Drainage problems in India

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1 General

Almost the whole of India is situated in the tropical or sub-tropical region. Most of the rainfall is concentrated in a period of about 3 months of the monsoon season. Figure 1 shows the isohyets of normal annual rainfall and also the boundaries of the various states forming the Federal Union of India. The areas subject to annual flooding and drainage congestion lie in the States of Uttar Pradesh, Bihar, West Bengal, Assam, Orissa and Andhra Pradesh. The annual rainfall in these areas varies between 1000 and 1500 mm. However, vast areas in the Punjab, Haryana and parts of Rajasthan also suffer from surface drainage problems due to the flat terrain and inadequacy of natural drainage, even though the annual rainfall is somewhat lower than 1000 mm. Areas in the flat plateaus of Madhya Pradesh also suffer occasionally from drainage congestion during spells of heavy monsoon rain lasting for 2 or 3 days.

The development of flood control and drainage in India started on a big scale only after the disastrous floods of 1954. Since then a total length of 26 119 km of drainage channels have been constructed in various States upto March 1985. Table 1 shows the progress of physical works in flood protection and drainage completed upto March 1985. The National Commission on Floods assessed that a total area of about 40 million ha is liable to floods and drainage congestion. Out of this, it was estimated that only about 80% or 32 million ha could be afforded reasonable protection. From Table 1 it will be seen that, upto March 1985, about 13 million ha is benefitted by flood protection and drainage measures. Separate figures for drainage are not available.

2 Waterlogging and salinization

The largest areas provided with surface drainage are located in the Punjab and Haryana in northern India. This is due to the fact that the natural drainage was most deficient in these States. Also these States contain the largest percentage of irrigated areas. Irrigation in the last few decades has led to a steady rise of the watertable, and to counteract this, an extensive programme was started to minimize groundwater recharge by improving surface drainage, lining canals and distributaries, and more recently, tertiary canals and watercourses. Figure 2 shows waterlogged areas, where the watertable is within one metre from the ground surface. Watertable contours of 3 metres and 6 metres are also shown in Figure 2. These areas in the States of Punjab, Haryana and Rajasthan can become affected by waterlogging and soil salinization, if remedial measures are not taken in time.

In the northern parts of Punjab and Haryana, the groundwater is fresh. In these areas, the increased abstraction from wells has kept the watertable under control. On the other hand, in the irrigated areas of Rajasthan and adjoining southwestern parts of Punjab and Haryana, the rainfall is low. The groundwater is brackish to saline in these areas.

Figure 3 shows the electrical conductivity (EC) of the groundwater expressed in micromhos per centimetre. Generally water with an EC value less than 2000 micromhos/cm is considered fresh and suitable for irrigation. Brackish water (EC between 2000 and 4000 micromhos/cm) is marginally usable. Water with an EC value greater than 4000 micromhos/cm is considered unsuitable for irrigation. Only the shallowest portions of groundwater are fresh and the EC value increases with depth. Extending

Table 1 Progress of physical works completed up to March, 1985

State/Union Territory	Length of embankments (km)	Length of drainage channels (km)	Town protection works (no's)	Villages raised (no's)	Area benefitted (in lakh ha)*
Andhra Pradesh	478	9400	15	21	9.93
Assam	4405	799	60	–	15.28
Bihar	2720	365	47	–	18.44
Gujarat	408	271	29	30	4.30
Haryana	556	3079	–	90	16.21
Himachal Pradesh	58	11	–	–	0.09
Jamnu & Kashmir	46	10	6	–	0.58
Karnataka	–	–	–	–	0.02
Kerala	82	12	3	6	0.24
Madhya Pradesh	13	–	29	–	0.02
Maharashtra	26	–	23	–	0.01
Manipur	273	76	1	1	0.80
Meghalaya	102	–	8	2	0.88
Orissa	997	103	13	29	4.53
Punjab	1021	6515	3	–	26.49
Rajasthan	140	170	16	–	0.40
Sikkim	–	–	2	–	–
Tamil Nadu	8	19	–	–	0.83
Tripura	103	94	10	–	0.27
Uttar Pradesh	1666	3429	64	4511	13.67
West Bengal	910	1284	44	–	16.22
Delhi	83	453	–	–	0.78
Goa, Daman & Diu	8	10	2	6	–
Pondicherry	59	19	–	–	0.07
Total	14162	26119	375	4696	130.06

