I.C.A.R. REVIEW SERIES PAMPHLETS

No.	Title	nP.
1.	Agricultural Implements for Indian Farmers *by* R.V. Ramiah and C.P. Srivastava ...	50
2.	Organic Manures *by* C.N. Acharya ...	37
3.	Phosphate Fertilization of Legumes *by* S. Sen and W.V.B. Sundara Rao ...	37
4.	Agricultural Practices in Ancient India *by* S.P. Raychaudhuri ...	50
5.	Buyers' Guide for Indian Agricultural Implements *by* R.V. Ramiah ...	50
6.	Green Manuring *by* T.J. Mirchandani and A.R. Khan ...	37
7.	Dry Farming *by* P. Krishna Rao and S.B. Priyavritha Rao ...	37
8.	Double Cropping *by* P.C. Raheja ...	37
9.	Control of Helminth Parasites with Special Reference to Livestock Farms *by* R.N. Mohan ...	50
10.	Virus Diseases of Potato and Their Control in India *by* R.S. Vasudeva. ...	60
11.	Thirty Years of Statistics in India *by* V.G. Panse ...	65
12.	Crop Rotation in India *by* T.J. Mirchandani and S. Sen ...	62
13.	Wheat Varieties *by* G.S. Murthi ...	75
14.	Dairying in India ...	25
15.	Principles of Feeding Farm Animals *by* K.C. Sen and S.C. Ray ...	37
16.	Camels and Their Management *by* P.N. Nanda ...	75
17.	Livestock Products *by* H.S. Bawa ...	50
18.	Diagnosis of Tuberculosis in Animals *by* J.M. Lall ...	30
19.	Contagious Caprine Pleuro Pneumonia *by* P.R. Krishna Iyer ...	25
20.	Fisheries and Fishing Industry in India *by* B.N. Chopra ...	37
21.	Establishment and Operation of the Farm *by* Arjan Singh ...	50
22.	Farm Management, Extension and Research *by* Arjan Singh ...	25
23.	Banana in India *by* T. Gopalan Nair ...	1.25
24.	Shifting Cultivation Practices in India *by* D.C. Kaith ...	1.25
25.	Soils of India *by* S.P. Raychaudhuri ...	60
26.	Incidence of Anaerobic Infections in Sheep *by* M.R. Dhanda and G.L. Sharma ...	55
27.	Swine Husbandry and Piggery Products *by* R.L. Kaura ...	1.30
28.	The Menace of Heart Rot Fungi to Forest Trees, their causes and effects *by* S.K. Bagchee ...	85
29.	Urea as a Fertilizer *by* P.C. Raheja and K.S. Yawalkar ...	1.00
30.	Effect of Residual Phosphorus on Crop Production *by* P.C. Raheja and S.S. Bains ...	60
31.	Nutrition and Lactation in Diary Cattle *by* K. C. Sen ...	85

SOILS OF INDIA

ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

First Printed 1958
Revised Edition May 1961

Price : 60 nP.

I. C. A. R. REVIEW SERIES No. 25

SOILS OF INDIA

By
S. P. RAYCHAUDHURI
M. Sc. (Cal.), Ph. D. (Lond.), D. Sc. (Cal.) F.R.I.C., F N.I
Chief Soil Survey Officer
Indian Agricultural Research Institute
New Delhi

ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

Soils are one of the important factors governing agriculture of a country. Therefore, knowledge of their various types is necessary in devising national agricultural schemes. This book-let is hoped to meet this requirement. It provides up-to-date information on the soils of India, dividing these into two divisions; those having direct bearing on agriculture and those involving forests, deserts, marshes and barren areas: their fertility is also discussed.

General Editor : D. Raghavan
Technical Editor : P. Kachroo

Printed at The Swan Press of Lahore Delhi-6.

INTRODUCTION

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 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 a 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 describing the different soil groups of India, it is necessary to understand the physiographic, geological, climatic, and vegetational regions of the country.

Physiography. 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 here the land shows a gradual slope 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 800 feet above sea level. 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.

Geology. 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 consistency, depth and composition. 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 parent geological formations.

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) the mesozaic and eocene calcareous rocks, and (b) the upper tertiary sandy rocks.

