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DRAINAGE OF HEAVY SOILS

by

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Abstract : *Heavy clay soils (Vertisols and associated soils) constitute a major group of soils in India. Because of their clayey nature, these soils are highly moisture retentive and hence possess high potential productivity with proper soil, water and crop management practices. Under irrigated irrigations these soils are very prone to waterlogging and soil salinization on account of their low saturated hydraulic conductivity and impeded internal drainage. Vertisols owe their poor drainability to their high clay content and characteristic swelling—shrinking property. Appropriate preventive measure must be taken to ensure sustained productivity of these soils through better management and control of irrigation water on farm and also of the main system. Where the problems already exist, in addition to preventive measures, suitable curative measures also must be adopted. Studies have shown that the open ditch drains are not very successful in Vertisols for a number of reasons. Vertical drainage is particularly suited to these soils which can also help to achieve water economy through conjunctive use of surface and ground water in the canal command areas. A recent innovation of "chimney" drains has shown considerable promise in effectively draining deep black cotton soils in two projects in Maharashtra. Similar experiments should be conducted elsewhere in the heavy soil areas.*

1. Introduction

To meet the ever-increasing demand of food, fibre and fodder scientific development and management of the land and water resources, which are the basic inputs for agriculture, must receive highest priority. Considerable emphasis has been given over the past 3 decades on creating irrigation potential to increase and stabilise agricultural production in the country. As a result, the irrigation potential of the country has increased from 19.5 million hectare (Mha) at the beginning of the plan period to 67.9 Mha in 1984-85 at an enormous investment of Rs. 150 billion (Randhawa, 1987). According to the Annual Report of the Ministry of Water Resources for 1987-88, an outlay of Rs. 3,255 crores had been provided last year to create an additional irrigation potential of 2.38 Mha.

In this effort of such fast development of irrigation potential, proper utilisation of the available water resources and the possible adverse effects on the precious land resource due to poor management of irrigation water received very little attention in the past. This resulted in the average efficiency of the irrigation project in the country being as low as 30--35%. The wasteful use, lack of control, and poor system and farm level management of water also resulted in the rise of water table, surface waterlogging and consequently soil salinization. According to recent reports, waterlogging and soil salinity has already affected about 7 M ha of good agricultural land and another 20 M ha suffer from salt accumulation to some degree which is detrimental to crop production (Randhawa 1987; Vora, 1988). There is now an increasing awareness of not only the need for providing remedial drainage to reclaim the waterlogged soils but also of the need of incorporating carefully planned drainage system as an integral part of any irrigation project right at the design stage. The lesson learnt from the experience of several irrigation projects in the past, which have resulted in large tracts of once good agricultural land and another 20 Mha suffer from salt accumulation to some degree which is detrimental to crop production (Randhawa 1987; Vora, 1988). There is now an increasing awareness of not only the need for providing remedial drainage to reclaim the waterlogged soils but also of the need of incorporating carefully planned drainage system as an integral part of any irrigation project right at the design stage. The lesson learnt from the experience of several irrigation projects in the past, which have resulted in large tracts of once good agricultural land due to neglect of drainage, that irrigation and drainage must go hand in hand has been amply emphasised by Fukuda (1978) by coining the new word "irrinage."

The development of and solutions for the drainage problems are quite complex and site specific. They require an in depth understanding of soil-water-plant relations, the agro-hydrological balance of soil moisture in the root zone of crops, and of the ground water in the subsoil underlying the root zone, the ground water flow through the subsoil layers, and the relationship of all these factors to development and control of soil salinity, because even with irrigation water of very good quality, appreciable amounts of salts are applied to land each year.

This paper addresses to the drainage problems of heavy black soils (Vertisols and associated soils) and critically analyses available information to suggest suitable drainage solutions applicable to regions with these heavy soils in the country.

2. Distribution, Origin and Characteristics of Vertisols

The black soils in the Deccan Plateau of India which become sticky when wet and hard when dry and the farmers find difficult to 'open' or plough when dry have been popularly known as the 'heavy soils'. They are also difficult to drain and to manage for sustained crop production. According to soil taxonomy they are essentially vertisols and associated soils namely, inceptisols and entisols. Because of their characteristic colour, they are also commonly referred to as Black soils. In Maharashtra and other adjoining areas, the farmers traditionally have been taking good cotton crops on these soils and hence they are also referred to as Black Cotton soils.

According to the latest soil classification soils over 0.5 m in depth, having at least 30% clay in all horizons above the lithic or paralithic contact or to a depth of 1 metre, whichever is shallower, having cracks at least 1 cm wide upto a depth of 0.5 m during part of most of the years and slickensides or wedge shaped natural aggregates some depth below the surface, and having the coefficient of linear extensibility (COLE) of 0.9 or more are referred to as Vertisols. Other shallow black soils with slight to moderate cracking, due to swelling (when moist) and shrinking (when dry) behaviour are referred to as associated Vertic soils (Palaskar and Varade. 1988).

The soils with the above characteristics are found in the low rainfall areas and occupy about 72.9 Mha area in India. They are distributed in decreasing order of aerial extent in the states of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, Tamil

Nadu, Rajasthan, Orissa and Uttar Pradesh (Table 1). They occur in penninsular India between 8°45' and 26°O'N latitudes and 66°O' and 83°45' E longitudes and thus occupy about 22.2 per cent of the total geographical area of the country (Murthy et al, 1982). The black soil region of the country is shown in Figure 1. It can be seen from Table 1 that Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu constitute about 94 percent of the total black soils region of the country which lies in the Deccan Plateau.

