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SOILS OF INDIA

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To Dr. Alexander Muir
with kind regards
S.P. Raychaudhuri

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SOILS OF INDIA

By

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Delhi

सत्यमेव जयते

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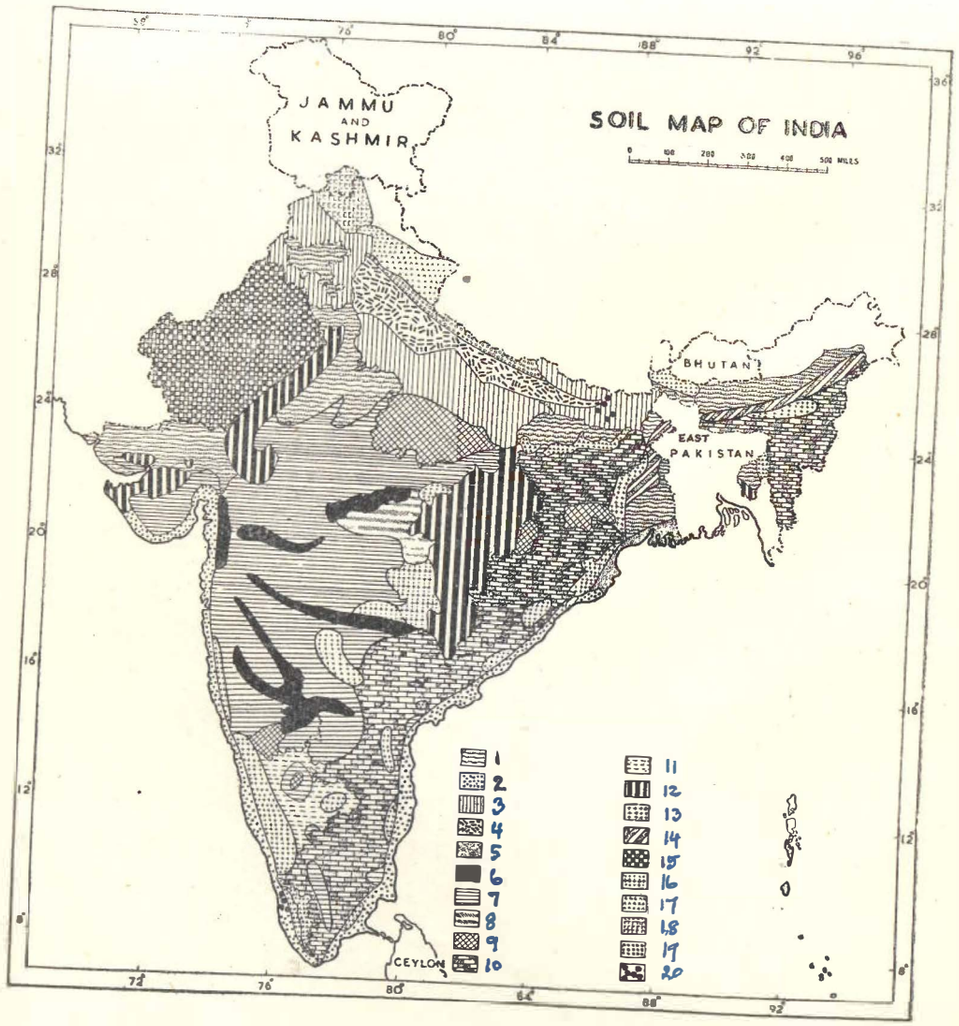


SOILS OF INDIA

THE agriculture of a country is dependent to a large extent on the nature and properties of its soils and climate. The nature and character of soils are again greatly dependent upon the climate of the region in which the soil occurs. Soils of this country which extend from temperate regions, through the subtropical, to the torrid zone, therefore, differ considerably. The development of the scientific study of soils has taken place almost entirely in the temperate regions. In recent years the study has been extended to the tropical and subtropical soils also.

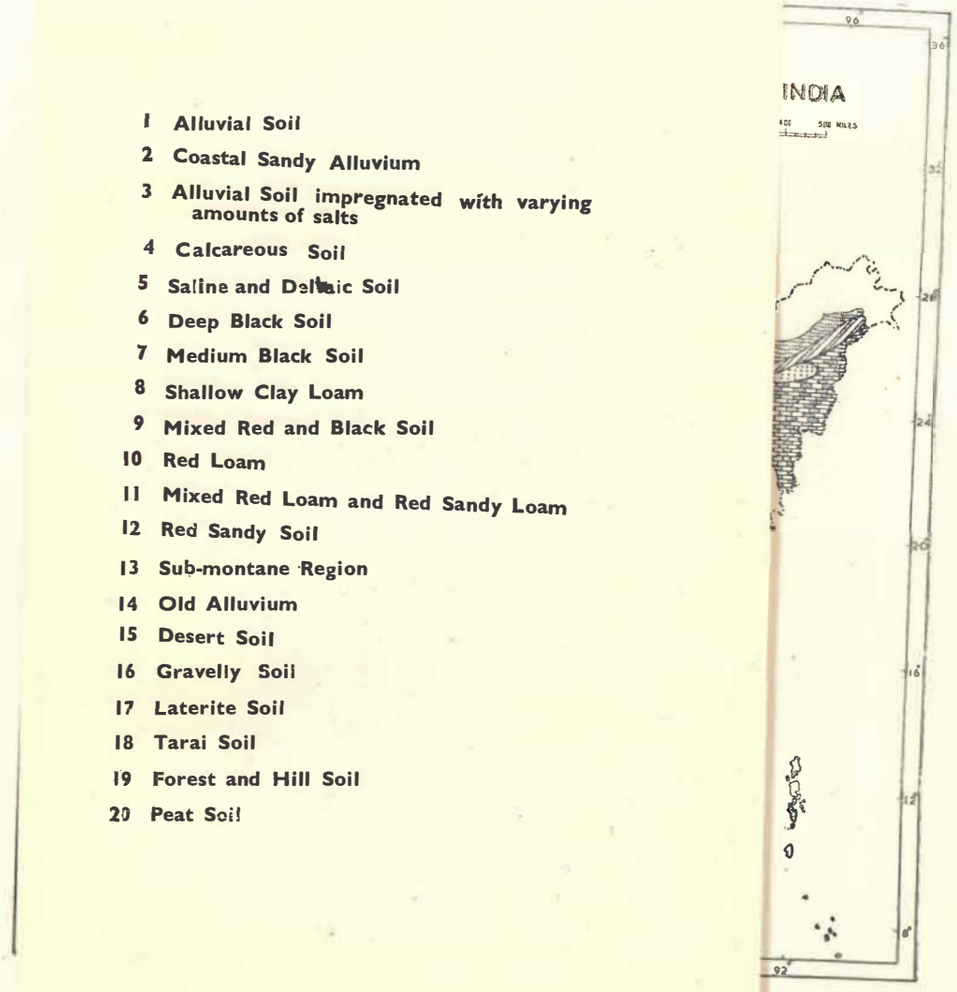
Before going to the description of the different soil groups of India, it is necessary to understand the physiographic, geological, climatic and vegetational regions of this country.