RECENT AND SUB-RECENT ROCK : A draft 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, and (e) Desert deposits.

Climate. India, probably, presents a greater variety of meteorological conditions, actions and features than any area of a smaller 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, and, etc. 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. The coasts are occasionally affected by cyclones, these cause storm waves that sweep over the low-coast lands of the lower Bengal or deltas of the Mahanadi, the Godavari and the 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.

Vegetation. 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. It seems, therefore, preferable to compare forests, found on average soils where the depth is medium and the soil is well drained, without having an undue favourable topographic situation.

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

I. MAJOR SOIL GROUPS

The formation of soil, from the geological point of view, has been studied by various workers of the Geological Survey of India and these records form an important contribution to our present knowledge of the Indian soils. Wadia *et al.* (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 soil formation 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, namely, the Indo-Gangetic alluvium, the black cotton or *regur* soils, the red soils lying on metamorphic rocks, and the laterite soils.

Indo-Gangetic Alluvium. This is by far the largest and the most important soil group 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 exist, the main features of the soils are derived from the deposition, as silt laid by the numerous tributaries of the 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 degrees of fineness; and 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 soil 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 promotes the accumulation of injurious salts of sodium and magnesium, these make the soil 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 camposed 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 along 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, the P_2O_5 content is good, the percentage of organic matter and nitrogen are 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, chemical composition and mechanical 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 the profile certain horizons give rise to clay pans.

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

The alluvial soils of Bihar may be divided into two main divisions, depending on the distinctness of their characters, e.g., (a) the alluvium north of the Ganges ; and (b) the alluvium south of the Ganges.

(a) The northern alluvium comprises the area between the Himalayas in the north and the Ganges in the south. The soil is of a sandy alluvial nature with a calcareous belt in the form of a triangle in the west, and broken inundated areas in the middle, these remain flooded for different periods in the year. Mukherjee (1952) further subdivided the soils as (1) highland soils, (2) soils liable to inundation, (3) saline soils, and (4) *diara* lands on the banks of big rivers. The soils vary from sandy loam to clay loam in texture, neutral to alkaline in reaction. CaO ranges between 0.5 to 20.25 per cent. They are rich in total and available potash but deficient in phosphorus.

(b) The southern alluvium comprises the area between the Ganges in the north and the hilly region in the south. The soils vary in colour and texture from light greyish loams to heavy black clays. The middle of the area has a depressed feature, which gets flooded during monsoon and looks like big lakes. The area has been subdivided as (1) highland soils, (2) soils liable to inundation, (3) saline soils, and (4) *diara* land soils. pH of the soils is almost neutral, becoming acidic towards the southern points. Available K_2O and P_2O_5 are higher but low in $CaCo_3$ content.

A good deal of work on alluvial soils of Uttar Pradesh has been reported by Agarwal and Mehrotra (1951, '52, '53, '58). 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.

The four classes into which these soils (of U.P.) may broadly be divided are : (a) alluvium of the west and north-west—lighter in texture, (b) alluvium of the east—heavier in texture, (c) alluvium in the centre—texture intermediate between the east and the west and (d) alluvium in the north-east—developed on calcareous parent material.

In Aligarh, the soils have been divided into six regions formed as a result of physical features and watersheds, i.e., the Yamuna *khadir*, Trans-Yamuna *khadir*, Western uplands, Central lowlands, the Eastern uplands and the Ganga *khadir*. Five types have been distinguished, based on the analysis of the profiles of the respective regions. On the basis of physical features, the district of Etah has been divided into five physiographic soil regions and five soil types have been established for the district. The physiographic regions of (I) the Ganga *khadir* and (2) the Ganga *tarai* have been assigned the type name as Etah type 1—Ganga loamy sand, (3) Eastern uplands as Etah type 2—Etah loam, (4) Southern lowlands as Etah type 3—Etah clay loam, (5) Western uplands (a) Ganga alluvium as Etah type 4—Etah sandy loam, (6) Yamuna alluvium as Etah type 5—Yamuna sandy loam. The district of Kanpur bas been divided into four more or less parallel tracts depending on watershed with three soil types. The soils of Farrukhabad have been divided into three physiographic regions with seven soil types. There are three tracts in Banaras district—Western

uplands, the Ganga *tarai* and eastern uplands. The two Banaras types, Banaras 1 and 2, are based on differentiation in colour, texture, pH, 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 depth. They are generally poor in P_2O_5, nitrogen and organic matter.