The Vertisols are derived from the basalt rich in basic minerals. The true Vertisols are formed *in situ* by the weathering of the parent rocks but there are also deep transported Vertisols formed by deposition of basaltic alluvium such as these found in Godavari and Krishna basins. The characteristic swelling and shrinking behaviour of Vertisols is caused by the presence of the clay mineral montmorillonite. It should be noted in this context that like all red soils are not laterites, all black soils found in the country are also not Vertisols. For example, the black soils found in Nainital Tarai are Mollisols, their rich black colour is due to high organic content and their clay mineralogy is different, they do not contain mont-morillonite and hence do not exhibit the swelling and shrinking properties.

The Vertisols being mostly clayey to silty-clay, they are highly moisture retentive having available water capacity of the order of 200 to 250 mm/m. Data compiled from various Reports of WALMI, Aurangabad is summarised in Table 2. These soils have, therefore, high potential productivity. Due to their high soil moisture retentivity the irrigation interval for most of the crops grown on these soils can be increased to 21 days in kharif and Rabi seasons and 10 to 14 days in Hot-weather.

Due to the presence of wide and deep cracks in dry conditions, the Vertisols have very high initial infiltration rates (infiltration capacity) which drastically decrease with increased wetting of the soil which causes progressive sealing of the cracks as a result of swelling. The basic infiltration rates determined after prolonged tests, when all the cracks are sealed and the entire soil profile is saturated in Vertisols from Maharashtra,

Table 1 : Distribution of black clay soil in India (After Murthy et. al., 1982)

State	Area (m. ha.)	% of gross area under black clay soil in India	% of total geographical area in India
Maharashtra	29.9	35.5	7.9
Madhya Pradesh	16.7	23.0	6.1
Gujarat	8 2	11.9	2.6
Andhra Pradesh	7.2	10.0	2.2
Karnataka	6.9	9.4	2.1
Tamil Nadu	3.2	4.2	1.0
Rajasthan	2.3	3.0	0.7
Orissa	1 3	2.0	0.4
Bihar	0.7	1.0	0.2
Uttar Pradesh	negligible	—	—

