DISTRIBUTION AND CHARACTERISTICS OF PROBLEM SOILS IN INDIA AND THEIR MANAGEMENT FOR CROP PRODUCTION

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Soils which set a limit to crop production due to mineral stress, drought, acidity, sodicity, waterlogging, etc. could be considered as problem soils. In a recent review, Beek *et al.*, 1980 have categorized the problem soils into Vertisols, acid sulfate soils, saline-sodic soils, peat soils and fine textured alluvial soils. Ikehashi and Ponnamperuma, 1978 observed that about 100 million hectares of land physiographically and climatically suited to rice lie idle because of soil toxicities caused by salt, alkali, acid or organic matter, besides vast areas where deficiencies of zinc, phosphate and iron, or excesses of iron, aluminum and manganese limit rice yields. A general definition of problem soils could be visualized as those which have adverse conditions, inherent or man-made (created), posing severe limitations to successful crop production. Thus, the soil profiles having high ground water tables and less permeable argillic horizon, eroded soils, sandy soils of low fertility, coastal soils which are inundated frequently, and the laterites (Oxic soils) could be considered as problem soils. However, because of the importance and magnitude of severity, only the saline and sodic, acid, and acid sulfate soils are discussed here, as they constitute approximately 60 million hectares out of about 140 million hectares of net area under cultivation in India.

1 Saline and Sodic Soils

Bhumbla (1977) has classified the salt-affected soils of the country into four broad groups based on the nature of soil problem and their geographical distribution (Table 1). Sodic soils of the Indo-Gangetic plains alone account for roughly one-third of the 7 million hectares of the salt affected soils in India. Murthy *et al.* (1980) have attempted classification of salt-affected soils in India, according to Soil Taxonomy, into 12 distinct units at the great group – association level (Table 2, Fig. 1).

The salient physico-chemical characteristics of sodic soils in the Indo-Gangetic plains are: (a) excess soluble salts with preponderance of sodium carbonate and bicarbonate, and high soil pH (up to 10.5) in 1:2 soil water suspension; (b) high exchangeable sodium percentage (80 – 90); (c) heavy texture in the subsurface soil; (d) usually calcareous nature with a zone of accumulation of calcium carbonate (sometimes with a calcic horizon); (e) highly dispersed and extremely impermeable to water and air; and (f) dominance of illite clay mineral. The other important characteristics these soils have in relation to crop production are – high boron content (the sand and silt fractions contributing 29 – 50% of the total B because of their high tourmaline content, in the saline-sodic soils of Punjab). Singh and Randhawa (1977) reported an average boron content of 0.8, 1.2 and 2.9 ppm respectively in the surface soils of some normal, sodic, and saline-sodic soils of Punjab. Recently, Abrol *et al.* (1981) studied the effect of ESP on the water extractable fluorine of 25 cultivated field samples and observed that fluorine content increased with increasing ESP. A fluorine content of 32 ppm in wheat straw which resulted in significant reduction in grain yield was associated with 22 ppm of water soluble fluorine in soil.

Crop growth on these soils is adversely affected owing to the effect of excess exchangeable sodium directly, and more importantly through its effect on the physical-chemical properties of

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Table 1 Types of salt-affected soils in India

Type of soils	States in which they occur	Approx. area (million ha)
1. Coastal salt-affected soils		
a) Coastal salt-affected soils of arid regions	Gujarat	0.714
b) Deltaic coastal salt-affected soils of the humid region	West Bengal, Orissa, Andhra Pradesh and Tamil Nadu	1.394
c) Acid salt-affected soils	Kerala	0.016
2. Salt-affected soils of the medium and deep black soil regions	Karnataka, Madhya Pradesh, Andhra Pradesh and Maharashtra	1.420
3. Salt-affected soils of the arid and semi-arid regions	Gujarat, Rajasthan, Punjab, Haryana and Uttar Pradesh	1.000
4. Sodic soils of the Indo-Gangetic plains	Haryana, Punjab, Uttar Pradesh, Bihar, Rajasthan and Madhya Pradesh	2.500
	Total	7.044