* 1 lakh ha = 100 000 ha

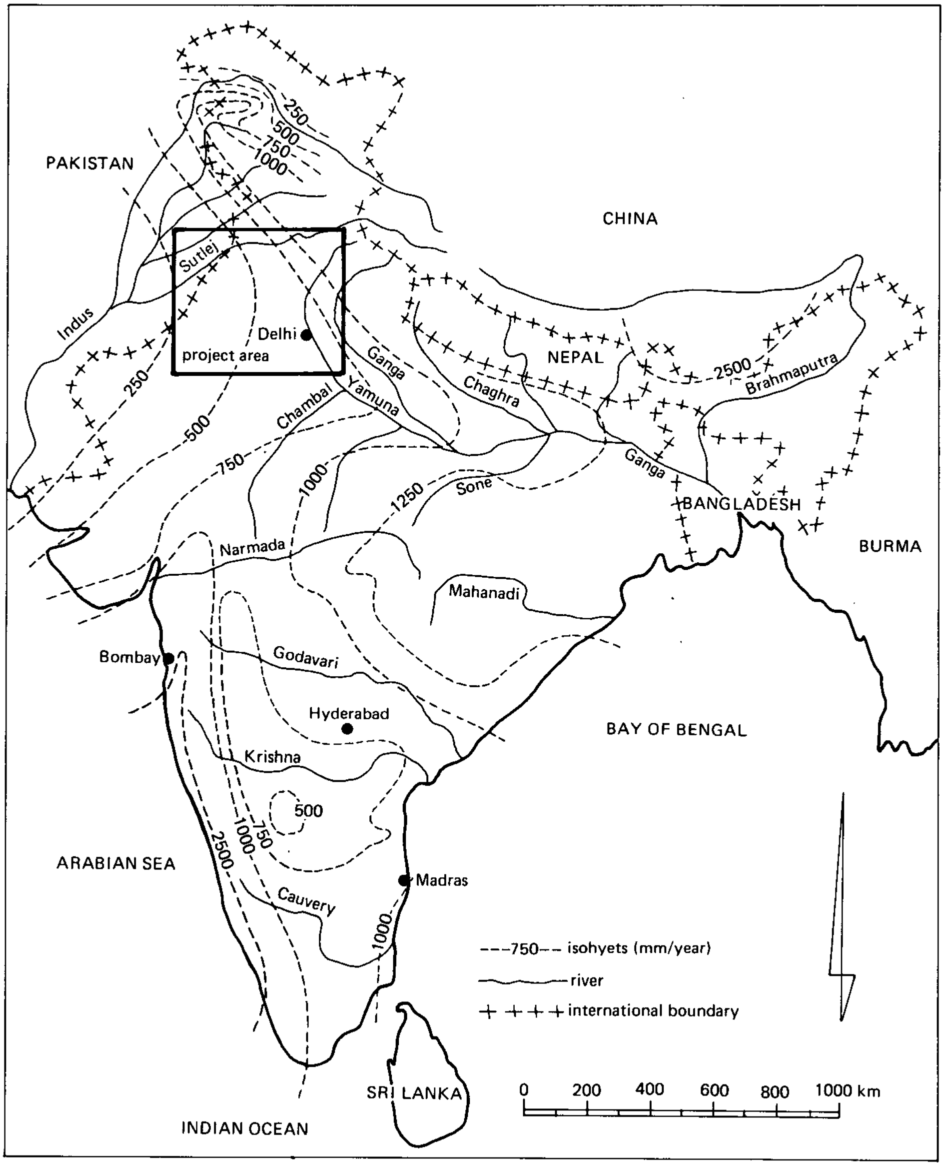

Figure 1 Mean annual rainfall in India

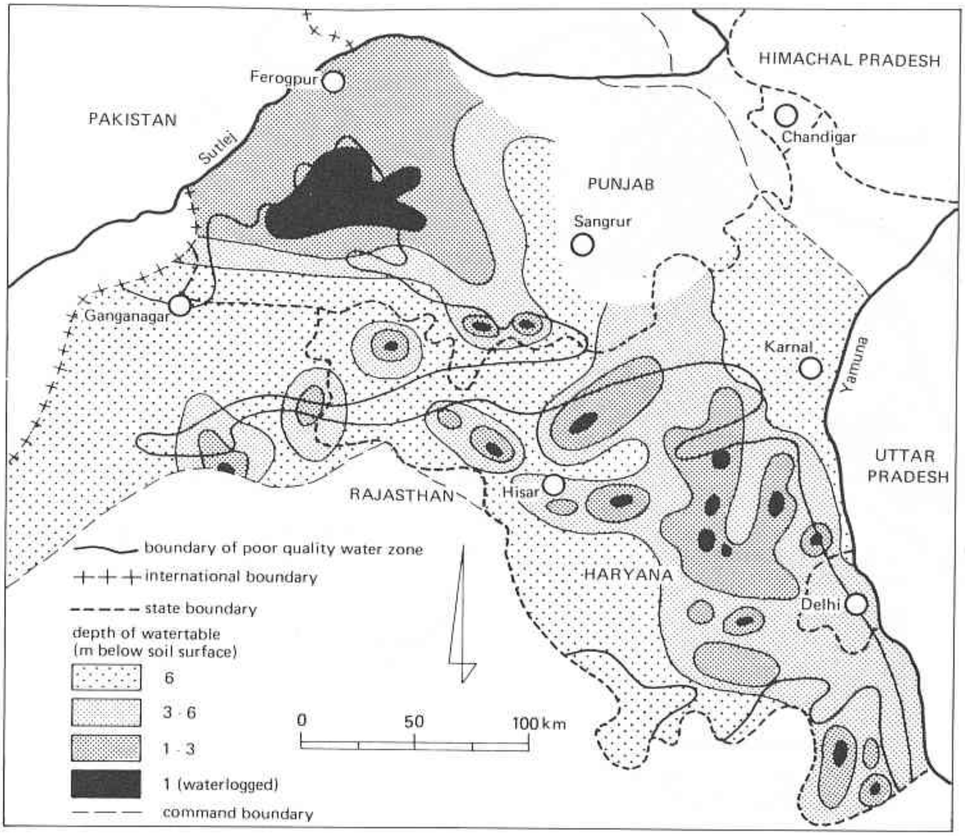

Figure 2 Waterlogged and critical areas in Punjab and Haryana

the irrigated area, the abstraction of the brackish groundwater by irrigation wells, diminished or stopped almost entirely. Thus, because of the introduction of irrigation in these areas, the watertable started rising, causing waterlogging and salinization problems. In some areas there has been a shift from cotton cultivation to rice crops. Subsurface drainage has so far not been installed, except experimentally, because of the high cost involved in relation to the value of crops produced.

A considerable length of drainage channels has been constructed in the State of Andhra Pradesh especially to speed up drainage of the areas around Colleru lake in the Krishna-Godavari delta. In the Sunderbans area of the Ganga river delta in West Bengal State, there are numerous estuaries subject to tidal action. The saucer-shaped land between the tidal creeks has been reclaimed by constructing embankments. Sluice gates and connecting link channels have been constructed to facilitate drainage during periods of low tide. Although drainage by gravity is slow, pumping is rarely resorted