Physiographic features

The physiographic and geographical features of India are of great importance in so far as they modify more or less considerably the lower air movement and hence the distribution of temperature, pressure, humidity and rainfall. This subcontinent projects southwards into the Indian Ocean, consisting of a peninsula proper to the south of latitude 22°N and of a broad low alluvial plain, the axis of which runs east and west. The peninsula is of comparatively low elevation and has a ridge of hills near the west coast from which the land slopes slowly eastwards. To the north of the peninsula, is the low plateau of central India, gradually levelling to the extensive Indo-gangetic plain, which rises nowhere except in the immediate vicinity of hills above 800 feet. To the north of this extensive plain is the lofty continuous barrier of the Himalayas. Further north is the elevated Tibetan Plateau. The continent then slopes northwards by a succession of slopes to the Arctic Ocean.

Geological features

It is known that certain well-marked rock-types give rise to certain definite types of soils. Variations in the rocks cause wide differences in the overlying soils with regard to consistancy, depth and composition.



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The soils are of course liable to important secondary modifications through climate, topography, organic agencies, etc. But the fundamental characters of the soil groups remain more or less the same as those deduced from the general nature of the geological formations from which they are derived.

The foundations of the soils of India have been classified into the following geological groups :

Ancient crystalline and metamorphic rocks. The oldest rocks constituting the basement of peninsular India as granites, gneisses and crystalline schists and subordinate rocks rich in ferromagnesian minerals. These rocks have given rise to the red soils.

Cuddapahs and Vindhyans. Besides the Vindhyan system of rocks, the soils include large parts of the Cuddapah system which are mainly siliceous. Being an ancient formation, the soils derived are all highly mature.

Gondwana. It occurs in the chains of basin like depressions in the tableland of the Peninsula filled with old river deposits, sands and silts. The Gondwana rocks give rise to comparatively immature soils of less variety and fertility.

Deccan trap. (A group of volcanic lava of basic composition rich in aluminous and ferromagnesian compounds). The typical soil derived from the Deccan trap is the *regur* or black cotton soil.

Tertiary and mesozoic sedimentary rocks of extra-peninsular India. Soils belonging to this division occupy small areas in the hilly and mountainous ground of extra-peninsular India, and are being chiefly found in the depressions and valley basins of the area, classified as

(a) Mesozoic and eocene calcareous rocks

(b) Upper tertiary sandy rocks

Recent and subrecent rock. A drift soil, entirely different in origin from the soils of southern India which are largely residual soils produced out of the decomposition products of rocks, they are represented as follows :

(a) Older Indo-Gangetic alluvium

(b) Newer Indo-Gangetic alluvium

(c) Deltaic alluvium

(d) Lateritic rocks

(e) Desert deposits

Climatic features

India probably presents a greater variety of meteorological conditions, actions and features than any area of similar size in the world. The climate of this vast region is varying. The north has very different conditions from the south, the coasts from the interior, the west coast from the east coast. The normal annual rainfall varies from about 460 inches in Assam hills and 300-400 inches at suitably exposed positions on the crests of the Western Ghats to less than three inches in Rajputana. At one period of the year, parts of India are deluged with rain ; at another, persistent dry weather prevails for weeks or months. Coasts are occasionally affected by cyclones. These bring up storm waves that sweep over the low-coast lands of lower Bengal or the deltas of Mahanadi, Godawari and Krishna.

India presents a noteworthy combination of tropical and temperate conditions. Tropical heat, heavy and frequent rain and fierce cyclones are prevalent at one period of the year while moderate temperature and rain with shallow extensive storms at another.

Vegetational features

The type of vegetation in a given locality depends on the climate, the soil and the past treatment. Topographical situation makes itself felt through its influence on local climate and soil.

In considering the relation of vegetation to climate in the wide sense, one would like to begin with the best developed growth on mature soils typical of the climate but the difficulties this procedure presents are at present too great and it seems preferable to compare forests found on average soils where the depth is medium and the soil is well drained without having undue favourable topographic situation.

Schimper describes various Indian types as definitely ascribable to edaphic influences, citing in forest on laterite, thorn forest on lime soils, *babul* on cotton soil and ascribes the absence of *sal* from the Western side of the Peninsula as connected with its preference for siliceous soils A case of special interest is the change from *sal* to *teak* in central India, the latter being mostly found on alluvium and the former on metamorphic rocks at the narrow overlap,

SOIL STUDIES IN RELATION TO GEOLOGY, VEGETATION, CLIMATE AND TOPOGRAPHY

STUDY of the formation of soil from the geological point of view has been done by various workers of the Geological Survey of India and forms an important contribution to our present knowledge of Indian soils. Wadia, Krishnan and Mukherjee (1935) have prepared a soil map of India on the basis of the geological formations. Troup (1921) recognised ten different geological forest regions of India. Champion (1936) divided the forests of India and Burma into 15 climatic types. On the basis of climatic variations, i.e. temperature and rainfall, India has been divided into a number of zones (Kendrew, 1941). Raman and Satukopan (1935) characterised the climate of India by annual rainfall minus the annual evaporation. Basu (1937) pointed out that soils of India showed certain differences in different zones, divided on the basis of Lang's factor. Viswanath and Ukil (1944) have attempted to place the soils of India into different climatic zones on the basis of N.S. Quotients. An integrated study of the effect of climate, vegetation and topography on the formation of the soil has been made by Raychaudhuri and Mathur (1954) who have divided India into 16 major basic soil regions and 108 minor basic soil regions.

