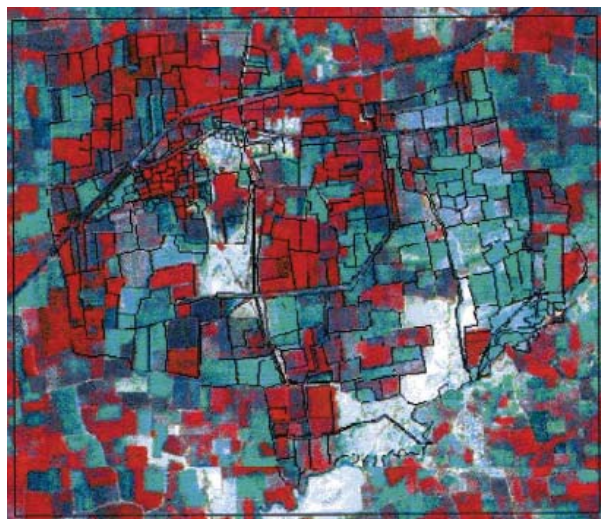
The most important policy measure could be a Government decision to treat the reclamation of waterlogged and salinity-affected areas in irrigation projects as equivalent in importance to the creation of fresh irrigation potential or its utilisation. Another policy decision is required to provide for drainage related needs in all new projects right at the time of inception of the projects, eg. designing the main drainage systems in such a way that later on singular subsurface drainage systems can be installed.

An approach, which involves location specific solutions and technologies being employed by integrated multi-disciplinary organisations of the State Government working jointly with the Water Users Associations who have fully adopted participatory irrigation water management, should be adopted. It is also recommended to formulate a State-level Advisory Group on Drainage to suggest remedial measures on situation basis from time to time.

Pre-drainage investigations

Drainage measures are generally location specific and vary according to soil, climate, irrigation, cropping pattern, socio-economic conditions of the farmer etc. It is advisable to foresee the minimum data requirements for the design and monitoring the performance of drainage systems and plan for obtaining these data for each specific project. The following information need to be collected/ considered before drainage systems are executed:

- Remotely sensed data to identify salt affected soils and waterlogged soils on large scales. At least 1:50000 scale should be made available which is found to be economically feasible.
- Topographic maps to collect ground truth.
- Information on hydraulic conductivity, soil porosity, infiltration rate, salinity, depth to impermeable layer, quality of ground water and irrigation water.



Mapping by Remote Sensing

- Existing performance of irrigation and drainage systems in detail.
- Ground water data including fluctuations, quality and degree of exploitation over years.
- Provision for the disposal of water from the main gravity/pumped outlet.
- Information on the mode of availability and transport of the equipment and materials required for laying the system.
- Agro meteorological data consisting of rainfall pattern, evapotranspiration losses, cropping pattern.
- Detailed information on yields, cost-benefit studies of similar type of experiment elsewhere.
- Socio-economic conditions of the farmers in terms of willingness to participate and contribute to drainage works and forming a co-operative group for better performance of the system in future.

Godavari Delta: Restoration of the natural drainage network

After independence the main drainage system in the Godavari Delta gradually deteriorated: bunds were widened to be used for shelter and the cultivation of tree and major open drains were poorly maintained. Due to this poor maintenance, heavy rains in 1986 caused severe flooding and most crops were lost. The main reason attributed to these floods was the blocking of major open drains. After the floods, the Government took up a large scale rehabilitation project to dig out and widen the open drains to restore their original cross sections. As a result of the rehabilitation of the main drainage system, the heavy monsoon rains of 1996 (the same order of magnitude in 1986) did not result in serious flooding and the standing crop was saved.

Drainage system requirements

In irrigated areas, the restoration of the (natural) drainage capacity, which is generally disrupted by the construction of the irrigation canal networks or other development activities, will considerably reduce the need (or intensity) of the subsurface drainage and will furthermore be needed to provide save outlet conditions. The availability of a good outlet for safe disposal of the drainage effluent (including the leached salts) is a prerequisite to make subsurface drainage a success. In land locked areas, 10 to 17 % of the land area can be converted into an evaporation/storage tank to store and dispose off the water at a later stage. Investments in subsurface drainage should go hand in hand with investments in improving irrigation efficiency. Reducing irrigation water losses can not

Reconstruction of natural drainage.