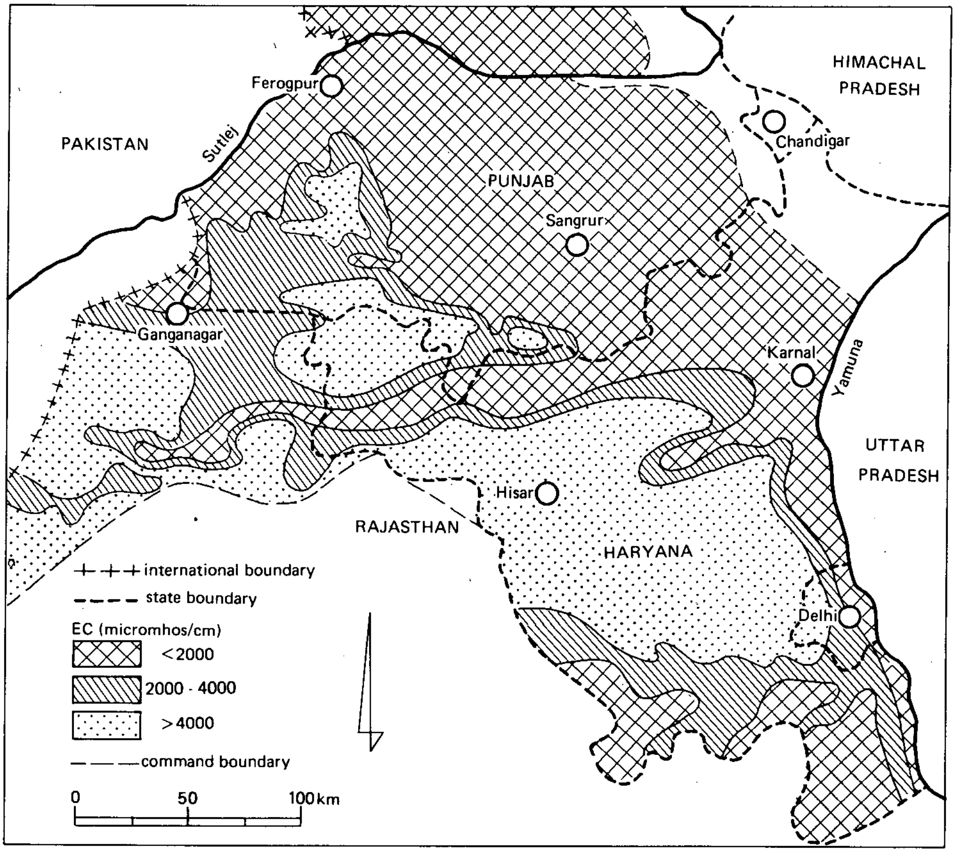

Figure 3 Groundwater quality in Punjab and Haryana

to. Subsurface drainage is not installed, because it is not required during the paddy growing season, and during the dry season, a second crop cannot be grown because of the shortage of fresh water for irrigation. Salinization does not seem to be much of a problem. However, salinization is a problem in the low-lying semi-arid areas along the Saurashtra coast in the State of Gujarat in western India.

3 Run-off

Areas where surface drainage is a problem is the Mokamah Tal area in Bihar State where run-off from upland areas remains locked up for several months because of high flood levels in the Ganga river at the outfall of the natural streams draining the area. Other areas, where drainage congestion occurs, is on the country side of flood protection embankments, such as along the Kosi river in northern Bihar. Here, sediment deposition on the berms of the embanked river tends to choke up the existing outfalls of streams draining the areas, protected by the embankments. Long drainage channels, running parallel to the embankments, have therefore to be constructed on a flatter slope to reach a suitable outfall point downstream, which is above the river flood levels. Even so, there is lockage of drainage during periods of high floods in the river. Similarly there is drainage congestion near the confluence of tributaries with the main river, especially where both are embanked. Other areas of drainage congestion are so-called 'chaurs', which are ox-bow lakes along abandoned courses of alluvial rivers, especially in northern Bihar.

Sometimes inter-state problems have arisen in the drainage of low-lying areas in some of the northern States like Punjab, Haryana, Rajasthan, Uttar Pradesh and the Union Territory of Delhi. Sometimes the upstream riparian States have constructed artificial drainage channels or improved natural drains, and consequently flood run-off from these areas has exceeded the discharging capacity of existing natural or artificial drains in the downstream riparian States. In such cases, there are difficulties and delays in arriving at amicable solutions regarding the design features of an integrated drainage system and/or the liability for the cost. Sometimes, difficulties also arise in bearing the cost of improvement of cross-drainage works in roads and railway lines intersecting the drainage lines.