The earliest investigations by Voelcker (1893) and the later studies by Leather (1898) distinguished four major types of soils, the Indo-Gangetic alluvium, the black cotton or *regur* soils, red soils lying on metamorphic rocks and the laterite soils.

Indo-Gangetic alluvium

This is by far the largest and most important of the soil groups of India, contributing the largest share to the agricultural wealth of the country. These soils cover 300,000 square miles, the area occupying the most populous portions of India.

In this immense tract, though a great deal of subordinate variations of soils exists, the main features of the soils are derived from their deposition as silts by the numerous tributaries of Indus, the Ganges

and the Brahmaputra systems. These streams draining the Himalayas, bring with them the products of weathering of the rocks constituting the mountains, in various degree of fineness, deposit them as they traverse the plains.

Geologically the alluvium is divided into *khadar*, i.e. newer alluvium of sandy, generally light coloured and less *kankary* composition, and *Bhangar* i.e. older alluvium of more clayey composition, generally of dark colour and full of *kankar*. The soils differ in consistency from drift sand to loams and from fine silts to stiff clays. A few occasional pebble-beds are also present. The presence of impervious clays in part obstructs the drainage and to some extent promote the accumulation of injurious salts of sodium and magnesium which make the soils sterile.

The formation of hard-pans at certain levels in the soil profile through the binding of soil grains by infilterating silica or calcareous matter forming an impervious layer is often observed in these alluvial soils. Layers of *kankar* in the Indo-Gangetic alluvium of U. P. and West Bengal and also occasionally layers composed of impure iron-oxides are instances of the formations of hard pans.

The most important characteristic of the soil of Assam is its acidity. Generally those on the old alluvium and hills are the most acid soils whereas the new alluvial soils of the river banks are less acidic, often neutral, even alkaline. Soils of the Brahmaputra valley are of sandy type ; available and total potash contents are fairly good, P_2O_5 content good, percentage of organic matter and nitrogen fairly moderate. The soils of the Surma Valley are fine in texture.

In West Bengal, portions of Murshidabad, Bankura, whole of Burdwan and the western half of Midnapur comprising the tract known as Rarh region are composed mainly of the old alluvium. There is hardly any regularity in the manner of deposition of the river borne materials. Some of the deposits which had been laid down very early have naturally been subjected to the climatic and other influences leading to soils which may be different from one another in texture, colour, profile features, chemical and mechanical composition and other physical properties.

Studies on the coastal soils of the Burdwan areas carried out by Mukherjee and co-workers show that soils vary from sands to heavy clays. The analytical data in general conform to the new alluvium. At a particular depth of profile certain horizons give rise to clay pans.

Soils of the Murshidabad district have been divided into two types (Mukerji, 1955) Vindhyan alluvium and Ganga alluvium. These are further subdivided into soil associations, considering the topography, mode of formation and the design of development of profiles.

Two broad soil divisions are distinguished in Bihar – (i) alluvium north of Ganges – soils clay loam to sandy loam, neutral to alkaline in reaction ; CaO varies from 0.5 per cent to 20.25 per cent, rich in total and available potash, deficient in P_2O_5 ; (ii) alluvium south of Ganges – soils heavier and finer in texture, available K_2O and P_2O_5 higher, lower $CaCO_3$ content, *p*H almost neutral becoming acidic towards the southern points.

A good deal of work on alluvial soils of Uttar Pradesh has been reported by Agarwal and Mehrotra (1951, 52 and 53). The State has been divided into a number of soil climatic regions. There are five principal regions which cater a number of districts from the respective regional centres.

In Aligarh, soils have been divided into six regions formed as a result of physical features and watersheds, i.e. Yamuna Khadir, Trans-yamuna Khadir, Western uplands, Central low lands, Eastern uplands and Ganga Khadir. Five types have been distinguished based on the analysis of the profiles of the respective regions. The District of Kanpur has been divided into four more or less parallel tracts depending on water-sheds, with three soil types. There are three tracts in the Banaras District—Western uplands, Ganga Tarai and Eastern uplands. The two types Banaras 1 and Banaras type 2 are based on the differentiation in colour, texture, *p*H, lime content and drainage. The soils contain varying amounts of $CaCO_3$ and soluble salts and have neutral to alkaline reaction. The calcium content usually increases at lower depths. They are generally poor in P_2O_5, nitrogen and organic matter.

On the coast of Orissa, there are stretches of sand and sand hills

alternating with deltaic swamps. Behind this coastal belt is an area of cultivated alluvial and lateritic formations. Soils are sandy and of finer texture, there is sufficient potash but not enough P_2O_5. Al_2O_3 is higher than Fe_2O_3.

The alluvial soils of Madras are transported and found in the deltaic areas and on the coastal line. Section of the profile reveals alternate layers of sand and silt deposited as they are brought in by the rivers. The composition of the strata varies with the nature of the silt brought by the rivers which in turn varies with the catchment areas and the tracts through which they flow. Godavari alluvium is different from that of the Cauvery ; the former carries black fertile mud, the latter poor. The soils of the former are also rich in CaO, P_2O_5, and K_2O. SiO_2/R_2O_3 varies from 2.5 to 3.0.