the soil. The management of these soils should basically meet two objectives – (a) replacement of excess Na on the soil exchange complex by Ca, and (b) leaching of the exchanged Na out of the root zone. The most commonly used soil amendment for the purpose in India is gypsum ($CaSo_4 \cdot 2H_2O$) although sulfuric acid or acid forming substances such as aluminum sulfate and pyrite have been used (Milap Chand *et al.,* 1977; Verma and Abrol, 1980; Raman and Goswami, unpub.). These studies show that pyrite is an inferior amendment compared to gypsum, its relative ineffectiveness being due to lack of oxidation once incorporated into a sodic soil with high pH. The scientists at the Central Soil Salinity Research Institute, Karnal (India) have evolved a management technology for the improvement of saline-sodic soils in the Indo-Gangetic plains, which essentially consists of: mixing of gypsum in shallower depths (10 – 15 cm soil), growing of crops in a rice-based cropping system, and application of balanced dose of NPK and zinc (Table 3). Management of these soils centres around cropping with rice owing to the fact that because of the peculiar situation under which it is grown it is tolerant to exchangeable Na. It has been found that rice can not only tolerate high ESP (up to 55 but at 80 the yield decline is about 50%), but it also results in high cumulative removal of soil exchangeable Na by mobilizing native insoluble calcium carbonate (Chhabra and Abrol, 1977). Raman and Goswami (unpub.) have studied the effect of gypsum and cropping system on the improvement of saline-sodic soils under field conditions and observed that rice-sugar cane system had the best reclamation effect followed by rice-berseem and rice-rice sequence. Patel *et al.* (1980) observed that gypsum application had little effect on the yield of a three-crop sequence of rice-wheat-rice as compared to that of NPK in saline-sodic soil (pHs 8.4, EC_e 30.0, ESP 20.4 and $CaCO_3$ 4.3% in the 0 – 15 cm layer). The ameliorative role of zinc (Dargan *et al.* 1976) in the growth of maize under saline-sodic conditions has been found

Table 2 **Classification of salt-affected soils**

Climate	State	Great group – Association level	Management problems
Arid to Semi-arid	Gujarat Rajasthan	Natrargids, Salorthids, Halaquepts, Cypsiorthids	Drainage and permeability problems make the reclamation uneconomical and difficult
Semi-arid	Southern part of Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Saline/sodic phases of Pellusterts, Chromusterts, Vertic Ustochrepts	Slow permeability, occurrence in depressions, dominance of montmorillonite causes great dispersion and reclamation is difficult (dispersion is even at ESP 10-15)
Semi-arid in the West to sub-humid in the East	North India plains, Punjab, Haryana, Delhi and West Uttar Pradesh	Natrustalfs, Natraqualfs, Halaquepts, Saline/sodic phases of Calciorthids and Camborthids	Reclamation can be effective by application of gypsum; leaching and suitable cropping pattern
Coastal and inundated (sea water) humid areas	Kuttanad region of Kerala, 24-Parganas of West Bengal	Acid sulfate soils, Tropaquept, Fluvaquent, Haplaquept	Engineering aspects include control of ingress of the sea and flooding of subsoil drainage, leaching and liming to remove acidity and salt toxicity (sulfate and chloride)

Adapted from Murthy *et al.* (1980)

to be associated with the enhanced absorption of Zn, Ca, and K and the widening of Ca/Na and K/Na ratios (Shukla and Mikhi, 1980). It has also been observed that tolerance to sodicity is related to lower Na/K ratio in the tillering phase of wheat. Any variety which can take up K in the face of competition from excess Na is more tolerant (Joshi *et al.*, 1980).