4 Design criteria

Because of large variations in the frequencies of high intensity long duration storms, in topography, in soil characteristics, and in nature of crops grown, different practices have developed in various States in the design criteria for drains. Many of these are based on recommendations of Technical Committees set up by State Governments in the past. Brief details are given below:

- The Reddy Committee, Delhi (1953), recommended that rural drains in Delhi be designed for 0.10 m^3/sec.km^2 (10 cusecs/$mile^2$) which could be the run-off from a 3-day storm rainfall of 5 years frequency to be drained in three days assuming a run-off coefficient of 15%;
- The West Bengal Flood Enquiry Committee (1959) also considered a 3-day rainfall of 5 years frequency, but increased the period of disposal to 14 days, as the main crop during the monsoon season is paddy which can withstand longer submergence. The Committee recommended a net run-off of 19 mm (3/4 inch) per day for deltaic rural areas, 38 mm ($1^1/_2$ inch) per day for semi-urban areas and agricultural areas having steep slopes, and a still higher index of 76 mm to 114 mm (3 to 4 inches) per day for urban areas. For the design of cross-drainage structures the Committee recommended 25% higher discharges. The run-off index of 19 mm (3/4 inch) per day corresponds roughly to 0.22 m^3/sec.km^2 (about 20 cusecs/$mile^2$);
- The North Bihar Drainage Committee (1967) recommended the disposal of a 3-day maximum rainfall of 15 years return period in a period of 10 days. This works out to 0.10 m^3/sec.km^2 (10 cusecs/$mile^2$). In the case of masonry structures the design

discharge recommended by the Committee was based on a 3-day rainfall of 50 years return period to be drained in 10 days, which works out to 0.20 m^3/sec.km^2 (18 cusecs/$mile^2$);

- The Indian Standard Guidelines for planning and design of surface drains (IS-8835-1978) recommends that run-off from a 3-day storm rainfall should be disposed of in a period depending on the tolerance of individual crops as indicated below:
  - Paddy 7 to 10 days
  - Maize, bajra (millets) and other similar crops 3 days
  - Sugarcane and bananas 7 days
  - Cotton 3 days
  - Vegetables 1 day;
- The following run-off coefficients were recommended for plain areas with different soils:
  - Loam, lightly cultivated or covered 0.40
  - Loam, largely cultivated and suburbs with gardens, lawns, macadamized roads 0.30
  - Sandy soils, light growth 0.20
  - Parks, lawns, meadows, gardens, cultivated area 0.05-0.20
  - Plateaus lightly covered 0.70
  - Clayey soils stiff and bare, and clayey soils lightly covered 0.55

Cross-drainage structures are to be designed for a 3-day rainfall of 50 years frequency, the time of disposal remaining the same depending on the type of crop. 'In fixing the waterways care should be taken to see that afflux is within the permissible limits'. In India the permissible limit is generally considered as two feet (0.6 m). The drains, which are generally unlined earthen channels are designed by Manning's formula (coefficient of rugosity = 0.025). The full supply level of the drains at their outfall into a river, is kept higher than the dominant flood level, which is defined as that stage of a river which is not exceeded for more than three days at a stretch for 75% of the flood events in a ten year period of record.

5 Construction, cost and maintenance

Generally, manual labour is used for constructing drainage channels. Sometimes for larger drains, draglines are used for excavation as well as desilting of drains. In urban areas, the channels may be lined in order to reduce the land width required. Sometimes the smaller drainage channels in city areas are covered. Generally only link drains and outfall drains into natural rivers or streams are constructed. Tertiary or field drains are rarely constructed.

A rough idea of the cost of flood control and drainage in India can be obtained from Table 2.

The figures for expenditure and area benefitted shown in Table 2 include figures for flood protection embankments, river bank protection, etc. However, the criteria for approval of embankment and drainage schemes are similar, i.e. that the benefit-cost

Table 2 Cost of flood control and drainage in India

Period	Expenditure	Area benefitted	Global cost per ha	
	(millions Rupees)	(million ha)	Rupees(Rs)	U.S. $
1954-56	132	1.00	132	10
1956-61	480	2.24	214	16.5
1961-66	820	2.19	374	29
1966-69	420	0.46	913	70
1969-74	1620	2.15	753	58
1974-77	1791	1.44	1244	96

ratio should exceed 1.5. So the figures of cost per ha may be taken as an indication for the cost of surface drainage projects.