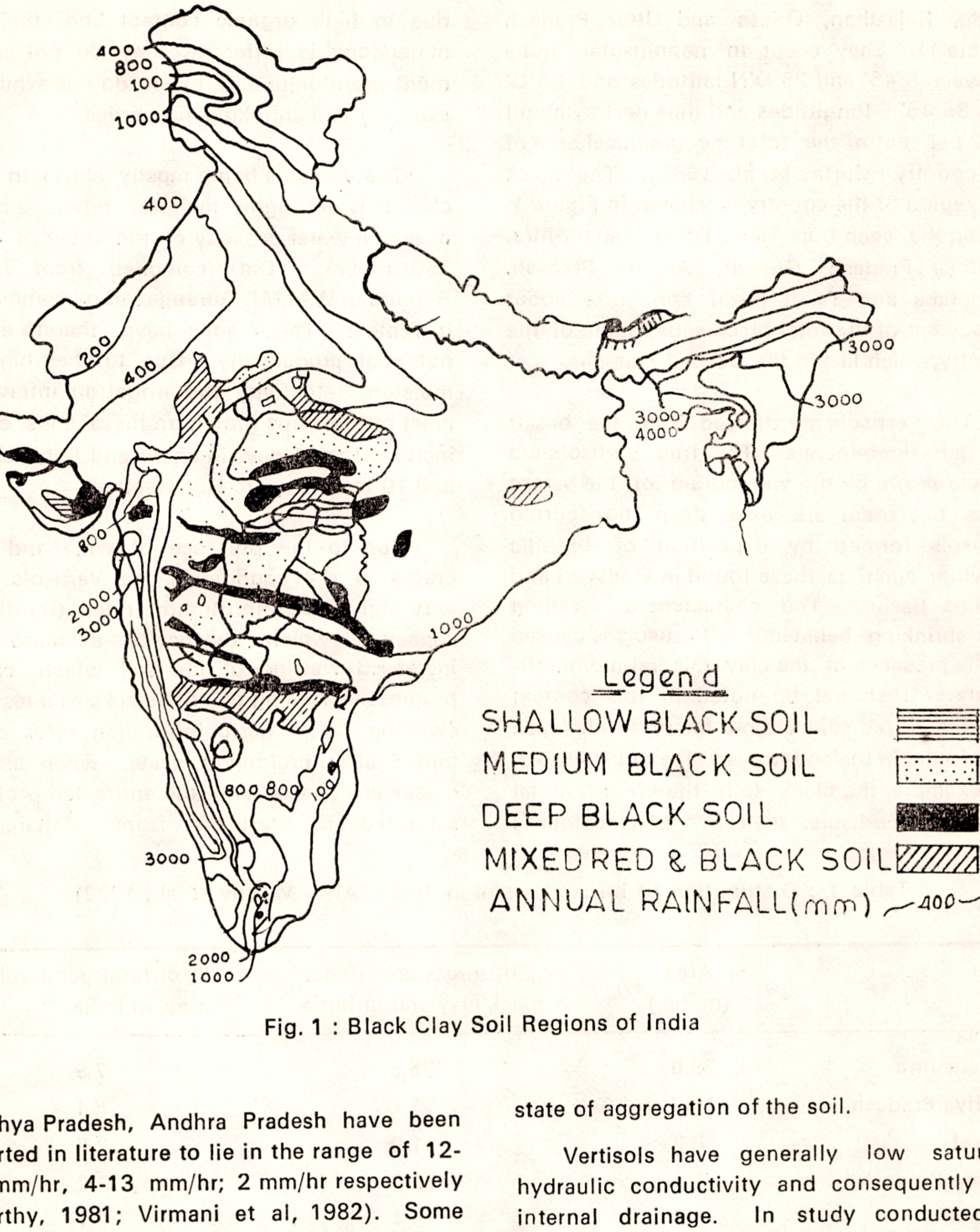

Fig. 1 : Black Clay Soil Regions of India

Madhya Pradesh, Andhra Pradesh have been reported in literature to lie in the range of 12-43 mm/hr, 4-13 mm/hr; 2 mm/hr respectively (Murthy, 1981; Virmani et al, 1982). Some typical basic infiltration rates from different sources are listed in Table 3. The terminal infiltration rates of Vertisols, although rather low vary many folds depending on clay content, exchangeable sodium ion content (Table 4), bulk density, soil surface conditions, soil tilth, antecedent moisture regime and the state of aggregation of the soil.

Vertisols have generally low saturated hydraulic conductivity and consequently poor internal drainage. In study conducted by WALMI, Aurangabad (1984) on heavy soils with drainage problems in the command of Jayakwadi Project in Maharashtra the saturated conductivity of Vertisols based on field experiments was found to range from less than 1 cm/day to about 10 cm/day in most of the places.

Table 2 : Soil Moisture Retention Characteristics of Vertisols of Maharashtra

Name of the Irrigation Project	Soil Type	% gravimetric soil moisture content			Bulk	Available
		Field Capacity	Permanent Wilting Point	Available water	Density gm/cm³	water capacity mm/m
Upper Wardha Project						
Morshi	Silty clay	33.7	15.5	18 2	1.20	218.00
	Silty loam	28.5	10.9	17.6	1.35	238.00
	Clay	38.1	16.7	21.4	1.05	225.00
Pus Irrigation Project						
Bhojla	Silty clay	30.87	15.70	15,17	1.31	199.00
	Silty loam	28 20	11.25	16.95	1.33	225.00
	Clay loam	31.00	16.10	12.90	1.31	195.00
Mula Irrigation Project						
Rahuri	Clay	40.08	22.47	17.61	1,10	194.00
Digraj	Clay	45.00	23.00	21.20	1.01	214 00
Sonai	Clay	30 80	15.00	15,80	1.25	197.00
Wadala	Clay loam	32.00	15.80	15.20	1.30	211.00
Dhom Irrigation Project						
Vyahali	Silty clay	33.50	15.90	17.60	1.25	220.00
		28.00	10.00	18.00	1.30	234.00
Suki Irrigation Project						
Sawkheda	Silty clay loam	32.00	15.00	17.00	1.26	214.00
Khandakwasla Irrigation Project						
Pune	Clay	42.00	22.00	20.00	1.14	228.00
Manjri	Clay	40.00	23.60	16.40	1.17	192.00
Bhim Irrigation Project						
Solapur	Clay	42.00	22.00	20.00	1.06	212.00
Mangalvedha	Clay	44.00	22.00	22.00	1.07	235.00
Jayakwadi Irrigation Project						
Changatpuri	Silty clay	34.00	18.70	15.30	1.30	199.00
Nirgudi Irrigation Project						
Palasgaon	Silty clay loam	35.10	19.00	16.10	1.25	201.00
Hira Irribation Project						
Padegaon		41.00	22.00	19.00	1.21	230,00

Table 3 Terminal Infiltration rates of some Vertisols

Location	Rate (mm/hr)	Source
Indore (JNKVV)	12.6	Gupta and Verma 1983
Jabalpur (JNKVV	4.7	Gupta st. al. 1976
Hyderabad (ICRISAT)	0.21	Krantz et. al. 1978
Rahuri (MAHARASHTRA)	6.4	Shinde et. al. 1982
Satna, Patera (Madhya Pradesh)	4.0	Gupta et. al. 1984
Parbhani Series (Maharashtra)	7.0	Ambegaonkar et al. 1984
Panna, Ragarpura (Madhya Pradesh) (Sundra Series)	5.0	Gupta et. al. 1984

Table 4 : Effect of Soil ESP on terminal infiltration rates of a Vertisol. (Gupta and Verma 1983)

Soil ESP	Infiltration rote (mm/hr.)	MWD (mm)
6.2 (Normal soil)	12.6	1.52
10.0	5.7	1.39
15.6	1.5	1.09
21.8	0.5	0.97
37.5	0.15	0 88

3. Drainage Problems in Heavy Soils

Most of the seven million hectare of agricultural land in the country which is affected by waterlogging and soil salinity lies in the arid or semi arid regions. The salt affected lands having deep black and medium deep black soils (Vertisols) in the states of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Rajasthan together comprise 1.42 Mha in area which is about 20 percent of the total salt affected soils in the country (Bhumbla, 1977). Figure 2 shows the areas which are either already damaged by soil salinisation or are likely to be damaged.

Experience shows that in most areas having heavy clay soils, with the introduction of irrigation the problems of waterlogging and soil salinity sooner or later begin to appear which grow in severity as well in extent with time. The alarming rate at which drainage problems can develop in heavy soils can be appreciated from the example of Jayakwadi Irrigation Project in Maharashtra where the total waterlogged area increased from 2642 ha in 1979-80 to 8448 ha in 1983-84 (Adkine and Kulkarni, 1986). A part of the Project command started receiving water in the year 1976. The extent of damaged areas in some selected irrigation projects in Maharashtra are listed in Table 5 as illustration.

