11. CONCLUSIONS AND RECOMMENDATIONS

Under the Indo-Dutch Network Project with the objective “Recommendations on Waterlogging and Salinity Control Based on Pilot Area Drainage Research”, 8 studies in 7 irrigation commands areas in 5 agro-ecological sub-regions of India were taken up where waterlogging and soil salinity have assumed serious dimension. Pilots areas covering 13 to 75 ha under SSD were laid out, monitored and evaluated over a period of 1 to 3 years. On the basis of this evaluation some general and few site specific conclusions have been drawn. They reflect the current state-of-the-art and should be treated as guidelines for other regions. Further research may be needed to refine and verify them.

11.1 Conclusions

11.1.1 Measures to Combat Waterlogging and Salinity

1. Horizontal subsurface drainage, either by pipe or open drains, has proved to be a technically feasible, cost-effective and socially acceptable technology to reclaim waterlogged and saline agricultural lands in irrigation commands under various soils, agro-climatic conditions and social settings.

2. Surface drainage is essential to remove excess water from the land surface in monsoon climatic conditions. However, surface drainage alone is often not sufficient. It should be integrated with subsurface drainage.

3. Restoration of the (natural) drainage capacity, which is generally disrupted by the construction of the irrigation network or other development activities, will considerably reduce the need for (or intensity of) subsurface drainage.

4. Horizontal subsurface drainage is an effective tool to remove excess water and salts and to sustain agriculture. Supplementary measures such as:
   - improving farm irrigation efficiency;
   - applying nitrogen (20 to 25% more than the recommended dose for unaffected lands), organic manure or green manure
   - applying gypsum

enhance the positive effects of horizontal subsurface drainage. A trade off between the additional investments made in irrigation and land management and saving in cost on drainage should be considered.
5. Horizontal subsurface drainage controls:
   - The water table at an optimum depth for crop growth (0.5 - 1.5 m or shallower in paddy fields), and;
   - The soil salinity at a safe level (< 4 dS m⁻¹).

   It has been shown that:
   - Excellent yields can be obtained with the shallow water tables mentioned while excessive drainage is avoided, and;
   - Harmful salts that are brought in by the irrigation water are effectively removed.

6. 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.

7. The availability of a good outlet for safe disposal of the drainage effluent (including the leached salts) is a pre-requisite to make subsurface drainage a success. In land locked areas, 10 to 18% of the land area can be converted into an evaporation/storage tank to store and dispose off the water at a later stage.

8. Subsurface drainage is an eco-friendly technology. The pilot area studies reveal 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; thus it is good water resource at times when water is not available from other sources;
   - During *rabi* and summer, drainage water has a high salt concentration, making it often unsuitable for reuse. In such cases, the option to temporally store the discharge for disposal at a later stage should be considered;
   - During the monsoon 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.

11.1.2 Design Specifications for Horizontal Subsurface Drainage Systems

9. 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.

10. So far only two methods for the construction of subsurface drainage system were available: manual and mechanical. 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.
11. The presently available guidelines on the need and selection of an envelope material seem appropriate. Pipe drains with and without envelopes designed based on these guidelines performed equally effectively. 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.

12. Flushing of lateral and collector pipe drains is essential when horizontal pipe drainage systems are laid under high water table conditions. A flushing method developed by the Hanumangarh Network Centre is very appropriate for this purpose.

13. Horizontal subsurface drainage can only be successful to combat salinity if sufficient good quality irrigation water or monsoon rainfall is available for leaching.

14. Operational scale subsurface drainage systems can only be installed on community basis and consequently Water Users Co-operatives or Drainage Committees have to be established to implement, operate and maintain these systems.

15. 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, could be considered. If gravity drainage is not an option, pumping the drainage effluent should be considered.

16. Subsurface drainage systems consisting of (deep) open drains 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.

17. Costs of horizontal subsurface drainage systems vary between Rs. 5,000-10,000 ha\(^{-1}\) for the most simple singular open drainage systems to Rs. 28,000-30,000 ha\(^{-1}\) for the most complex composite pipe drainage system depending upon spacing and depth.

18. Horizontal subsurface drainage systems are extremely beneficial; cost benefits ratios are in the range of 1.3-4.0, internal rates of return in the range of 35-60 and pay back periods of 3-5 years except at UKP command where pay back period for composite system was 9-10 years.

11.1.3 Supplementary Activities in Water Management

19. A shallow water table can help to meet part of the irrigation water requirement of crops. As such, irrigation water requirement can be reduced by 20-25%. This can be achieved either by reducing the depth of irrigation water application or by reducing irrigation frequency.

20. Reduction in canal water supply is commonly advocated as a mitigative measure to control waterlogging. Although technically sound, our 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.