In Bombay State, the alluvial soils are confined to the North Gujerat tract, Ahmedabad and Kaira districts, and they are locally known as '*Goradu*'. The '*Gorat*' soil of Baroda corresponds to the older alluvium consisting of brown clay with *kankar*. Those that are of recent depositions are known as '*Bhata*'. The soils to a great extent are of secondary deposition, fairly deep, poor in organic matter and nitrogen but fairly rich in P_2O_5 and K_2O.

The light sandy red and yellow soils found in the Mahanadi basin (Madhya Pradesh) including the Balaghat and three districts of Drug, Raipur and Bilaspur are of alluvial origin.

Soils of the Punjab plains belong to the same class of alluvial soil typical of the Indo-Gangetic plains. Majority of the soils are loam or sandy loams consisting of a soil crust of varying depth. Hardly any profile characteristics are observed ; soluble salts are present in considerable amounts. Lower layers contain *kankar* nodules. Soils have generally an alkaline reaction due to the presence of sodium in the clay complex. They are adequately supplied with phosphorus and potash but lack organic matter and nitrogen.

The formations in north and west coast of Travancore consist mostly of the sands deposited from the sea. They are of low fertility. In Cochin, the west coast lying near the sea shore is sandy. About two

miles to the east of the boundary in Trichur taluk lies the fertile alluvial areas known as the '*Kole*' lands.

Black cotton or regur soils

The typical soil derived from the Deccan trap is the *regur* or black cotton soil. It is common in the Bombay Deccan, western parts of Madhya Pradesh, Hyderabad, parts of Gujarat and some parts of Madras including the districts of Ramnad and Tinnavelly to the extreme south. It is comparable with the 'chernozems' of Russia and with the 'prairie soil' of the cotton growing states of the United States of America and especially with the 'black adobe' of California. It is derived from two types of rocks, the Deccan and Rajmahal trap and ferruginous gneisses and schists occuring in the Madras State under semiarid conditions. The former attain sometimes considerable depths while the later are generally shallow. There is frequently no change in colour for a thickness of 6–10 feet.

Many black soil areas have a high degree of fertility but some, especially in the uplands, are rather poor. They are somewhat sandy on the slopes and uplands are moderately productive with a good monsoon. In the broken country, between the hills and plains they are darker, deeper and richer and are constantly enriched by additions washed down from the hills.

Black soils are highly argillaceous, very fine grained and dark coloured and contain a high proportion of calcium and magnesium carbonates. They are very tenacious to moisture and exceedingly sticky when wet. Owing to considerable contraction on drying, large and deep cracks are formed. They contain much iron and fairly high quantities of lime, magnesia and allumina. Potash has a wilde range. They are poor in phosphorus, nitrogen, and organic matter. In all *regur* areas in general and in those derived from ferromagnesian schists in particular, there is generally a layer rich in *kankar* nodules formed by segregation of calcium carbonate at some depth below the surface and above the weathered rock. The soils are generally rich in montmorillonitic and beidellitic group of minerals.

In Bombay, soils derived from the Deccan trap occupy quite a large area. On the uplands and on the slopes, soils are light coloured,

thin and poor. On the low lands and in the valleys, deep and relatively clayey black soils are found. Along the Ghats, the soils are very coarse and gravelly. In the valleys of the Tapti, the Narmada, the Godavari and Krishna rivers, heavy black soil is often 20 feet deep. The subsoil contains a good deal of lime. Outside the Deccan trap area, the black cotton soil predominates in Surat and Broach districts. Degraded solonised black soils locally known as *Chopan* occur in areas in the canal zones of the Bombay Deccan.

Basu and Sirur (1932-43) had carried out a survey and classification of black soil area of six major canals in the Bombay State, viz. Nira right and left bank, Godavari right and left bank and Pravara right and left bank. Twelve distinct types named alphabetically from A to L have been distinguished. The influence of topography, drainage and subsoil water table on the soil formation is predominant. Zones of accumulation of soluble salts and eluviation of clay have been useful in confirming the morphology of soil types.

A number of black soil profiles have been examined in Madras. They are either deep or shallow and may or may not contain gypsum n their profile and accordingly four types of profiles are distinguished : (i) shallow with gypsum, (ii) shallow without gypsum, (iii) deep with gypsum and (iv) deep without gypsum.

The shallow profiles range in depth from 3 ft. to 4 ft. and in most cases; partially weathered rock material is met with even at a depth of 1½ to 2 feet. The deep ones extend even up to 9 ft. and more. The black soils are very heavy and contain up to 65 to 80 per cent finer fractions, have high *p*H (8.5 to 9.0) and are rich in lime (5 to 7 per cent). They have low permeability and high values of hygroscopic coefficient, pore-space, maximum water-holding capacity and true specific gravity. They are low in nitrogen but contain sufficient potash and P_2O_5.

Black soils have generally a high base status and high base exchange capacity (40 to 60 meq.). Analysis of clay fractions shows that the iron content is about 10-13 per cent. CaO and MgO contents are high. SiO_2/R_2O_3 varies from 3 to 3.5. The soils are found to be formed from a variety of rocks which include traps, granites and gneisses.

In Madhya Pradesh, two distinct kinds of black soils are found viz. (i) deep heavy black soil covering the Narmada valley and (2) shallow black soil in the districts of Nimar, Wardha and the west of Nagpur and in Saugor and Jabalpur. The cotton growing areas are mainly covered by deep heavy black soils but there are also soils of lighter texture as shown by mechanical analysis. The profiles of virgin and cultivated medium black cotton soil at Nagpur and Akola have been examined by Bal (1935). Morphological examinations show that the soils gradually change in colour (from deep black to light) in the depths of the profile. The $CaCO_3$ content increases with depth. Clay content varies from 35 to 50 per cent. Organic matter content is low and SiO_2/R_2O_3 varies from 3 to 3.5.

Padoley and Tamhane (1956) have studied black soils of Madhya Pradesh developed on different parent materials for physical, chemical and minerological composition. Although these soils do not reveal any difference for outward appearance, the differences of parent rocks are reflected in the physical and chemical composition of soils as well as clay fractions separated from them.