For maintenance of embankments an Expert Committee, set up by the Ministry of Irrigation, recommended in January 1983 the following annual provisions for maintenance of drainage channels:

Discharge upto 5 m^3/sec	Rs. 2000/km
Discharge between 5 to 15 m^3/sec	Rs. 2500/km
Discharge above 15 m^3/sec	Rs. 5000/km

The above rates are applicable for non-tidal channels. In case of channels in tidal areas, these rates are to be increased by 50%.

The construction and maintenance of drainage projects is generally carried out by the Irrigation and Flood Control Departments of State Governments. They have the usual hierarchy with Assistant Engineers at the lowest professional level, supervised by the Executive Engineers, Superintending Engineers and Chief Engineers. The construction is generally done through contractors on the basis of open tenders. Maintenance is generally done departmentally.

The maintenance problems which arise are usually due to insufficient allocation of funds, silting of drains and weed growth. Generally the weed removal and desilting is done manually.

Subsurface drainage has been tried in pilot projects by using tile drains installed in manually excavated trenches. Machinery for laying perforated PVC pipe drains have not yet come into use, because subsurface drainage is generally considered uneconomic in the prevailing agro-economic situation in India.

Land drainage in the Atlantic region of Costa Rica

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1 Introduction

Costa Rica is a small tropical country located in the southern part of Central America with an area of 51 000 km^2 and a population of approximately 2 500 000 inhabitants. It is in between the latitudes 8 and 11 degrees North and the longitudes 82 and 86 degrees West and has borders with the Republic of Nicaragua in the north and with the Republic of Panama in the south-east. Furthermore Costa Rica has a coast-line with the Caribbean Sea in the east, and with the Pacific in the west and south-west.

The climate is predominantly warm (mean annual temperature varies from 28 to 32°C) and humid in the lowlands and coastal areas lower than 500 m above sea level (the Atlantic and Pacific regions), temperate in between 900-1500 m above sea level and cool in the mountainous regions. There is a great variety of microclimates due to the irregularity of the topography in Costa Rica.

Figure 1 shows the mean annual rainfall in Costa Rica, varying between 1000-7000 mm. Mean rainfall values are 1600 mm at the Central plateau, 1900 mm in the Pacific region and 3500 mm in the Atlantic region.

Since colonial times the agricultural activities have been the main source for economic development of the country. The main agricultural products are coffee, sugarcane and rice. In the Atlantic and Pacific humid regions bananas, oil palm, cacao, corn, pineapple and recently tropical and ornamental plants are cultivated.

2 Drainage problems and solutions

According to governmental investigations, Costa Rica has extensive areas with very good soils, although some areas have drainage problems. It has been estimated that in the Atlantic region out of a total area of 300 000 ha with drainage and flood control problems (temporary, seasonal, or permanent), an area of 250 000 ha with high agricultural potential could be reclaimed by drainage and flood control measures. At the moment, in spite of the almost uniform rainfall distribution except in critical periods with more than 400 mm per month, these areas are hardly used for agricultural purposes.

The development of the areas in the Atlantic region is mostly initiated by private companies, who are introducing drainage and flood control measures. They built dikes and cleared waterways near the plantations together with land smoothing. Results were not always positive, sometimes even negative. Flash floods during the wet season in the sediment-loaded rivers with small hydraulic cross-sections caused flooding and as a consequence high groundwater levels in the plantations.

In recent years the banana production of Standard Fruit Company and some others has increased considerably due to the introduction of subsurface drainage systems, especially in areas with medium and coarse textured soils where pipe drains were installed. Corrugated pipes (Rib-loc and ADS) have been used. In sandy or silty textured soils, the pipe drains were mostly prewrapped with a spun bounded nylon filter. The high hydraulic conductivity values of these soils in the banana plantations are an advantage for the proper functioning of the installed subsurface drains (see Table 1).