The soils of Deoria and Gorakhpur, lying on the north-east of the State, have developed on limestone parent material. Barring minor variations, these soils have been classified into three distinct pedological types on the basis of calcium leaching as follows :

Type 1—Calcium soil with a large reserve of soft lime.

Type 2—Leached calcium soil with a layer of $CaCO_3$ accumulation at the bottom of the profile.

Type 3—Degraded calcium soils free of carbonates and showing signs of an unsaturated exchange complex.

The soils of the districts are quite fertile and sugarcane is the most important crop of the region.

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 a 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. A section of its 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, in turn varies with the catchment areas and the tracts through which they flow. The Godavari alluvium is different from that of the Cauvery ; the former carries black fertile mud, and the latter is 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 from the 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, Rajpur and Bilaspur, are of alluvial origin.

The soils of the Punjab plains belong to the same class of alluvial soil that is typical of the Indo-Gangetic plains. The 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. The lower layer contain *kankar* nodules. The 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 soils of Ludhiana district have been classified into 22 utilitarian soil series on the basis of primary and secondary characteristics and other associated land features. Similarly, the alluviums of Patiala district have been divided into 16 utilitarian soil series.

In Kerala, two types of alluvial soils, viz., coastal alluvium and alluvium on river banks are met with. In central Kerala, the width of the coastal alluvial tracts increases while in the north and south they are comparatively narrow. The alluvial soils of Kuttanad form a low lying area, believed to be once a part of the sea and later filled up by silt carried down by the Pumpa and other rivers. The coastal alluviums are sandy, having a low water-holding capacity and a low nutrient status. The alluviums on the banks of rivers are fertile.

Black Cotton or Regur Soils. The typical soils 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 Gujerat, 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 the 'prairie soil' of the cotton growing States of the United States, especially the 'black adobe' of California. It is derived from two types of rocks, the Deccan and the Rajmahal trap and ferruginous gneisses and schists occurring in the Madras State under semi-arid conditions. The former attain sometimes considerable depths while the latter are generally shallow. There is frequently no change in colour for a thickness of six to ten 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 wild 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 the Krishna rivers, heavy black soil is often 20 feet deep. The sub-soil 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 classified the black soil area of six major canals in Bombay State, viz., the Nira right and left bank, the Godavari right and left bank, and the Pravara right and left bank. Twelve distinct types, named alphabetically from A to L, have been distinguished. The influence of topography, drainage and sub-soil water-table on the soil formation is found 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 has been examined in Madras. They are either deep or shallow and may or may not contain gypsum in their profiles 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 three to four feet and in most cases ; partially weathered rock material is met with even at a depth of one and a half to two feet. The deep ones extend even up to nine feet and more. The black soils are very heavy and contain up to 65 to 80 per cent finer fractions, have high pH (8.5 to 9.0) and are rich in lime (five to seven 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 ten 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 (ii) 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 increase with depth. The clay content varies from 35 to 50 per cent. The 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 in outward appearance, the differences of parent rocks are reflected in the physical and chemical composition of the soils as well as clay fractions separated from them.

The black soils of Mysore are fairly heavy with high salt concenteration. 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 *et al.* (1956) have studied the morphological and chemical characteristics of a group of black clay soils, popularly known as *karail*, occurring 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 to the *mar* of Bundelkhand or *regur* of Central India. Their parent material is similar to that of the black cotton soils. Their formation has been attributed to a transported basaltic type of alluvium received by the Ganges from the rivers draining the trap rocks of Bundelkhand and laid down in its basin at places where conditions were favourable.

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 comparison with the *regur*, these soils are poorer in lime, potash and iron-oxide and are also uniformly low in their phosphorus contents. 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 a 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. Red and yellow soils are also seen side by side. Very little is known about the yellow soils. Their colour is probably due to a higher degree of hydration of the feric oxide in these than that in the red soil

From the morphological point of view, the red soils can be divided into two broad sub-groups (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, the latter are acidic. The soils are rather shallow, open in texture, have a pH ranging from 6.6 to 8.0 ; they have a low base status and their exchange capacity is low. They are also deficient in organic matter and poor in plant nutrients. An analysis of their clay fractions gives a 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 district 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 these 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 sufficient amounts of total P_2O_5 (0.05 to 0.3 per cent) their lime content varies from 0.1 to 0.8 per cent. Nitrogen is below 0.1 per cent.