The black soils of Mysore are fairly heavy with high salt concentration. The soils are generally rich in lime and magnesia, the SiO_2/R_2O_3 ratio of clay fraction is 3.6.

Genetic study of black cotton soils of Hyderabad State has been carried out by Desai (1942). These soils are the results of accumulation of products of decomposition of rocks irrespective of the composition of the rocks in combination with the humic material.

Agarwal, Mehrotra and Gupta (1956) have studied the morphological and chemical characteristics of a group of black clay soils, popularly known as '*Karail*' occuring in the lower Gangetic basin in Uttar Pradesh. These soils are distinct from their zonal associates developed under similar environments on the Gangetic alluvium and show greater resemblance with the *mar* of Bundelkhand or *regur* of Central India. They possess a parent material similar to the black cotton soils. Their formation has been attributed to a transported basaltic type of alluvium received from the Ganges.

Red soils

Red soils comprise practically the whole of Madras, Mysore, south-east Bombay, east of Hyderabad, Madhya Pradesh, Orissa and Chhotanagpur. In the north, the red soil area extends into and includes the greater part of Santhal Paraganas in Bihar, the Birbhum district of Bengal, the Mirzapur, Jhansi and Hamirpur districts of Uttar Pradesh.

The ancient crystalline and metamorphic rocks on meteoric weathering have given rise to what are called the red soils. The colour of the soil is due more to the wide diffusion rather than to a high proportion of the iron content. The soils grade from the poor, thin, gravelly and light coloured varieties of the uplands to the much more fertile, deep, dark varieties of the plains and valleys. They are generally poor in nitrogen, phosphorus and humus. In comprison with the *regur*, these soils are poorer in lime, potash and iron oxide and are also uniformly low in phosphorus content. Many of the so called red soils of South India have no red colour. On the other hand, some red soils are of lateritic origin and of quite different nature.

The clay fraction of the red soil is rich in kaolinitic type of mineral. Red soils have also been found under forest vegetation. Side by side, red and yellow soils are also seen. Very little is known about these yellow soils. The yellow colour is probably due to higher degree of hydration of the ferric oxide in these than in the red soils.

From the morphological point of view, the red soils can be divided into two broad subgroups (Raychaudhuri, 1941) : (i) red loams characterised by agrillaceous soil with a cloddy structure and the presence of only a few concretionary material and (ii) red earths where the top soil is loose and friable but rich in secondary concretions as a consequence of sesquioxide type of clay.

The red soils in Madras occupy the largest area and constitute nearly two-thirds of the cultivated area. They are all in *situ* formations formed from the rock below under the influence of climatic conditions. The rocks are micacious or red granites which are acidic. The soils are rather shallow, open in texture, have a *p*H ranging between 6.6 and 8.0 ; they have a low base status and exchange capacity is low.

They are also deficient in organic matter, poor in plant nutrients and analysis of their clay fractions gives SiO_2/R_2O_3 ratio of 2.5 to 3.0.

The predominant soil in the eastern tract of Mysore is the red soil overlying the granite from which it is derived. Especially in the districts of Bangalore, Kolar, Mysore, Tumkur and Mandya this is the chief type which varies in depth from a few inches to several feet. There are shades of red and finally they pass on to yellows. Loamy red soils are predominant in the plantation districts of Shimoga, Hassan and Kadur. They are rich in total and available K_2O and contain decent amounts of total P_2O_5 (0.05 to 0.3 per cent). Lime content varies from 0.1 to 0.8 per cent. Nitrogen is below 0.1 per cent. Iron and alumina are high, 30 to 40 per cent.

A broad strip of area running between eastern and western parts of Coorg is red loam, easily drained with fairly dense tree growth.

The acid soils towards the south of Bihar, viz. those of Ranchi, Hazaribagh, Santhal Paraganas, Manbhum and Singhbum are red soils. The *p*H of soils vary from 5.0 to 6.8. Another distinctive feature is the high percentage of acid soluble Fe_2O_3 compared with Al_2O_3. Available potash is quite sufficient but P_2O_5 is low. Raychaudhuri *et al.* (1941-42) studied a number of profiles of red soils of Bihar. The soils from Manbhum and Palamau and Singbhum are preponderant in zircon, hornblende and rutile respectively, those of Ranchi contain mixture of epidole and hornblende, neither preponderating.

In West Bengal, the red soils, sometimes misrepresented as laterites are the transported soils from the hills of the Chhotanagpur plateau.

A typical red soil profile at Chandkhuri farm, Raipur reveals that the percentage of concretions increases down the profile. The total exchangeable bases is about 20 m.e. The SiO_2/R_2O_3 ratio of the clay fraction varies between 2 and 3 and C/N ratio is near about 10.

A part of Jhansi district in Uttar Pradesh comprises red soils. There are two types locally known as ***Parwa*** and ***Rakar***. ***Parwa*** is a

brownish grey soil varying from good loam to sandy or clay loam. *Rakar* is the true red soil which is generally not useful for cultivation.

In the Telingana division of Hyderabad where the predominating geological formation is granite—gneissic complex both red and black soils predominate. The red soils or '*Chalkas*' are sandy loam located at higher levels. Such soils are utilised for cultivation of *kharif* crops.

Laterites

Laterite is a formation peculiar to India and some other tropical countries with intermittently moist climate. It is a compact to vesicular rock composed essentialy of a mixture of the hydrated oxides, of aluminium and iron with small amounts of manganese oxides, titania, etc. It is derived from the atmospheric weathering of several types of rock. Under monsoon conditions of alternating wet dry seasons, the siliceous matter of the rocks is leached away almost completely during weathering.

Laterite may become broken off and be carried to lower levels by the action of streams and when redeposited at lower levels may become cemented again into a compact mass by the segregative action of the hydrates inculding sand grains of quartz and other minerals. Thus there are high level laterites resting on the rocks at whose expense they have been formed and low level laterites formed in the usual way of detrital deposits.