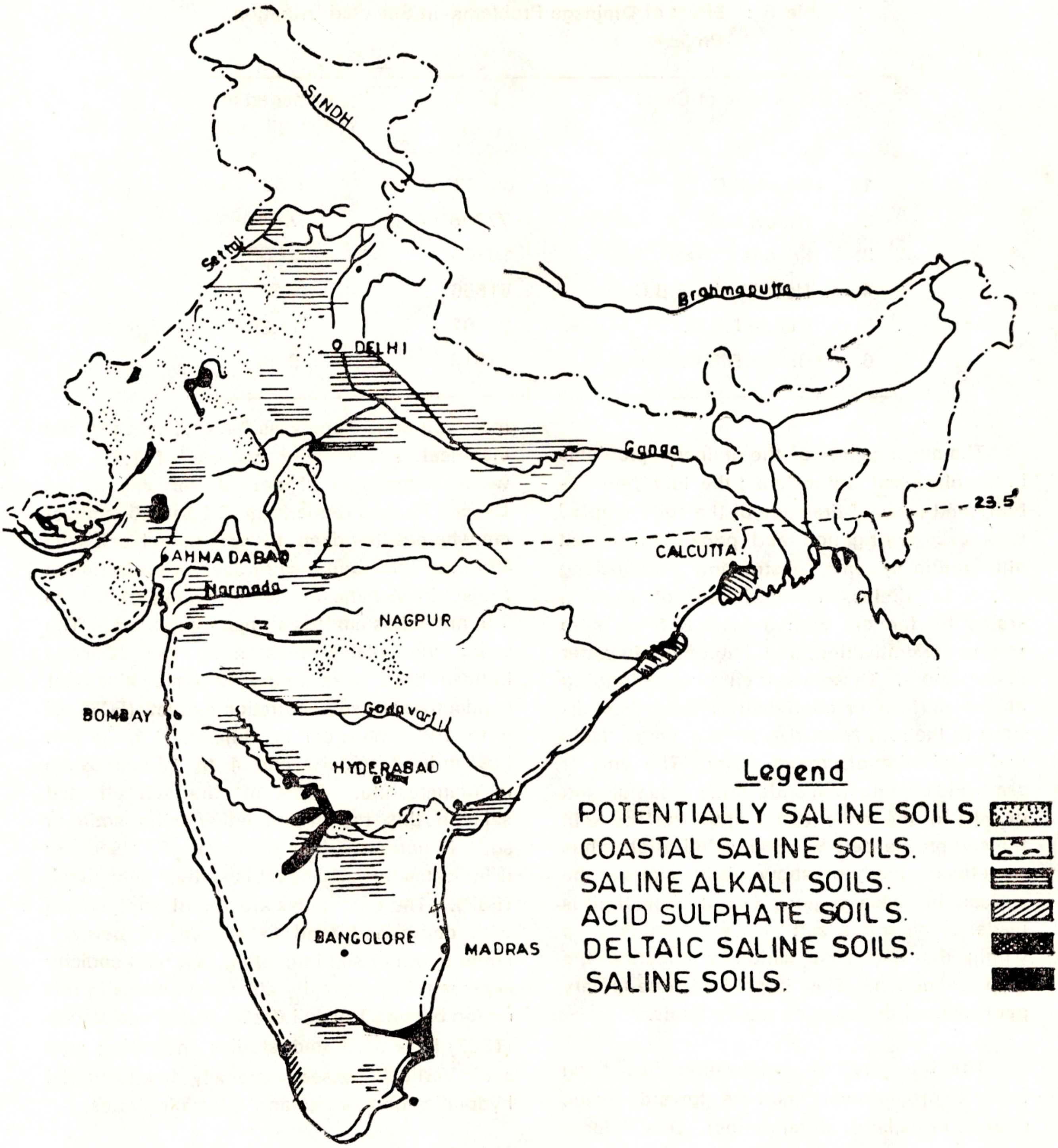

Fig. 2 : Salt Affected Soils of India

Table 5 : Effect of Drainage Problems in Selected Irrigation Projects

Sr. No.	Name of Canal	I.C.A. (ha)	% damaged area (1984-85 year)
1.	Nira L.B.C.	60632	6.52
2.	Nira R.B.C.	77308	7.44
3.	Krishna Canals	10706	32.35
4.	New Mutha R.B.C	61556	6.37
5.	Ghode L.B.C.	24602	11.36
6.	Ghode R.B.C.	11019	9.80

The major causes of the drainage problems in the black soil regions are : the low permeability and internal drainage of the soils coupled with excess irrigation and poor management of irrigation systems, obstruction or chocking of natural drains, encroachment of existing drains by farmers with a view to bring more area under cultivation, and improper rain water management. These result either waterlogging at the surface or continually saturated conditions in the root zone, rise in the water table and salinization of ground water. The arid or semi-arid climate then arids in the accumulation of salts in the soils either at the surface or in the soil profile below. Soil salinization, thus sometimes may not show visible signs at the surface in these regions but if a small pit is made, considerable salt accumulation is seen within the root zone seriously affecting the crop production. This is primarily due to very poor internal drainage of the Vertisols.