### 11.1.4 Supplementary Activities in Soil and Land Management

21. It has been shown that in heavy clay soils (clay content > 45%), presently available guidelines on the limits of ESP where adverse effects start appearing (ESP > 15) do not hold true. Sugarcane yields decrease even at an ESP of 8. Drainage installation followed by gypsum application helps in land reclamation of heavy clay soils. Soil tests, however, need to be carried out to establish recommended gypsum application rates.

### 11.1.5 Institutional and Policy Issues

22. Drainage Policy Papers at National and State Levels should be prepared emphasising time bound action plan to reclaim waterlogged and salt-affected lands.

23. At the National level, CSSRI, with its well-equipped training infrastructure in land reclamation and agricultural land drainage, should be made a nodal agency for imparting training in this area of specialisation.

24. At State Level, the enhanced capacity at the four State Agricultural Universities should be utilised to strengthen both government and private organisations in activities aiming to combat waterlogging and salinity. These activities can include problem identification, creating awareness at State, Central and Farmer level, recommending solutions and dissemination of knowledge through training and advisory services.

25. Implementation of horizontal subsurface drainage should graduate from the pilot scale to full-fledged drainage programs under the relevant Ministries and Departments.

26. The Central Government norm of Rs. 12,000/ha for the execution of subsurface drainage projects needs to be revised as it is highly inadequate at the current prices.

### 11.2 Specific Recommendations for Different Regions

For the four agro-ecological sub-regions, in which the drainage pilot areas were located, the additional recommendations are valid:

#### 11.2.1 Haryana: Western Yamuna Canal Command

- For areas with medium textured soils as in Western Yamuna Canal and Bhakra Canal
commands (annual rainfall: 500-700 mm) having high water table and salinity problems, a composite pipe drainage system with the following characteristics is recommended.

- Drain spacing: 75 m
- Drain depth: 1.1-1.5 m
- Envelope: Geotextiles

- In addition to the above, following package would help to make the process of land reclamation efficient and sustainable:
  - Land levelling and bunding for rainwater conservation and uniform leaching.
  - A heavy pre-sowing irrigation for leaching of salts following leaching through rain water.
  - Application of 20-25% more nitrogen and seed rate compared to the recommended dose for normal soils.

11.2.2 Andhra Pradesh: Nagarjuna Sagar Right Command and Krishna Western Delta

- For areas with sandy loam to clay loam soils as in Nagarjuna Sagar Project Right Canal Command area (annual rainfall: 800 to 900 mm) having salinity, sodicity and waterlogging problems, a pipe subsurface drainage system with the following characteristics is recommended.
  - Drain spacing: 60 m
  - Drain depth: 1.0 m
  - Envelope: Geotextile

This package will increase paddy yields by around 50% in 2 years.

- In addition to the above, the following supplementary measure are recommended:
  - Growing green manure crops like Dhaincha in combination with application of organic manure @ 5t ha\(^{-1}\) along with gypsum @ 50% of requirement, if necessary;
  - Cultivation of salt resistant rice varieties such as MTU 4870 (Deepthi), NLR-T-145 (Swarnamukhi) and NLR 33641 (Tellamolakolukulu).

- For areas with sandy clay loam soils as in Krishna Western Delta (annual rainfall: 900 to 1000 mm) with saline groundwater conditions, a pipe drainage system with deeper drains (depth 1.20 to 1.35 m) is recommended.

- For areas with high salinity problem, open drains lower the salinity levels quite fast. Even though open drains are much cheaper, farmers with small holdings may resist for their installation owing to the loss of cultivable land in construction of drains. Whenever they are acceptable, the open drains with the following characteristics are recommended:
  - Drain spacing: 75 m
  - Drain depth: 1.0 to 1.2 m
11.2.3 Gujarat: Ukai- Kakrapar Command

- For sugarcane crop in heavy black soil areas as in Ukai- Kakrapar Command (annual rainfall: 1000 to 1500 mm) with waterlogging and/or salinity problems, a subsurface (open or pipe) drainage system with the following characteristics is recommended:
  - Drain spacing 45 m
  - Drain depth 0.90 to 1.20 m
  - Envelope not required.

This package will increase yield by about 40%.

- In addition to the above, the supplementary measures of applying organic manure @ 5t ha\(^{-1}\) along with gypsum @ 5-10 t ha\(^{-1}\) (depending upon the ESP) are recommended.

- In commands where sugarcane is the single most important crop and where existing networks of sugar co-operatives play vital role in helping the farmers on all cultivation aspects, these networks should take lead in implementation of drainage system in the command.