Laterites are specially well developed on the summits of hills of the Deccan, Mysore, Travancore, Madhya Pradesh, the Eastern Ghat, regions of Orissa, South Bombay, Malabar and part of Assam. All lateritic soils are very poor in lime and magnesia and deficient in nitrogen. Occasionally the P_2O_5 content may be high, probably present in the form of the iron phosphate but K_2O is deficient. There is occasionally a higher content of humus.

In Madras, there are both high level and low level laterites which are formed from a variety of rock materials under peculiar climatic and weather conditions. They are both *in situ* and sedimentary formations and are found all along the West Coast where the rainfall

is heavy and humid climate prevails and also in some parts of the East Coast.

The laterites on a lower elevation grow paddy while those situated in higher elevation grow tea, cinchona, rubber and coffee. The soils are rich in nutrients and contain 10-20 per cent organic matter. *p*H is generally low, particularly of the soils under tea (*p*H 3.5 to 4.0) and the higher the elevation, the more acidic the soils are. In Coorg, laterite appears sporadically almost all over the country.

In Bombay, laterites are found only in Ratnagiri and Kanara. The soils of Kanara are coarse, poor in lime and P_2O_5 but fairly good in organic matter, viz. nitrogen and potash. In the soils of Ratnagiri, coarse material is in large quantities. These are rich in plant food constituents except lime.

In Travancore, in between the broad sea belt consisting of sandy soil and sandy loams and the eastern regions comprising the forest and plantation soils, the mainland contains residual laterite. These are poor in total and available P_2O_5, available K_2O and CaO. Laterite rock in Cochin is found to the east of the alluvial areas in Trichur, Talapalli and Mukundapuram taluks. Soils are mostly lateritic in Trichur taluk. Nitrogen varies from 0.03 to 0.33 per cent. Lime is very poor. Magnesium is between 0.11 to 0.45 per cent.

The laterite soils in Mysore occur in the western parts of the districts of Shimoga, Hassan, Kadur and Mysore. All the soils are comparable to the laterites and to the similar formations found in Malabar, Nilgiris, etc. of the Madras State. These soils are very low in bases like lime, due to severe leaching and erosion. These are poor in P_2O_5. The *p*H is not so low as in the case of plantation soils.

In West Bengal, the area between the Damodar and the Bhagirathi is interspersed with some basaltic and granitic hills with laterite capping. The soils of the region divide themselves into two district groups ; to the first group belong the soils of Midnapur, Bankura, Burdwan and Birbhum. Bankura district is known to be located in the lateritic soil zone. The SiO_2/Al_2O_3 ratio of the clay fraction is quite high. The percentage of K_2O, P_2O_5 and N are also low showing considerable

leaching and washing out of these substances as a result of chemical weathering.

The soils of Burdwan are in all respects similar to the Birbhum and Bankura soils with one or two small exceptions. A high value of the SiO_2/Al_2O_3 ratio is again peculiar.

In Bihar, laterite occurs principally as cap on the higher plateau but is also found in fair thickness in some valleys. In most cases, it appears to rest directly on the gneiss or a felsparic granite from the high values of the alkaline soluble silica and the SiO_2/R_2O_3 and SiO_2/Al_2O_3 ratios of the Singbhum soils. Raychaudhuri (1941) has classed them as lithomargic laterite in the sense of the term used by Fox (1936).

The laterites of Orissa are found largely capping hills and plateau occasionally in considerable thickness. Large areas in Khurda are occupied by laterites. The laterite of Balasore is gravelly and appears to be detrital. Raychaudhuri and co-workers (1941-42) have studied the morphological character of laterite profiles from several places in Orissa and also the chemical and mechanical composition of profile samples. Two types of laterites have been distinguished : (i) the laterite murrum, and (ii) the laterite rock. They are also found to occur together.

A typical section of the profile examined near Adesar (Eastern Kutch) by Satyanarayana (1955) reveals one to two feet deep hard, highly ferruginous laterite crust followed by a zone of white earthy rock with thin yellowish brown and reddish brown bands of iron oxides which gradually disappear with depth. The white clay has a *p*H of 8.3, 0.05 per cent of soluble salts and a cation exchange capacity of 6 m.e./ 100 gm.

In addition to the four soil groups described above, there are four more groups of soils which include (i) forest and hill soils, (ii) desert and semidesert soils, (iii) saline and alkaline soils, (iv) peaty and marshy soils although these have not been studied with equal emphasis.

Forest and hill soils

Nearly 14 per cent of the total area of this country is under forests.

Studies on the nature of forest soils is essential particularly in connection with any project of afforestation (Haward, 1944). The formation of these soils is mainly governed by the characteristic deposition of the organic matter derived from the forest growth. The problem is, therefore, very complex as fundamentally different soil climates occur on hills and in plains.

Broadly two conditions of soil formation may be distinguished : (1) soils formed under acid condition with the presence of acid humus and low base status and (2) soils formed under slightly acid or neutral condition with high base status which is favourable for the formation of brown earths.

It has been found in Malabar forests that after the forests under teak have been clearfelled, the soil undergoes laterisation (Davis, 1940). It is observed that SiO_2/R_2O_3 and free SiO_2/combined SiO_2 ratios go hand in hand with teak growth.

The soils of the hilly districts of Assam reveal high content of organic matter and nitrogen. This may be due to the virgin nature of the hill soils. Both chemical and mechanical composition show great variations; soils appear to be of fine texture.

In Uttar Pradesh, the sub-Himalayan tract comprises three distinct portions, viz. bhabar area immediately below the hills, tarai and plains. Four major groups, i.e. red loams, brown forest soils, podsols and transitional podsols and wiesenboden have been observed in the Himalayan tract, of which brown forest soils and podsols are predominant (Mukherjee and Das, 1940, 41 and 42). The tarai area are characterised by extreme unhealthiness caused by excessive soil moisture and prolific growth of vegetation. Soils have been classified into three major textural groups by Agarwal *et al.* (1955), clay loam, loam and sandy loam. Loam has been further subdivided into three classes depending on its lime status, i.e. loamy with enrichment of lime, loam with minor quantities of lime and loam free of lime.