The intensity of salinization has been found to progressively increase towards rivers, streams or nallas (natural drains). Due to large capillary rise of the order of 1.5 m in the heavy soils, the water tables even at 2m depth can significantly contribute in salt accumulation in the root zone of the soils. The situation is further aggrevated if the ground water itself is saline. The bench-mark soil profile analyses have shown that the electrical conductivity values of 1:2.5 soil water suspension of normal Vertisols of the Deccan Plateau range from 0.1 to 0.5 mmhos/cm whereas the deep to very deep black soils from the command area of Jayakwadi Irrigation Project in Maharashtra the EC values of 0.1 to 1.9 millimhos/cm have been reported. The saline vertisols profiles from the Deccan Plateau have been found to have electrical conductivity of soil saturation extract (ECE) of 9 to 106 mmhos/cm in Gujarat, 6 to 24 mm hos/cm in Karnataka, and 4 to 16 mmhos/cm in Maharashtra. Most of the salt affected soils in this region are either saline-sodic or sodic in nature (Tables 6 and 7). Soil sodicity is indicated by exchangeable sodium percentage (ESP). The ESP values are found to increase with depth and tend to exceed 15 below 1 meter depth of soil indicating that soil sodicity is present in practically all the Vertisols in this region beyond 1 m soil depth. Gupta and Verma (1983) have presented studies indicating that sodic Vertisols posses extremely low saturated hydraulic conductivity and infiltration rates.

As a consequence of very low saturated hydraulic conductivity coupled with impeded internal drainage and low non-capillary porosity, many upland kharif crops in high rainfall Vertisol regions of the country produce low yields due to oxygen stress in the root

Table 6 : Physical and Chemical Characteristics of some salt affected Vertisols from different areas of Maharashtra

Characteristics	Sangli Sodic	(L T. Schemes) Saline — Sodic I	II	Parbhani (Purna command) Sodic	Saline-Sodic	Beed (Jayak-wadi command) Saline — Sodic	Satra (Krishna command) Saline—Sodic
ECe (mmhos/cm)	2.4	0.2—0.6% (T.S.S.)*	16	0.85	4.5	1—2% (T.S.S.)	0.6—1.0% (T.S.S.)
PH	8.5	9.0—9.3	8.5	8.8	8.8	6.9—8,6	8.3—8.4
ESP	25	14—34	40	23	15.5	20—28	1.8—5.7
Texture	Clayey	Clayey	Clayey	Clayey	Clayey	Clayey	Clayey
CaCo3 (%)	(N.A.)	8.9	N.A.	18.0	N.A.	8.12	4—5
Hydraulic Conductivity (cm/hr)	0 095	N.A.	0.052	0.62	N.A.	N.A.	N.A.
Gypsum requirement (t/ha)	N.A.	—	N.A.	7.0	N.A.	—	—

*T.S.S. = Total Soluble Salt

Table 7 : Nature of salt affected soils in Gujarat and Karnataka States

State and Locality	ECe (mmhos/cm)	ESP	PH	Remarks/References
Gujarat				
(a) Jodia Tq.	71—106	41—45	7.0—8.1	Soil depth varying from 1.5 to 2 m
(b) Khambalia Tq.	10—56	61—84	7.2—8.2	Calcium carbonate content ranging from 6 to 34%. Soils are saline-sodic in nature.
(c) Malia Tq.	9—34	35—90	7.2—7.9	
Karnataka				
Tungbhadra Project	6—24	20—71	7.0—7r8	Values are cited from several profiles. ECe and ESP values decrease with the depth of profile. Maximum value of ECe and ESP occur in 0-15 cm layer.

zone particularly during rainy days, The root growth is adversely affected particularly when the aeration porosity is less than 12 per cent of the soil volume (Robinson, 1964). The rainfall distribution of Vertisol regions is quite erratic. The average annual rainfall varies from 250 - 750 mm in the low rainfall areas to 750 — 1250 mm in medium to high rainfall areas (Figure 3). Rain storms of more than 20 cm with two to three days duration may be expected once in 10 years in these areas. This causes frequent inundation of relatively flatlands and accelerated run off and soil erosion in slopy lands because of poor infiltrability of these soils.

Radhawa and Rao (1981) have estimated the soil erosion caused by runoff in deep black soil regions to the tune of 10 to 43 t/ha. In many cases, rainfall builds up a psuedo or perched water table just below the top layer having higher permeability due to the activity of plant roots or presence of filled layer (Jaggi et. al, 1976). This further adds to the drainage problems in these areas.

The farmers in the heavy soil regions having high rainfall are compelled to leave the low lying lands fallow during kharif in the absence of adequate surface drainage. These farmers raise bunds around their land and keep it submerged during monsoon. This delays planting of the rabi crops. This practice known as 'Haveli' cultivation is still very common in Central Madhya Pradesh. The soil on the upper reaches on the other hand, do not get fully recharged with moisture due to low infiltrability resulting in poor yields of rabi crops.