1. Salorthid — Natrargid
2. Halaquept — saline phases of Ustochrept
3. Halaquepts — Salorthid — saline phases of Chromustert
4. Salorthid — Gypsiorthid
5. Malaquept — saline phases of Ustochrept and Chromustert
6. Natraqualf — Natrustalf — Halaquept — saline/sodic phases of Calciorthid, Haplargid, Camborthid, Ustochrept
7. Halaquept — saline phases of Ustochrept, Haplaquept, Fluvaquent
8. Halaquept — saline phases of Haplaquept
9. Saline/sodic phases of Pellustert, Chromustert, Ustifluvent, Ustropept, Natrustalf
10. Tropaquept — Fluvaquent (acid sulfate)
11. Haplaquept (acid sulfate)
12. Acid phases of Fluvaquent

The map depicts only classification of saline/sodic soils which occur in patches in association with normal soils. Material is drawn from the Bureau and other sources.

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Fig. 1 Distribution and classification of salt-affected soils.

Table 3 Effect of application of zinc, gypsum and farmyard manure on the yield of IR8-68 in a highly sodic soil (Dargan *et al.*, 1976)

Treatment	Rice yield (ton/ha)	
	No Zinc	Zinc
Control	5.4	7.2
FYM 25 ton/ha	6.6	7.8
FYM 50 ton/ha	7.7	8.5
Gypsum 11 ton/ha	6.7	8.9
Gypsum 11 ton/ha + FYM 25 ton/ha	7.7	9.2
Gypsum 11 ton/ha + FYM 50 ton/ha	8.4	8.9

1) Gypsum and farmyard manure were applied to the previous crop of berseem *(Trifolium alexandrium).*

2) Zinc applied as zinc sulfate at 45 kg/ha before transplanting.

Saline-sodic soils contain low amounts of exchangeable Fe, Mn, Zn and Cu but available Mo content is high. The available Zn is lower in calcareous sodic soils than in non calcareous soils (Takkar, 1978). The effect of excess fluorine on the reduction in crop yield is associated with higher Na and lower K, Ca and P contents in the plant. Addition of high levels of P reverses the situation to a great extent (Singh *et al.*, 1979). The saline-sodic soils have peculiar physical and chemical properties which influence adversely the water and solute movement and are responsible for deficiencies or toxicities of nutrient elements. Therefore, efficient management of such soils for successful crop production does require an efficient and economic use of fertilizers, besides leaching and application of amendment such as gypsum, pyrite, organic matter, green manuring, rice husk, etc.

Management of saline soils involves reclamation measures for leaching of soluble salts and drainage and once the excess salts have been removed from the surface soil layers, growing of crops simultaneously with leaching. Rice is again an effective crop, as it grows satisfactorily under flooding, and green manuring with berseem (*Trifolium alexandrinum*) after rice hastens the process of salt leaching. The author and associates (Dravid *et al.*, 1976; Goswami *et al.*, 1977; Kamath *et al.*, 1977; Oza *et al.*, 1978) have made extensive studies under field conditions on the interactions between soil salinity and plant genotype and between soil salinity and soil fertility. Their findings indicate that there is a definite varietal difference amongst maize and wheat cultivars in their susceptibility/tolerance to salinity. The index of "salinity-elasticity coefficient" (this represents per cent change in yield for a per cent change in salinity level) has been used by Dravid *et al.* (1976) to determine the response of different cultivars to varying degrees of salinity (Table 4). It has been further observed that application of Fe and Zn mitigates to a large extent the adverse effects of

Table 4 **Average yields of different maize varieties and their regression coefficients and salinity-elasticity coefficients with respect to salinity level (EC) before sowing (Dravid *et al.*, 1976)**

Varieties	Average experimental yield under saline condition (q/ha)	Regression coefficient for x (i.e. E.C. before sowing) (b)	R^2	Salinity-elasticity coefficient at x=4	x=6	x=8
Kisan	28.26	−0.960	0.023	−0.123	−0.197	−3.218
Ganga 5	33.27	−2.748	0.153	−0.263	−0.455	−0.715
Vikram	21.05	−3.415	0.180	−0.433	−0.829	−1.526
Deccan	32.43	−4.128*	0.349*	−0.366	−0.672	−1.154
Sona	15.88	0.585	0.013	0.166	0.230	0.285
Jawahar	26.60	−1.648	0.119	−0.208	−0.349	−0.526