In Punjab, Taylor and his collaborators (1935) have conducted investigations on the forest soils of the Kulu division. They have examined typical soil profiles under *deodar*, *spruce*, blue pine and *chir*.

The soil profiles are related to the podsols but have significant differences, probably, mainly due to the relatively high calcium content of the first layer. These differences are brought out in the high degree of saturation of various horizons.

The weathering of metamorphic rocks in Coorg has produced deep surface soil of great fertility which annually receives the decomposition products of the virgin forest. The areas towards the west are for the greater part reserved forests and mountain areas. The land surface is full of pebbles, easily drained and has a laterite bed.

In the Nilambur teak forests of Madras, a few years after deforestation and planting, the teak plant thrives well, after which, degeneration sets in. This happens on the hill tops and slopes. The soils from the area which do not grow teak are more clayey, contain more MnO and possess a lower SiO_2/R_2O_3 ratio. SiO_2/R_2O_3 ratio, thus appears to be a better index of the suitability of the soil for teak plantation.

Analytical data on the cinchona growing soils of West Bengal have been reported by Dhamija *et al.* (1956). These soils resemble brown earths. The surface layers consist of well decomposed humus and mineral soil which shades off gradually and at varying depths into the colour of the 'parent rock'; soils are strongly acidic in reaction. The high base exchange capacity of these soils is due to the presence of high organic matter content. Water soluble manganese is present in appreciable amount.

The very few investigations mentioned above merely suggest that systematic studies on both high level and low level forest soils should be undertaken and the characteristics of podsols and other important soil groups ascertained with great care and attention.

Desert soil

A large part of the arid region belonging to Rajputana and south Punjab, lying between the Indus and the Aravallis, is affected by desert conditions of geologically recent origin. This part is covered under a mantle of blown sand which inhibit soil growth.

The Rajputana desert proper occupies an area of about 40,000 sq. miles. Owing to the physiographic conditions of its situation, the area,

though lying in the track of the south-west monsoon, receives no rain. The sands with which it is covered are partly derived from the disintegration of subjacent tracks but are largely blown in from the coastal regions and the Indus valley. Some of these soils contain high percentage of souble salts, possess high *p*H, low loss on ignition figures, varying percentage of calcium carbonate and are poor in organic matter. The limiting factor being mainly water; soil may be reclaimed if proper facilities of irrigation are available.

Saline and alkaline soils

The distribution of saline and alkaline soils is extensive throughout India in all climatic zones. Many parts of the drier tracts of the north, especially of Bihar, Uttar Pradesh, Punjab and Rajputana give rise to saline and alkaline efflorescences in the same way as the soils capping the upper tertiary rocks. There are many yet undercomposed mineral fragments in these alluvial clays and silts which on weathering, liberate sodium, magnesium and calcium salts. Large areas, once fertile and populous have become impregnated with these salts known locally as *reh* or *kallar* with highly deleterious effects on their cultivation. The injurious salts are confined to the top layers of the soils, these being charged by capillary transference of saline solutions from the lower layers. In the districts irrigated by canal waters, this transference is facilitated.

Reh is a mixture of sodium carbonate, sulphate and chloride with some calcium and magnesium salts. Besides their origin in the soil itself, some of these salts are introduced by river and canal water. In many parts of the great alluvial plains, without any undergroud drainage, the salts become concentrated. Capillary action during the summer months brings them to the surface where they form a white efflorescent crust.

It has been estimated that 2 lakh acres of land in Uttar Pradesh and 5 lakh acres of land in Punjab have been affected by *usar* and 25 thousand acres are being added every year in Punjab. Methods of reclamation based on irrigation, application of lime or gypsum were necessary and growth of salt resistant crops like rice, berseem and sugarcane have been suggested. In cases of badly damaged alkali patches,

treatment with sulphur or gypsum accompanied by adequate watering has led to steady improvement in the soil and successful crops have been raised.

According to Agarwal and Yadav (1954) in soils of Hardoi, Lucknow and Kanpur districts, the internal drainage is greatly restricted and soils are characterised by very high *p*H values and almost complete absence of gypsum. Soils appear to be the carbonate chloride type of saline alkali in contrast to soils of more arid localities of temperate climates.

Mukherjee. Agarwal and Mukherji (1946) have classified the alkaline soils of Unao district into three types viz., (i) immature salty alkaline soils, (ii) salty alkali soils : (a) without zone of accumulation of $CaCO_3$ and (b) with zone of $CaCO_3$ accumulation and (iii) degraded salty alkali soils. The occurrence of alkalinity in these soils has been due to downward leaching of salty solution arising primarily from soil decomposition.

Reclamation of *kallar* is one of the major problems in the Punjab plains too. The downward movement of salts is very much less than the upward movement with the result that salts accumlate in high concentrations at or near the surface. These saline soils slowly deteriorate into alkaline soils. The sodium salts enter the clay complex and form sodium clay by the displacement of calcium. The only method of improving these soils is either by the addition of calcium salts or by making use of the reserve calcium already present in the soil (Dalip Singh and Nijhawn, 1936).

Alkali soils are met with all over the State of Bombay but badly affected lands are found in Gujrat, Karnatak and the Deccan. In the Deccan, a very large area has been affected due to the construction of Deccan canals. In Gujrat, the area round the gulf of Cambay is affected by sea-tides carrying salt laden silt deposits. Nearly 67,000 sq. miles comprising the estuaries of the Narmada, Tapti, Mahi and Sabarmathi have been damaged in this way. Such soils show high content of exchangeable monovalent bases and of magnesium with a predominance of chlorides amounting to more than 50 per cent Reclamation of these lands by bunding and leaching of soluble salts is

possible. Basu (1950) has classified the saline soils of the Bombay State into three important heads (a) natural saline soils, (b) saline soils developed due to irrigation, and (c) saline soils developed due to flooding of sea water.