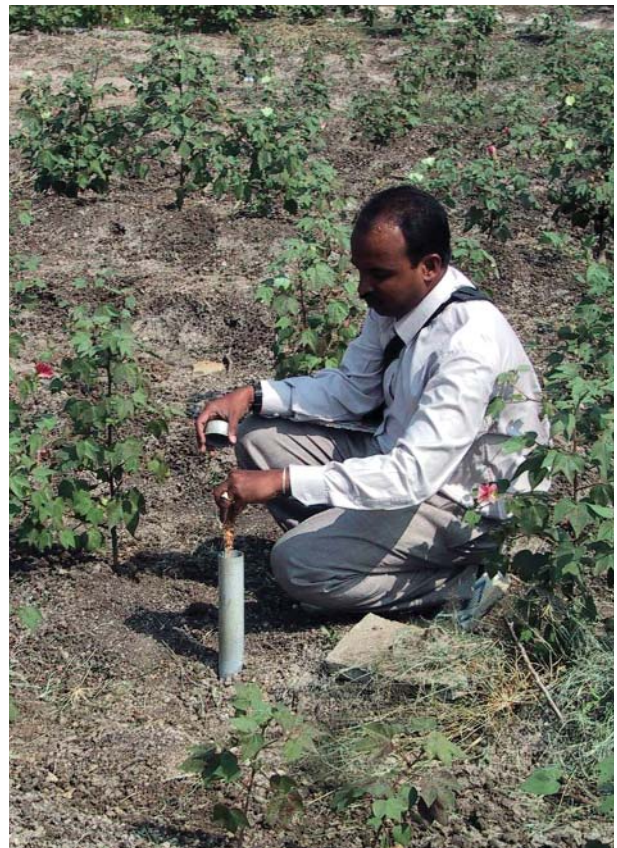
only reduce the problem of waterlogging and salinity but will also reduce the overall cost in subsurface drainage. Subsurface drainage can be made still more effective by introducing controlled systems to halt the drainage flow in times of water scarcity and to prevent excessive leaching of valuable nutrients. This will also avoid excessive loss of irrigation water in paddy fields.

Post-drainage investigations

Continuous monitoring should be carried out for 10-15 years after installation of systems to assess the performance of the system and to refine design criteria whenever needed. As a part of the monitoring the performance of drainage systems, the arrangements should be made to measure/study the following: water table fluctuations, discharge from pipe and open drains, changes in soil salinity, changes in crop yields and cropping pattern, regular maintenance of open drains.

Computer models can be used to calculate the salt and water balance of the systems and to predict and optimize the performance of system which in turn can influence the payback periods.

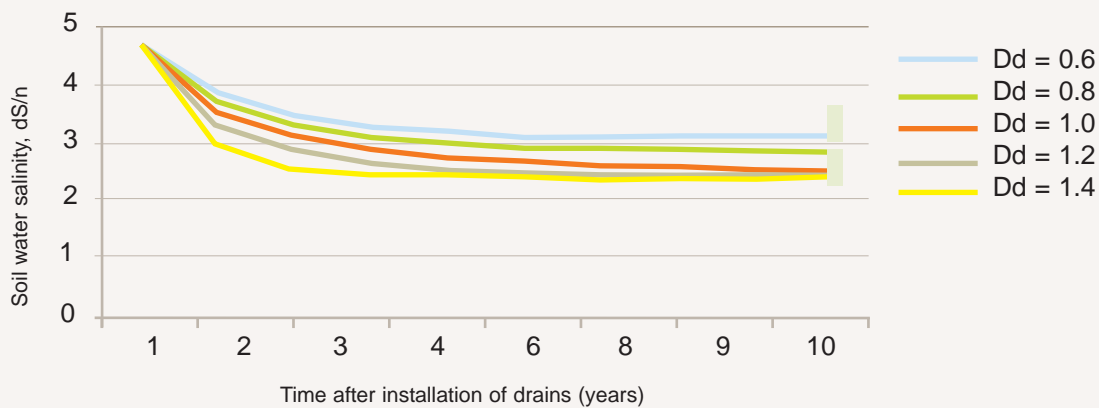
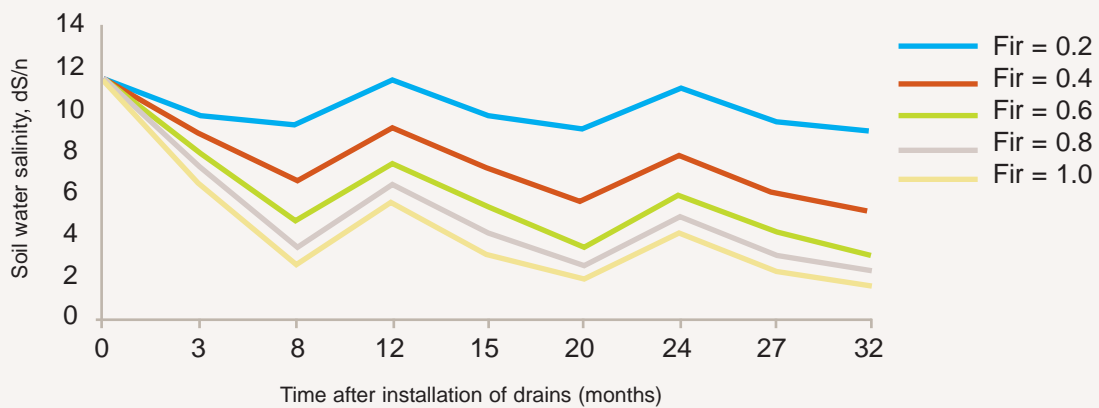
Monitoring of depth to water table



Analysis of Salt and Water Balances at Konanki by Computer Simulation

Long-term field experiments are required to develop suitable salt and water balance strategies, but are expensive, site specific and time consuming. Simulation models, however, can be used to test a wider range of conditions than met in the field. Once calibrated using experimental information, models could aid as management and decision making tools to obtain quantitative guidance in developing and evaluating drainage and irrigation strategies.