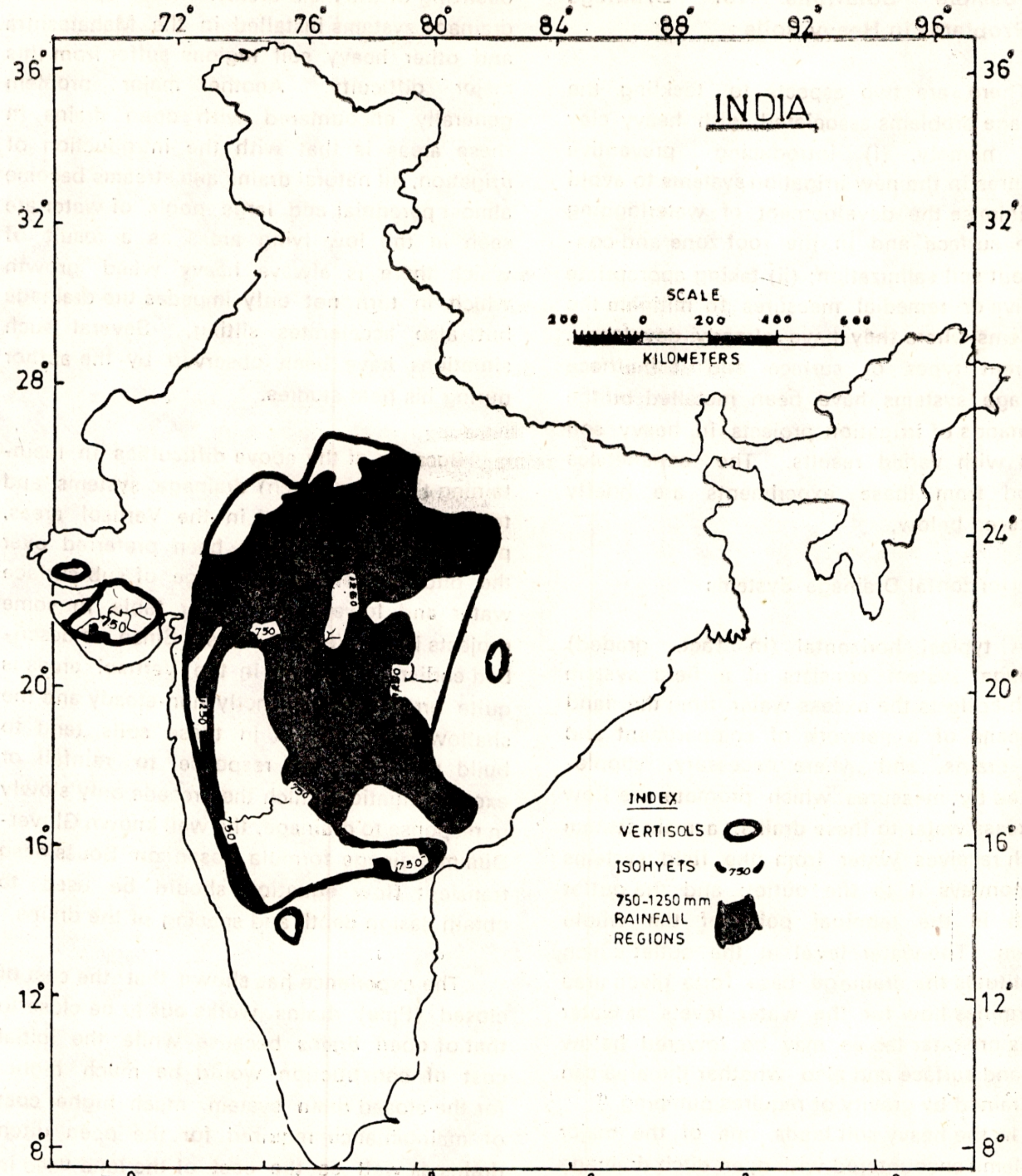

Fig. 3 : The Distribution of Medium to High Rainfall (750-1250mm/yr)
in the Vertisol Areas of India
(Adapted from Virmani et al, 1981)

4. Possible Solutions for Drainage Problems in Heavy Soils :

There are two aspects to tackling the drainage problems associated with heavy clay soils namely, (i) introducing preventive measures in the new irrigation systems to avoid or minimise the development of waterlogging at the surface and in the root zone and consequeut soil salinization; (ii) taking appropriate curative or remedial measures to mitigate the problems where they have already developed. Different types of surface and subsurface drainage systems have been installed in the commands of irrigation projects in heavy soil areas with varied results. The experiences gained from these experiments are briefly discussed below,

4.1 Horizontal Drainage Systems

A typical horizontal (in fact, graded) drainage system consists of a field system which collects the excess water from the land by means of a network of compartment and field drains, and where necessary, supplemented by measures which promote the flow of excess water to these drains; a main system which receives water from the field systems and conveys it to the outlet; and the outlet which is the terminal point of the whole system. The water level at the outlet which constitutes the drainage base for a given area determines how far the water levels or water levels or water tables may be lowered below the land surface and also whether the area can be drained by gravity or requires pumping.

In the heavy soil lands, one of the major problems encountered with open ditch drainage system whether for draining excess overland water or draining the sub-surface water or both is the instability of the ditches, soil erosion and silting in the main drains or nallas leading ultimately to a condition when the minimum clear outfall of about 0.5 m. which is necessary for the drainage system to function is no longer available. This requires a frequent desilting of the main drains. Most open ditch drainage systems installed in the Maharashtra and other heavy soil regions suffer from this major difficulty. Another major problem generally encountered with open drains in these areas is that with the introduction of irrigation, all natural drains and streams become almost perennial and large pools of water are seen in the low lying areas as a result of which there is always heavy weed growth which in turn not only impedes the drainage but also accelerates silting, Several such situations have been observed by the author during his field studies.

Because of the above difficulties in maintaining the open (ditch) drainage systems and to keep them functional in the Vertisol areas, pipe drainage system has been preferred over the ditch system for drainage of sub-surface water and lowering of water table in some projects in the Vertisol areas. Since, as described earlier, the rainfall in the Vertisol areas is quite erratic and distinctly non-steady and the shallow water tables in these soils tend to build up quickly in response to rainfall or excess irrigation which then recede only slowly in response to drainage, the well known Glover-Dumm drainage formula based on Boussinesq transient flow equation should be used to obtain design depth and spacing of the drains.

The experience has shown that the cost of closed (Pipe) drains works out to be close to that of open drains because while the initial cost of construction would be much higher for the closed drain system, much higher cost of maintainance required for the open ditch drains as well as the cost of the land used in laying open drains might offset the difference in the cost of construction alone (Sahni et al, 1988).