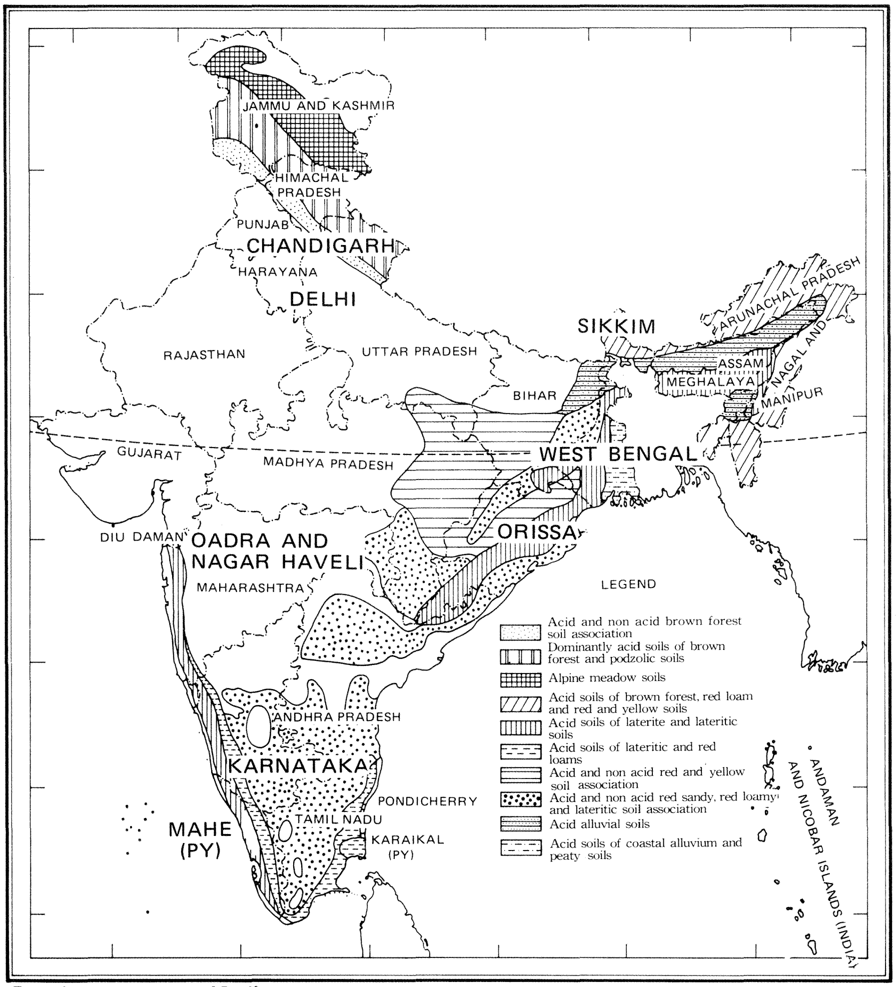
salinity on yield and nutrient uptake by crops (Dravid and Goswami, unpub.).

2 Acid Soils

About 49 million hectares are considered acidic of which 26 million hectares have pH below 5.6 and 23 million hectares pH between 5.6 and 6.5. These soils include red, laterite, mixed red and yellow, brown forest, foot hill soils, peat soils and varieties of acid sulfate soils (Mandal, 1976). Acid soils have been mainly formed as a result of drastic weathering under humid climate and heavy precipitation. Laterization, podzolization, intense leaching and accumulation of undecomposed organic matter under marshy conditions are the contributory processes for acid soil development. However, there is considerable heterogeneity in the morphological, physical and chemical characteristics which may be attributed to various soil forming factors in the development of these soils in the various regions of the country (Fig. 2).