Portions of Dharwar district and of Bijapur taluks are affected by what is locally known as *karl* soils which are saline alkaline and fairly deep clayey soils. The salt lands of the Nira valley have developed as a result of excessive irrigation given on the deep black soils of the locality. Profile examination and analysis of soil samples by Basu and Tagare [1943] have shown that two groups of profiles might be distinguished, one resembling steppee alkali soils and the second, the solonetz.

Raychaudhuri and co-workers after conducting investigations on soils from the northern and southern zones of Delhi State have classified them into three pedogenic groups (i) saline soils (mostly in the *khadar* area), (ii) saline-alkali soils (in *dabar*, *bangar* and in old deposits of *khadar* areas), (iii) saline-alkali soils with *kankar* formation (mostly in *dabar* and *bangar* areas and in repression of *khadar* areas).

Peaty and marshy soils

Peaty soils originate in humid regions as a result of accumulation of large amounts of organic matter in the soil. They may contain in addition considerable amount of soluble salts. Such typical peaty saline soils (*Kari*) have been observed in Travancore Cochin. The soils are generally submerged under water during the monsoon As soon as the rains cease, these are put under paddy cultivation Soils are black, heavy and highly acidic, *p*H being as low as 3.9 and contain 10 to 40 per cent of organic matter. The acidity of these soils is due to the decomposition of organic matter under anaerobic conditions and no nitrification is possible. Sometimes the soils contain ferrous and aluminium sulphates. Ths area under such lands is 50 to 60 sq. miles. The *kari* areas have an accumulation of large quantities of water soluble alkali salts.

The depressions formed by dried river basins and lakes in alluvial and coastal areas sometimes give rise to peculiar water logged and anaerobic conditions of the soils. The soils of these places are generally blue due to the presence of ferrous iron and also contain varying

amounts of organic matter. Marshy soils of this type are found in coastal tracts of Orissa, in the Sunderbans and other places in Bengal, in the central portion of north Bihar, in the Almora district of Uttar Pradesh and in the southeast coast of Madras. The extent and nature of these soils are not fully known and a survey for the reclamation and proper utilisation of these soils is necessary.

Soil maps

Attempts have been made by several investigators to draw soil maps of India. The first attempt to prepare such a map was made by Schokalasky (1932). The relation between the broad soil zones of the country and the basic foundations have been given by Wadia, Krishnan and Mukherjee (1935). They have pointed out that the approximate boundaries of these soil groups are nearly coterminous with the boundaries of the geological outcrops. The soil map was further modified and brought upto date in 1954. (See attached map).

Fertility status of Indian soils

The primary deficiency of nitrogen in all Indian soils demands the highest priority to be given to the production and use of nitrogenous fertilizers. While ammonium sulphate has so far been the only important fertilizer of this type that has been used and found to respond well ; fertilizers like urea, ammonium nitrate, ammonium sulphate nitrate have of late been receiving consideration. The performance of these new fertilizers is being tested in field experiments of government farms as well as on cultivators' fields at 40 different centres located in different soil type regions.

Results on paddy and wheat crops have definitely shown that the new nitrogen carrying fertilizers are generally as efficient as ammonium sulphate on most Indian soils. Extensive agronomic trials have also cleared some doubts regarding the use of phosphoric fertilizers; while increased yields are obtained by the use of nitrogen fertilizers, it along with a supplementary dose of phosphate on many of the soils will produce a sufficient additional response so as to give economic return for the application of phosphate fertilizers. While superphosphate continues to be the standard phosphatic fertilizer for most soils, there is enough evidence to show that citrate soluble phosphate materials

like di-calcium phosphate could serve as equally efficient fertilizer and may even prove superior to acidic and heavy soils on which response of superphosphate is apt to be reduced by fixation. Recent experiments on di-calcium phosphate carried in the Indian Agricultural Reseach Institute show that the response of paddy in neutral and alkaline calcareous soils is comparable to that of superphosphate.

The use of potassic fertilizers has given no response except in some experiments in Bihar in which additional yields of the order of 2.5 mds. of paddy per acre with 20 lb. K_2O have been reported. In general, Indian soils would appear to be well provided with natural reserves of potash for the requirement of crops except sugarcane, tobacco, jute, etc. which need supplementary potash ; more work need to be done on this line.

Fundamental investigations on phosphorus in plants and soils by using radio-active phosphorus (p^{32}) as tracer are also in progress which have revealed the phosphorus nutrient status of Indian soils, the best method of placement of phosphorus and its exchange reactions in the soil. The technique for measurement of surface soil phosphorus by isotopic exchange with P^{32} is also being worked out.

No systematic work on the distribution of trace elements like boron, copper, cobalt, manganese, molybdenum and zinc in Indian soils has been done. The nutritional requirements of these elements by different crops have also not been properly assessed. The amounts of these elements absorbed by plants under certain conditions of soil and climate from the soil are not enough to supply normal requirements. Widespread nature of deficiencies of these elements in our crops and soils has also been recognised More attention has to be paid to this important aspect of nutritional science with reference to micro-nutrients.

Thus, it can be seen that soil studies have not been meagre but not done under uniform and standardised methods adaptable to the country; in the system of classification there is a great lack of co-ordination and understanding on the genetic relationship of various soils. Unlike in the temperate countries, soil survey and soil classification in the tropical and subtropical countries have not made much progress due to natural disadvantages. In recent years, however, increased attention

is being paid to this problem. Under an Indo-U.S. Programme, soil survey is also being carried out in 40 centres all over India on soil climate basis as followed in Uttar Pradesh and a few other places. The main object of this work is to find out representative profiles in the different regions and classify the soils accordingly. Work has been completed in almost all the centres.

Adequate soil classification in our country, therefore, depends first of all on greatly increased soil research. A great deal of field research is necessary to correlate combinations of soil characteristics as determined by detailed morphological studies in the field and chemical, physical and minerological studies in the laboratory. It is expected that the all-India Soil Survey proposed on a soil region basis, sponsored in the Second Five-Year-Plan, will achieve this objective.

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