4.2 Vertical Drainage and Conjunctive Use :

One of the major limitations of the gravity drainage system in irrigated heavy soils is that due to the low permeabilities of such soils, they are often not effective in lowering the water table to the desired depth and at a rate fast enough to avoid inundation for a period longer than permissible for the crops grown. This problem would be even more serious in the deep black cotton soils where the underlying more permeable murum layer occurs at greater depths.

Another limitation of gravity subsurface drains as a consequence of very low permeabilities in the Vertisol profile arises from the fact the drainage design requires very narrow drain spacing involving prohitive costs.

The success of gravity drains also largely depends on the availability of sufficient gradient and clear outfall at the junction of carrier drains and the main drains. Unless these favourable conditions exist in the field, the gravity drains can not be functional.

When either of the above constraints or combination thereof occur, the only effective way to lower water table is to pump the water out. On undulating land pumped water can be disposed off through pipelines connecting various wells. Excessive earth moving is thus avoided as no deep canals need to be dug through topographic ridges.

In areas with deep B.C. soils underlain by murum, artesian pressures may often to be present. A typical soil profile found in deep B.C. soils in Maharashtra is shown in Table 8. In such, cases, pumping ground water from the murum and other premeable sub-strata may lower the peizometric surface below the water table creating a vertical downward flow from the upper layers. Where such permeable layers are found at a depth of 5 m or more, it is only with well drainage that full benefit can be derived from such favourable geohydrological conditions in lowering the water table to desired depth (Sahni et al, 1988).

If the ground water pumped by the well drains is of a quality acceptable for the crops to be grown, it can be let into the fields for irrigation. Ground water withdrawn from the aquifers by these vertical drains can be conjunctively used with the canal water supply for irrigation adopting several different ways, leading to economic and optimum use of the two resources. In areas where the water table is quite shallow, lowering of the water table to deeper layers with the help of vertical drainage will help in getting additional induced recharge to ground water in the rainy season.

One of the practical difficulties in constructing pipe drainage system is that since the drainage water has to be conveyed to main drains or nallas which may often be located quite far, it would require willingness and co-operation of all the farmers under whose fields the system has to be laid including the provision of man-holes. On the other hand, individual farmers or groups of farmers can install the vertical drainage serving smaller areas.

A major limitation of vertical drainage is the additional cost of energy required for operating a multiple well system. Vertical drainage system is also expensive to construct. However, the cost of well drainage can be reduced by constructing radial horizontal bores in deeper and more permeable layers through the vertical wells.

4.3 Chimney Drains

This is an innovative sub-surface drainage system which has recently been installed on an experimental basis in the commands of two irrigation projects in Maharashtra, namely, Purna and Jayakwadi Projects.

The system can be considered as a sort of combination of buried lateral drain and a vertical drain without pumping. In the pilot areas selected for these experimental drainage schemes, the highly permeable mu um layer

Table 8 : General soil profile in black cotton soil for Mabarashtra

Description of layer	Thickness of layer in m.	Hy. conductivity of layer
Layer No. 1		
Tilled layer	0.2 — 0.3	1 m/day
Layer No. 2		
Untilled low pervious layer but get self ploughed when dry to shrinkage, cracks, occured naturally upto deeper layers. Earth worm culturing may increase permeability.	0.5 — 1.00	0.01m/day
Layer No. 3		
Contains lime concentration, pervious clay with iron concentration and organic remains or peat of light texture material layer. Sometimes chopan soil is also found.	Varying thickness	Moderate to high
Layer No. 4		
Murum derived from basalt, schist or weathered rock layer.	Varying thickness	High
Layer No. 5		
Bed rock layer or basalt rock. Soft and hard strata are found alternately below this upto certain depth.	Varying thicknnss	Impervious layer

underlying the deep B.C. soils forms a good aquifer under confined conditions. Excess water from surface has infiltrated and recharged this aquifer creating artesian conditions. The vertical chimney drains which are essentially riser pipes provide a vertical outlet to the water in the murum layer which may not have a direct horizontal outlet nearby. Lateral drains of perforated P.V.C. pipe installed in a graded trench of 2 m. depth collect the water brought up by the chimney drains in the filter material filled around the lateral and such laterals ultimately deliver the water to the collector drain pipes which empty into the main drains (Fig. 4). Other constructional details are available elsewhere (Patil et. al, 1988 and Kokil et. al, 1988).

Such buried pipe-cum-chimney drain system was installed in the Purna Project at Katneshwer in summer of 1986 and about a year lateral at Aral which represent upland and lowland conditions respectiyely. Both the drainage schemes are reported to be functioning well. Monitoring of the scheme and data collection with regard to improvement of land