A hydro salinity model SALTMOD was used to analyze salt and water balances at Konanki pilot area to make long-term predictions of soil salinity and depth to water table. For calibration the leaching efficiency in respect to root zone salinity was simulated and compared with observed data. The model predicts that due to the existence of drainage system, the root zone soil water salinity will be reduced to 4, 3 and 2.5 dS/m (from an initial value of 11.5 dS/m) during the first, second and third seasons within six years, with is in good agreement with the measured data. Next, the model was used to simulate different drain depth scenarios. It also predicts that closer than the present spacing will not be of any advantage and further deepening of the drains from the present depth of 1 m to 1.4 m will not have any better influence on reduction of the root zone salinity than in the present situation.



Root zone salinity during second (paddy crop) seasons as influenced by drain depth

Capacity building

The project enhanced the capacity building at the four State Agricultural Universities by adopting a step-wise approach in technology transfer through training:

- Basic training by sending project staff to regular training courses at specialised centres in India and abroad;
- Advanced training by sending project staff and selected university staff of the four Network Centres to tailor-made training course on subject matters in India;
- Project expert meetings in which project staff exchanged experiences, discussed and synchronised their research activities;
- In-depth training by sending project staff for collaborative research programmes at Universities and specialised research organisations abroad.

These training activities were supplemented by in-service training of visiting consultants at the Network Centres; study tours to acquaint senior project staff with practices from elsewhere and to disseminate the knowledge and experiences obtained in the project to a broader audience by participation in international workshops and symposia; and National Training courses to



Tailor-made training of project staff

disseminate the knowledge and experiences obtained by the project within India.

Scale model of Konanki pilot area for farmers' fair



Support a Farmer's Initiative in Subsurface Drainage

The ultimate goal of conducting research or developing improved technologies is that the findings should reach the farmers and that they should be able to adopt them in their fields. By going through the success stories of Konanki and Uppugunduru published in the news papers, seven farmers of Doppalapudi village in Ponnur mandal of Guntur district approached the Indo-Dutch Network Project in May 2002 and sought the assistance to reclaim about 5 ha of land of salt-affect land. The situation was so severe (yields from 1.0 to 1.2 t/ha) that the farmers were not willing to harvest the crop as it was not economical to do that. The farmers request technical assistance and expressed their willingness to bear the entire expenditure.

After carrying out pre-drainage investigations, an interceptor open drainage system was proposed. The cost of construction of the drainage system and the expenditure incurred for the maintenance of the systems by the farmers was worked out to be Rs. 3,600 per ha. With supervision of the IDNP project staff, the drainage system was installed by the farmers. After installation, the farmers took every care in maintaining the system properly. The saline seepage water from the uplands was intercepted effectively and disposed safely into the natural drain. As a result, crop has established very well in almost all the fields and a remarkable increase in the yields of paddy was obtained, the average yield increased from 4.0 to 5.2 t/ha.

Participatory approach

The universities created awareness on the need for drainage in their states by:

- Conducting farmers' days to promote the benefits of drainage
- Publishing leaflets, folders and training manuals in local language
- Making broadcasts on radio and television
- Excursions for government officials to the various pilot areas
- Organising state level workshops.

The above has resulted among others that progressive farmers have approached the universities for technical advice to install subsurface drainage in their own lands at their own costs.

Group action is very essential in implementation of drainage system as drainage involves more than one farmer. Drainage requires also a regional infrastructure to safely discharge the excess drainage water, thus farmers should realize that they have to co-operate with each other and with regional agencies. In canal command areas paddy is a principal crop and it warrants a mutual co-operation between the farmers on every aspect of cultivation which requires collective effort in implementation of drainage system.

Impact analysis

After the implementation of subsurface drainage systems surveys were conducted to assess farmer's views on the technical feasibility and economic viability and perceptions towards subsurface drainage. The survey revealed that:

- Farmers favour system installation on large scale;
- Farmers feel that there is a need for Government intervention in solving the problems;
- Farmers are willing to participate in future drainage projects, but expect that a fair share of the costs is paid by the Government;
- Farmers are willing to take up the operation and maintenance of the field drainage systems, but feel that the maintenance of main drains is the responsibility of the government.



'before'