Iron and alumina are high, being 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 Singhbhum are red soils. The pH 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 a 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 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 two to three and C/N ratio is near about ten.

A part of Jhansi district in Uttar Pradesh comprises red soils. There are two types, locally known as *parwa* and *rakar*. The *parwa* is a brownish grey soil varying from good loam to sandy or clay loam. The *rakar* is the true red soil which is generally not useful for cultivation. The soils of Banaras and Mirzapur, developed on the Vindhyan parent materials, have also been classified under tropical and sub-tropical red loams.

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, essentially, of a mixture of the hydrated oxides of aluminium and iron with small amounts of managanese oxides, titania, etc. It is derived from the atmospheric weathering of several types of rocks. 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 hydrate, including 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, Kerala, Madhya Pradesh, the Eastern Ghat regions of Orissa, Maharashtra, 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 rainfall is heavy and humid climate prevails and also in some parts of the East Coast.

On the laterites at a lower elevation paddy is grown while on those situated at higher elevation tea, cinchona, rubber and coffee are grown. The soils are rich in nutrients and contain 10 to 20 per cent organic matter. The pH is generally low, particularly of the soils under tea (pH, 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 found in large quantities. These are rich in plant food constituents, except lime.

In Kerala, both high level and low level laterites are met with : high level laterites growing plantation crops are rich soils because of their proper management. The laterites on lower elevations have poor nutrient status, those of the West Coast generally grow plantation crops, like tea, rubber, cinchona, coconut, arecanut, etc., but at low elevations paddy is also grown. The soils are generally poor in N, P, K and organic matter, the pH ranges between 4.5 and 6.0. SiO_2/R_2O_3 ratio gradually increases with decreasing elevations (from 1.32 to 2.08).

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 also are poor in P_2O_5. The pH is not so low as that 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 are differentiated into two distinct 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 percentages 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 a cap on the higher plateaus 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 plateaus occasionally in considerable thickness. Large areas in Khurda are occupied by laterites, those of Balasore are gravelly and appear to be detrital. Raychaudhuri *et al.* (1941-42) have studied the morphological characters of laterite profiles from several places in Orissa and also the chemical and mechanical composition of profile samples ; as a result, two types of laterites have been distinguished : (i) the laterite murrum and (ii) the laterite rock. These types 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; the latter gradually disappear with depth. The white clay has a pH of 8.3, 0.05 per cent of soluble salts and a cation exchange capacity of 6 m.e./100 gm.

II. OTHER SOIL GROUPS

In addition to the four soil groups described above, there are four more groups which include (i) the forest and hill soils, (ii) the desert and semi-desert soils, (iii) the saline and alkaline soils, and (iv) the peaty and marshy soils. However, 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 are 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 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 conditions with the presence of acid humus and low base status, and (2) soils formed under slightly acid or neutral conditions with a 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 clear felled, the soil undergoes laterisation (Davis, 1940). It is observed that the 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 a 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 loam, brown forest soils, podsols and transitional podsols and wiesenboden have been observed in the Himalayan tract, of these brown forest soils and podsols are predominant (Mukherjee aud Das, 1940, '41, '42). The *tarai* areas 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. The loam has been further subdivided into three classes depending on its lime status, i.e., loam with enrichment of lime, loam with minor quantities of lime, and loam free of lime.

In the Punjab, Taylor *et al.* (1935) have conducted investigations on the forest soils of 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 whole of Himachal Pradesh is under the mountainous influence of the Himalayas and the soils, thus, formed are mainly dependent on geology, topography, climate and vegetation of the Himalayan ranges. The soils of the territory have been grouped into five zones on broad lines, based on altitude, e.g., (1) low hill soil zone (0-3000' a.s.l), (2) mid hill soil zone (3000'–5000' a.s.l), (3) high hill soil zone (5000'—7000' a.s.l.), (4) mountainous soil zone (7000'—10,000' a.s.l.) and (5) dry hill soil zone. The soil gets heavier with increasing altitude whereas pH decreases.