Murthy *et al.* (1976) have classified the acid soils according to Soil Taxonomy (Table 5). Acid soils have generally kaolinite, hydrous mica and illitic type of clay minerals. The acid laterite and lateritic soils which have kaolinitic clay minerals have low cation exchange capacity, varying from 3 to 10 meq/100 g soil, while some of the red and alluvial soils may have slightly more CEC because of the presence of illite. On the other hand, the organic matter rich acid sulfate soils (*kari* and *pokkali*) have CEC as high as 40 – 55 meq/100 g of soil. Since the acid sulfate soils form a distinct class by themselves, these are discussed separately. Illite is the dominant clay mineral in *tarai* (foothill) soils and chlorite is next in order of abundance. In some *tarai* soils of Nainital district (U.P.), vermiculite, smectite, kaolinite, and allophane are found to occur as associated minerals. The dominant clay minerals in the acid alluvial soils are illite, smectite and kaolinite (Ghosh and Raychaudhuri, 1974). Exchangeable aluminum is the main contributing factor in acid laterie and alluvial soils (Alfisols and Inceptisols, Entisols) while exchangeable hydrogen is the main cause of soil acidity in *tarai* and brown forest soils (Mollisol and Spodosol).

Acid soils are generally deficient in calcium and magnesium, the degree of base saturation being usually 20 – 25% in most of them. Exchangeable magnesium has been reported to be higher than exchangeable calcium in the acidic red soils of Bihar and alluvial soils of Assam (Mandal, 1976). The soils are poor in organic matter and total nitrogen except in the forest areas (*tarai* soil of Himachal Pradesh and in the acid soils of Assam). These soils are generally low in phosphorus, having high phosphorus fixing capacity. In the acid soils of Assam, organic phosphorus contributes



Based upon survey of India map with the permission of the Surveyor General of India.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (reorganization) Act. 1971 but has yet to be verified.

Fig. 2 Distribution of acid soils.

Table 5 Classification of acid soils of India (Murthy *et al.*, 1976)

Location	Classification: Traditional	Classification: Soil Taxonomy (1970)
Himalayas		
Western Himalayas		
(a) Middle	Brown forest soils	Hapludolls, Udifluvents, Udorthents, Dystrochrepts, Haplumbrepts.
(b) Upper	Brown forest soils, Brown Podzolics	Hapludolls, Udorthents, Haplumbrepts, Dystrochrepts.
U.P. Himalayas		
(a) Lower	Brown forest soils	Haplumbrepts, Hapludalfs, Udorthents, Udifluvents, Dystrochrepts.
(b) Upper	Brown forest soils, Podzolics	Mollic Hapludalfs, Ultic Hapludalfs, Haplumbrepts.
Eastern Himalayas		
(a) Lower	Grey brown soils	Udifluvents, Udorthents, Dystrochrepts, Haplumbrepts, Hapludalfs.
Peninsula	Laterites and lateritic soils	Paleudalfs, Hapludalfs, Hapludults, Tropohumults, Dystropepts, Ustropepts and Oxic intergrades.
	Red loams	Paleudalfs, Udifluvents, Udorthents, Plinthaquepts, Tropaquepts, Oxic and Ultic intergrades.
	Red and yellow soils	Dystrochrepts, Udifluvents, Hapludalfs.
Eastern plains	Alluvial soils	Haplumbrepts, Udifluvents, Sulfaquepts.
Coastal plains	Coastal alluvium peaty soils, marshy soils	Tropofluvents, Sulfaquepts, Haplaquents, Udifluvents.

about three-fourths of the total phosphorus while aluminum and iron bound phosphorus constitutes the main phosphorus fractions in the acidic red and laterite soils. Usually potassium is not deficient except in the acid laterite and red soils. Acid soils belonging to these groups have moderately good store of potassium but the availability depends on the mechanism of release in relation to potash bearing minerals and presence of clay minerals of hydrous mica type. In the acid red loams of Bihar the exchangeable K varies from 0.2 to 8.7 meq/100 g. The degree of K saturation varies from 3 to 8% while potash fixing capacity ranges between 0 and 17% (Mandal, 1976). Acid soils are well supplied with Fe, Mn, Zn and Cu but have low content of Mo and B.