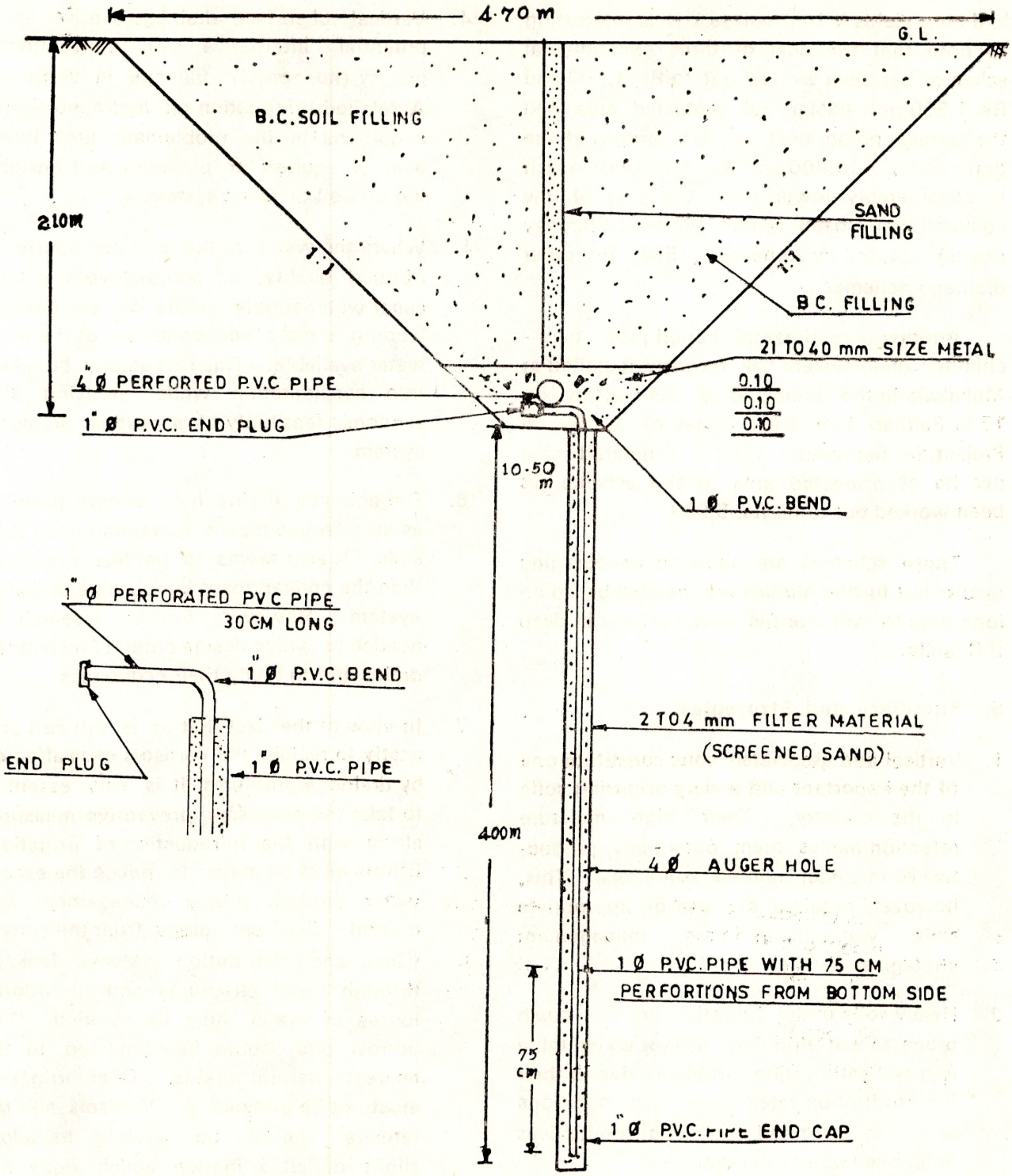

Fig. 4 : Details of Chimney Drain System

and crop yields is in progress. It is interesting to note that the cost of three experimental schemes has been worked out to Rs. 1,100 and Rs. 1,350 per hectare of protected area and the corresponding cost ker km length of the drain as Rs. 1,14,000 and Rs. 1,65,000, which is considerably lower than the cost of the conventional closed drains (without Chimney drains) reported by Abhange (1986) for other drainage schemes.

Another experimental buried pipe - cum - chimney drain system has recently installed at Mahakala in the command of Distributory No. 15 of Paithan Left Bank Canal of Jayakwadi Project in September 1987. Estimated cost per ha of protected area in this scheme has been worked out to be Rs. 5,920.

These schemes are showing encouraging results but further studies are needed based on long data to evaluate the new systems in deep B.C. soils.

5. Summary and Strategies

1. Vertical and associated soils constitute one of the important and widely occurring soils in the country. Their high moisture retention makes them potentially productive even under rainfed conditions. This, however, requires the use of appropriate soils, water and crop management strategies.

2. Heavy soils under irrigation are very much prone to waterlogging. rise of water table and soil salinization problems due to their low infiltration rates under wet conditions and poor saturated hydraulic conductives and impeded internal drainage.

3. Due to their very low permeability and high hydraulic resistance in the profile, these soils require very close spacing of subsurface gravity drains for effective lowering of water table thereby considerably increasing the cost of the drainage scheme.

4. Vertical subsurface drainage can provide a potential alternative to conventional gravity (horizontal) drainage in vertisols. A detailed information on hydrogeological conditions in the problematic area, however, is required for planning and designing of well drainage system.

5. Where the water in the pumped aquifer is of good quality, its conjunctive use with canal water supply should be encouraged leading to more economic use of the total water available. This fact should be taken into consideration while studying the economic feasibility of a vertical drainage system.

6. The chimney drains have shown promise as an effective means of draining deep B C. soils. It also seems to be less expensive than the conventional buried pipe drainage system. However, further research is needed to evolve design criteria for chimney drains and to study their economics.

7. In view of the fact that it is difficult and costly to reclaim the Vertisols once affected by drainage problems, it is very essential to take the necessary preventive measures along with the introduction of irrigation. Efforts must be made to reduce the excess water through proper management and control. Seepage losses from the conveyance and distribution systems, leakage through canal structures and operational losses of water must be avoided. The borrow pits should be connected to the nearest natural drains. Over irrigation must not be allowed on Vertisols and the farmers should be advised to adopt slight deficit irrigation which does not adversely affect the crop yield.

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