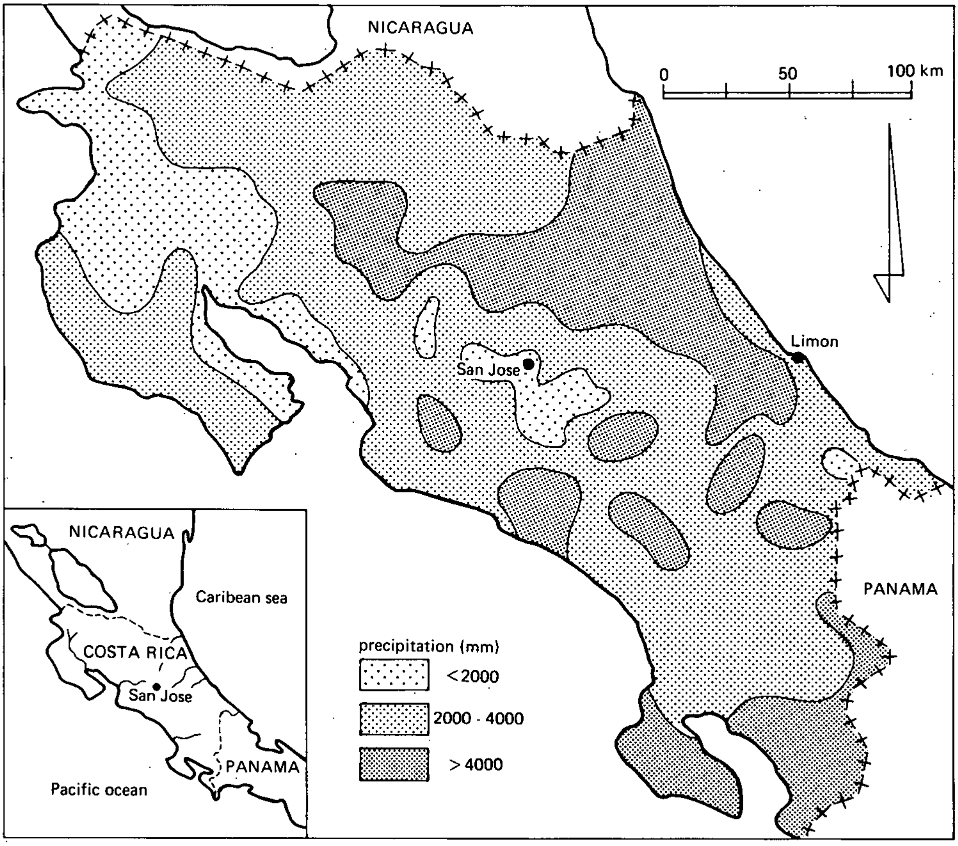

Figure 1 Mean annual rainfall inCosta Rica

Table 1 Hydraulic conductivity values of soils in different areas of La Estrella Valle, Limon, Costa Rica

Place	K(m/d)	Place	K(m/d)	Place	K(m/d)	Place	K(m/d)
M-8	9.39	N-3-1	4.09	0-1-1	16.70	Q-1-3	8.45
M-9	15.96	N-3-2	16.74	0-1	7.71	Q-1-3	8.84
M-10	11.63					Q-1-4	16.48
M-11	20.15						
M-25	12.70						
M-26	15.65						
M-27	17.00						

(Source: Fernandez and Aguilar, 1981)

Some of the general criteria used in the design of these drainage systems are:
- The watertable must decrease to a depth of 1.10-1.20 m in 24 hours;
- The formulas to calculate the drain spacing are the Hooghoudt formula for homogeneous soils and the Ernst formula for stratified soils;
- The drainage coefficient is 60-70 mm/day, which value is derived from a 3-day average rainfall of 100-125 mm/day for a return period of 5 years. These intensities are in general smaller than the soil infiltration values in these plantations (5-15 cm/hour).

The reliability of the above described drainage design criteria has been evaluated by measuring watertable levels and drain discharges. The hydraulic conductivity values elaborated by this method were similar or higher than the values previously determined by applying the auger-hole method.

The construction of the pipe drainage systems is done manually to avoid damages within the plantations. Machinery is only used for digging of the collectors and main drains.