11.2.4 Rajasthan: Indira Gandhi Nahar Pariyojana Command

- For areas with sandy soils and collapsing soil conditions (quick sand) as in IGNP (annual rainfall: 300 mm), a composite pipe drainage system with the following characteristics is recommended:
  - Drain spacing 150 m
  - Drain depth 1.20 m
  - Envelope material geotextile

- To install horizontal pipe drainage systems under the adverse (quick sand) conditions in IGNP the following techniques are recommended:
  - Dewatering by having bore holes around the sump and continuously pumping for 72 hours for the construction of sumps;
  - Prefabricated RCC rings with in-built bottom plate for manholes;
  - Mechanical installation using machinery like excavators and tractor driven trenchers. Though installation is possible with manual labour, it is much time consuming, costly and hazardous due to collapsing nature of soil.
  - As the system is laid under muddy conditions, flushing of the laterals and collector is essential.

- In the absence of a natural drainage outlet, the creation of safe disposal options is a prerequisite for successful introduction of subsurface drainage on a large scale in IGNP. To reduce the volume, supplementary measures like evaporation ponds and re-use have to be further developed.
11.2.5 Karnataka: Upper Krishna and Tungabhadra Commands

- For areas with black soils such as in the Upper Krishna command (annual rainfall: 770 mm) and waterlogging and salinity problems, a subsurface drainage system with open or pipe drains with the following characteristics is recommended:
  - Drain spacing: 50 m
  - Drain depth: 1.0 to 1.2 m
  - Envelope: not required for soils with a clay content > 50%.

These drains are to be complemented with surface drains for efficient performance.

- In addition to the above, the following supplementary measures are recommended:
  - Gypsum application @ 5-7.5 t ha⁻¹, if the soil ESP is high;
  - Lining of field irrigation channels by providing a murrum cushion of 15-20 cm thickness. This will minimise the conveyance losses considerably (by half) in comparison with the existing lining without murrum cushion;
  - Application of an additional 30 to 60 cm good quality irrigation water (in 10 cm instalments) for the initial leaching of the soil;
  - Land levelling and bunding to save 35 to 50% irrigation water;
  - Nala cleaning.
REFERENCES


### ABBREVIATIONS

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANGRAU</td>
<td>Acharya N.G.Ranga Agricultural University</td>
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<tr>
<td>B-C ratio</td>
<td>Benefit – cost ratio</td>
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<tr>
<td>bgl</td>
<td>below ground level</td>
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<td>CADA</td>
<td>Command Area Development Authority</td>
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<tr>
<td>CEC</td>
<td>Cation exchange capacity (meq/100 g)</td>
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<td>CI</td>
<td>Cropping intensity</td>
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<td>CSSD</td>
<td>Closed subsurface drainage system</td>
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<td>CSSRI</td>
<td>Central Soil Salinity Research Institute</td>
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<tr>
<td>EC_e</td>
<td>Electrical conductivity of the soil saturation extract</td>
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<td>ESP</td>
<td>Exchangeable sodium percentage</td>
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<td>FIC</td>
<td>Field irrigation channel</td>
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<td>GAU</td>
<td>Gujarat Agricultural University</td>
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<td>HOPP</td>
<td>Haryana Operational Pilot Project</td>
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<tr>
<td>i_e</td>
<td>Hydraulic gradient, envelope</td>
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<tr>
<td>i_s</td>
<td>Hydraulic gradient, soil</td>
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<tr>
<td>IGNP</td>
<td>Indira Gandhi Nahar Pariyojana</td>
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<tr>
<td>IRR</td>
<td>Internal rate of return</td>
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<td>K</td>
<td>Potassium</td>
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<td>KWD</td>
<td>Krishna Western Delta</td>
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<td>MSL</td>
<td>Mean sea level</td>
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<td>N</td>
<td>Nitrogen</td>
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<td>NRC</td>
<td>Nagarjuna Sagar Right Command</td>
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<td>NRCC</td>
<td>Non-reinforced cement concrete</td>
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<td>NPW</td>
<td>Net present worth</td>
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<td>ORP</td>
<td>Operational Research Project</td>
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<td>OSSD</td>
<td>Open subsurface drainage</td>
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<table>
<thead>
<tr>
<th>Acronym</th>
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<tr>
<td>P</td>
<td>Phosphorous</td>
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<td>PSSD</td>
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<td>PVC</td>
<td>Poly-vinyl chloride</td>
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<tr>
<td>RAU</td>
<td>Rajasthan Agricultural University</td>
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<tr>
<td>RSC</td>
<td>Residual sodium carbonate</td>
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<tr>
<td>RY</td>
<td>Relative yield</td>
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<tr>
<td>SAR</td>
<td>Sodium adsorption ratio (m mol l$^{-1})^{1/2}$</td>
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<td>SSD</td>
<td>Subsurface drainage</td>
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<td>TBP</td>
<td>Tungabhadra Project</td>
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<td>UAS</td>
<td>University of Agricultural Science</td>
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<td>UKP</td>
<td>Upper Krishna Project</td>
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<td>United State Department of Agriculture</td>
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