The management problems of acid soils for successful crop production are related to: (a) toxicity of Al, (b) availability of P, (c) supply of Ca and Mg, and (d) deficiency of Mo. Application of lime is the main approach in the management of acid soils, and supplementary application of organic matter has been found to be necessary for the improvement of acid laterite soils. However, bulk of the experimental evidence on lowland rice suggests that liming may not be necessary for rice (Goswami *et al.*, 1976). For upland crops also such as maize and wheat, liming may not be required in moderately acid soils provided their phosphate requirement is satisfied (Dyanand *et al.*, 1976). On the other hand, in multiple corpping systems with legume as a component crop, liming is beneficial. The importance of liming even on irrigated wheat gets minimized once application of balanced doses of N and P, and in some cases, NPK has been made (Tables 6 and 7). From the point of view of supply of Ca, Mg and P, basic slag and rock phosphates have been found beneficial in acid soils.

Table 6 Average yield of wheat as affected by lime and fertilizer treatment at Palampur (kg/ha)
Soil - Grey Brown Podzolic, pH 5.6, org.C 0.50%, CEC 6.2 meq/100 g soil
(Goswami *et al.*, 1976)

Dose of lime	Fertilizer treatments			
	N	NP	NPK	Average
0	2,247	4,152	4,726	3,708
784(a)	3,525	4,664	5,464	4,551
924(b)	3,214	4,600	5,691	4,502
Average	2,995	4,472	5,294	4,254

(a) Lime requirement by the method of
Shoemaker, H.E., McLean, E.O. and Pratt, P.F. (1961)
Proc. Soil Sci. Soc. Am. 25, 274

(b) Lime requirement by the method of Mehlich, A.
as described by M. Peech *In*: Methods of Soil Analysis,
American Society of Agronomy, Madison, Wisconsin, 1965.

Table 7 Yield of wheat (kg/ha) under different treatments in acid red loam soils of Bihar (Average of 7 years) (Prasad *et al.*, 1976)

Treatment	Mean
Control	561
N	439
NP	1,807
NPK	1,903
FYM	1,248
FYM + P	1,251
FYM + PK	1,264
L + NPK	1,978
L + FYM + PK	1,396

The lime requirement based on exchange acidity (N KCl extractable Al^{3+} and H^{+}) with a lime factor varying between 1 and 3, depending upon the degree of acidity and crop characteristics, has been found to be optimum for the acid soils (Goswami and Bandyopadhyay, unpub.). Proper selection of crops and crop varieties which are tolerant to excess Al has been another useful approach in the management of acid soils for crop production. In this approach a crop which is highly responsive to liming and/or tolerant to Al is included as the first crop in the rotation in order to realize maximum benefit from liming and also from the standpoint of economics of liming. Mandal *et al.* (1966) have classified the upland crops according to their responsiveness to liming: (a) high response – pigeonpea, soybean, cotton; (b) medium response – gram, lentil, peas, groundnut, sorghum, maize; and (c) low response – small millets, rice, mustard and potato.

3 Acid Sulfate Soils

Acid sulfate (also included are the saline acid and saline waterlogged soils) soils constitute an important group of problem soils in India. Although they are limited in extent, these soils comprise an area of over 108,000 hectares in the coastal areas of the western parts of Kerala, i.e. 12% of the area under rice cultivation in this state, and over 280,000 hectares in the southern parts of West Bengal (Van Breemen and Pons, 1978). These soils are both saline and acidic, occurring in areas which remain submerged under water for the major part of the year and are situated at a depth of 1 to 1.5 meter below the sea level (Money and Sukumaran, 1973).

In addition to the peculiar physical, chemical and biological characteristics common to waterlogged soils, the permanently waterlogged lands in Kerala present other typical features of their own, such as acid saline soils, acid sulfate soils, peat marshes, alternate inundation with saline and fresh water, and situation below the sea level endangering drainage. In the Kuttanand area of Kerala, these soils are locally named as : – (1) *Kayal* – These are situated 2 – 3m below sea level, and occupy about 8,000 hectares. These soils have slightly acidic to neutral pH, very low organic matter, and available plant nutrients but are fairly rich in calcium. Major soil limitation is salinity;