The main steps during the construction of the pipe drains are:
- Surveying and levelling of the pipe lines in the field;
- Installation of wooden stakes at every 20 m of the pipe line indicating the respective cuts for control of the trench bottom slope (3-4%);
- Man-made excavation of the trench to the required depth;
- Installation of the drain pipes at the trench bottom, sometimes a filtermaterial is placed in an extra operation;
- Backfill of the trench with the excavated soil.

Careful supervision is needed during the whole construction period.

The drain spacing varies between 20-45 m, while the mean drain depth ranges from 1.2-1.8 m and the maximum pipe line length is more than 300 m (see Figure 2). A jetting nozzle is used for cleaning these pipe drains.

With an average total pipe line length of 300-400 m per ha, the average cost of these pipe drainage systems amounts to US$ 1200-1500/ha including open drains, pipes, filtermaterial, etc.

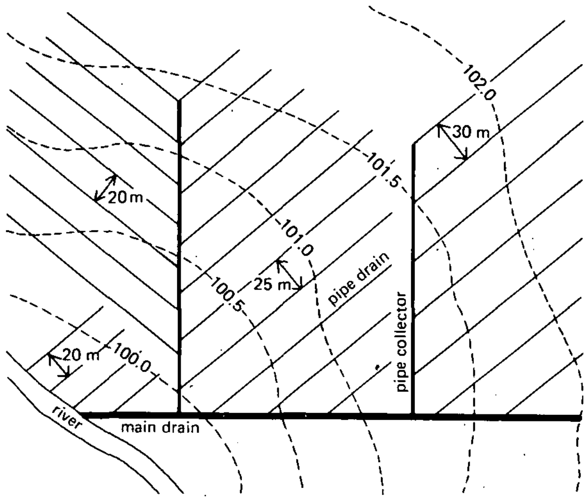

Figure 2 Typical lay-out of a subsurface drainage system in a banana plantation in the Atlantic region of Costa Rica

3 Other drainage programmes

The Costa Rican government policy is to stimulate these types of projects for improving agricultural production. The aims of these projects are:
- To reactivate agricultural production in the country;
- To increase national production levels and to create jobs for the population in the Atlantic region of Costa Rica.

Some of the main actions to attain these purposes are:
- The creation of the National Service of Groundwater, Irrigation and Land Drainage (SENARA) in 1983 to give an impulse to the farming development in the country through drainage, irrigation and flood control;
- The National Development Plan 1982-86 gave priority to the farming sector, setting the basis for adequate watershed management for flood control in the Atlantic region;
- A technical cooperation programme signed with the government of Japan in May 1985.

Due to these actions the Costa Rican government, represented by SENARA, and the government of Japan, represented by the Japan International Cooperation Agency (JICA), signed an agreement in order to obtain technical assistance for an agricultural development project in the northeastern part of the Atlantic region. This agreement considers the study and development of three watersheds along the rivers Reventazon, Pacuare and Chirripo covering a total area of 64 000 ha (pilot areas). It also considers the establishment of a pilot watershed to be used as an experimental and demonstration area.

The criteria for the selection of the three watersheds were:
- Good agricultural soils;
- Good accessibility to the main population centers.

The estimated cost for the development of the pilot areas and the feasibility studies in the pilot watershed is US$ 300 000 and 700 000 respectively. The agreement sets a tentative 20-months period for the field work and 23-months for the final results.

References

Barrantes, J.A., A. Liao and A. Rosales 1985. Atlas climatológico de Costa Rica. San Jóse, MAG-IMN.

Barrantes, L.V. 1981. Práctica de especialidad. Drenaje subterráneo en Rio Frio. ITCR, Cartago. Costa Rica.

Fernández, F. and J. Aguilar 1981. Práctica de especialidad. Drenaje subterráneo en el Valle de la Estrella. ITCR, Cartago. Costa Rica.

Hernández, A. 1979. El riego, el drenaje y el control de inundaciones. San José, CONARIEGO.

SENARA, 1985. Programa de rehabilitación de tierras, control de avenidas y drenaje de tierras agricolas (primera parte). San José.