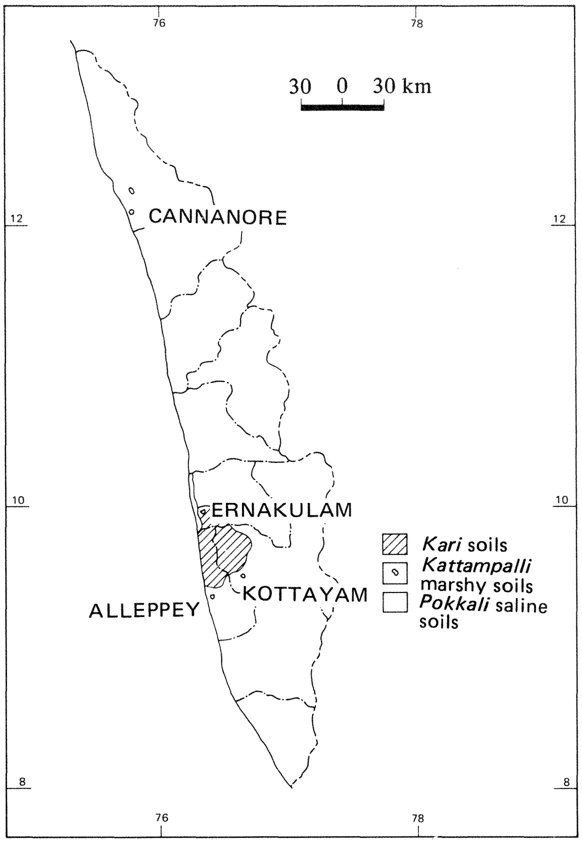


Fig. 3 Location of acid sulfate soils (Kerala).

(2) *Karappadom* soils (Typic Tropaquepts) occurring along the inland water ways and rivers over an area of 41,000 hectares. These soils are characterized by high acidity, high salt content, high iron but low available P and Ca; (3) *Kari* soils (Tropic Fluvaquents) – These are peat soils covering about 20,000 ha and having deep black colour, heavy texture, poor aeration, bad drainage, low fertility, high salt contents, high acidity (Fe and Al), and high sulfate and free sulfuric acid contents (depending upon reduction – oxidation conditions); (4) *Kole* lands of 10,000 ha in the coast are the reclaimed lake beds having the problem of acidity, salinity, poor drainage and presence of toxic salts; (5) *Pokkali* and *Kaipad* lands are the low lying "acid saline" marshes found near the Arabian sea, occupying about 24,000 ha. These are river borne alluvium, loam to clay in texture, highly acidic (2.1 – 3.9 pH) and highly saline (15 – 17 mmhos/cm), fairly rich in N,

K and Mg but deficient in phosphorus and calcium. These are typical saline lands and are water-logged and ill drained; and (6) *Kattampalli* swamp soils occupying about 2,500 ha.

Murthy (1971) has reported three distinct types of acid sulfate soils – locally known as *kari, pokkali* and *kattampalli* swamp soils (Fig. 3). In the FAO/UNESCO soil legend, these soils have been named Thionic Gleysols and in the Soil Taxonomy (USDA) Sulfaquepts at the great group level. Various subgroups and intergrades of Typic Sulfaquepts have been proposed. Murthy *et al.* (1980) have classified acid sulfate soils as Tropaquept – Fluvaquent association, and Haplaquepts (the *kari* soils of Kerala as Tropic Fluvaquents and similar soils in West Bengal as Typic Haplaquepts). Salient characteristics of three typical acid sulfate soils viz., *kari, pokkali* and *kattampalli* soils are given in Table 8.

Table 8 Characteristics of acid sulfate soils of Kerala (Kuruvila and Patnaik, 1973)

Characteristics	*Kari*	*Kattampalli* swamp	*Pokkali* saline soil
pH (1:2.5)	3.2	3.8	3.3
EC_e, mmhos/cm	4.6	9.0	15.1
Total N, per cent	0.28	0.16	0.24
Organic C, per cent	7.1	1.8	3.5
CEC, meq, per cent	21.2	12.8	20.0
Exch. Ca meq, per cent	2.65	3.55	5.10
Exch. Mg meq, per cent	1.30	3.85	6.45
Exch. Fe meq, per cent	0.08	0.08	0.09
Exch. Al meq, per cent	2.40	2.55	2.95
Water soluble Ca meq, per cent	3.3	1.5	3.2
Water soluble Mg meq, per cent	5.5	4.3	9.9
Water soluble SO_4 meq, per cent	15.8	10.5	18.7
Water soluble Al ppm	235	28	44
Water soluble Fe ppm	17	Traces	Traces
Water soluble Mn ppm	7	1	0.5
Lime requirement (ton/ha)	17	11	15

According to Ghosh *et al.* (1976), who studied the physical, chemical and mineralogical characteristics of some typical acid sulfate soils of Kerala, these soils have heavy texture (clay loam), low bulk density (1.24 – 1.40 g/cm^3), strong acidity (pH 3.2 – 3.8) and high organic matter (2.3 – 7.0%). They have low contents of K, Ca and Mg, medium contents of P and Fe but high contents of Al, Mn, Cu, Zn, sulfate S, and total S (which is mainly in organic form). Kaolinite is the dominant clay mineral but is associated with fairly large amounts of smectite and small amounts of halloysite.

Rice is the single most important crop grown on these soils and the major soil limitations for crop production are the toxicity of Al and Fe and deficiency of P and Ca. Besides leaching and adequate drainage, application of suitable amendment such as lime which can inactivate Al and Fe is the main management solution to these problems. Liming and application of phosphate are necessary for crop production. Kuruvila and Patnaik (1973) suggested that flushing of the soil followed by application of lime at half the amount required to raise the soil pH to 6.5 in combination with nitrate or MnO_2 increased the pH and markedly decreased the salt content and concentration of Fe and Al on submergence, and thereby resulted in good rice crop.

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Discussion

Kyuma, K. (Japan): 1) Among the salt-affected soils what is the percentage of naturally or initially salt-affected soils and what is the percentage of man-induced or secondarily salinized soils? 2) What measures are being adopted in India to prevent secondary salinization in the process of reclamation of arid zone soils?

Answer: It is difficult to give a separate estimate of the percentage of the areas with naturally or secondarily salt-affected soils as these two processes have been occurring simultaneously. But bringing newer areas under irrigation (not more than 20 million hectares for the last 20 years) seems to have accentuated the problem of salinity, particularly where there has been faulty water management and no effective drainage. 2) Lowering of the water table, improvement of the surface drainage and efficient soil and water management techniques are important. Such measures are being taken particularly in the most recent irrigation schemes.

Schlichting, E. (Germany): Would it not be advisable to avoid the broad terms of "salt-affected" or "acid" soils and rather distinguish them according to the type of salts and the kind of acidity (H or Al)? This would allow better decisions with regard to the amelioration procedures or the selection of adapted crops.

Answer: I entirely agree with you. Besides the kind of acidity, factors such as clay mineralogy, buffering capacity, organic matter content should be taken into consideration. While liming alone may be effective in acid soils where H is the chief contributing factor and CEC is not so low, in the case of acid soils with Al and low CEC, application of both lime and phosphate would perhaps be necessary. The cropping systems and selection of crops would also be different under these two conditions.

Tanaka, A. (Japan): According to the table you presented, more than 9 ton/ha of rice can be obtained on sodic soils by applying gypsum, farmyard manure and zinc. Does that mean that sodic soils are better than ordinary soils?

Answer: Once these soils are reclaimed with application of gypsum and/or farmyard manure and suitable cropping systems are followed with adequate application of NPK and zinc, such soils become highly productive for rice. In fact, it has been reported that rice can tolerate an exchangeable sodium saturation of 50 to 60% without reduction in yield.

Kanwar, J.S. (ICRISAT) **Comment:** The high yields of rice reported on saline alkali soils after reclamation are not related to the saline condition of soil but have been brought about by better soil management, the arid climate in this part of India, heavy application of fertilizers including micronutrients like zinc and the cultivation of IR type of rice. These soils have a high potential for production of rice but yields used to be low due to nutrient deficiency, machine stress and poor soil management.