The weathering of metamorphic rocks in Coorg has produced deep surface soil of great fertility, annually it 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 defores tation and planting, the teak plant thrives well, after this 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. The 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 West Bengal soils for growing cinchona 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 their high organic matter content. Water soluble manganese is present in appreciable amounts.

The few investigations mentioned above 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 group ascertained with great care and attention.

Desert Soils. 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 a geologically recent origin. This part is covered under a mantle of blown sand which inhibits 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 little 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 percentages of soluble salts, possess high pH, 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 undecomposed 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.

The *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 underground 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 two lakh acres of land in Uttar Pradesh and five lakh acres of land in the Punjab have been affected by *usar* and 25 thousand acres are being added every year in the Punjab. The 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 suggesed. 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 the soils of Hardoi, Lucknow and Kanpur districts, the internal drainage is greatly restricted and soils are characterised by very high pH values and almost complete absence of gypsum. The soils appear to be the carbonate-chloride type of saline alkali in contrast to the soils of more arid localities of temperate climates.

Mukherjee *et al.*(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 $CaCO_3$, 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 the 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 accumulate 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). Recent studies revealed that the *kallar* soils are both saline and sodic having been developed in areas subject to flooding and having impeded drainage. $CaCO_3$ is usually present in the profiles as hard caliche layer and the water-table is within six feet. These soils have been improved by the use of fertilizer, rotation with *dhaincha* (G.M.), paddy-berseem provided drainage of the soil is not a problem.

Alkali soils are met with all over the State of Bombay but badly affected lands are found in Gujarat, Karnatak and the Deccan. In the Deccan, a very large area has been affected due to the construction of Deccan canals. In Gujarat, 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, the Tapti, the Mahi and the Sabarmathi have been demaged in this way. Such soils show a 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 Bombay State into three important heads : (a) the natural saline soils, (b) the saline soils developed due to irrigation, and (c) the 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 *et al.*, after conducting investigations on soils from the northern and southern zones of Delhi State, have classified them into three pedogenic groups : (i) The saline soils (mostly in the *khadar* area), (ii) the saline-alkali soils (in *dabar bangar* and in old deposits of *khadar* areas), and (iii) the 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 soil (*kari*) have been observed in Kerala The soils are generally submerged in water during the monsoon. As soon as the rains cease, these are put under paddy cultivation. The soils are black, heavy and highly acidic, pH being as low as 3.9 and contain ten 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. The 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 costal 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 *et al.* (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 up to date in 1954 (see map......).

III. 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 fertiliezrs. While ammonium sulphate has so far been the only important fertilizers of this type that has been used and found to respond well, fertilizer 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 sulphhte 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 fertilizer. 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 an 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 on in the Indian Agricultural Research Insitute 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 md. 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 is needed 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 measuring surface soil phosphorus by isotopic exchange with P^{32} is being worked out.

No systematic work has been done on the distribution of trace elements like boron, copper, cobalt, manganese, molybdenum and zinc in Indian soils. 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 micronutrients.

Thus, whereas it can be seen that soil studies have not been meagre, these have not been 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. The All India soil and Land Use Survey Organisation, with four regional Centres at Delhi, Kharagpur at present Calcutta, Nagpur and Bangalore, is carrying out standard soil survey throughout the country. The results of these surveys will help in formulating croping patterns of the different regions and programmes of soil and water conservation.

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 will achieve this objective.

REFERENCES

Agarwal, R. R. and Mehrotra, C. L. 1952. *Soil survey and soil work in Uttar Pradesh.* **2.**

———and——— 1953. *ibid* **3.**

———and———and Gangwar, B. R. 1958. *ibid.* **4.**

———and Yadav, J.S.P. 1954. Saline and alkali soils of the Indian Gangetic alluvium in U.P. *J. Soil Sci.* **5** (2) : 300-306.

———, Mehrotra, C. L. and Gupta, C. P. 1955. Soil classification and soil maping in Nanital Tarai. *Proc. Nat. Acad. Sci. India* **24** : 40-60.

———, ———and——— 1956. *Genesis and phedochemical characteristics of 'Karail' black clayey soils in the Lower Gangetic basin of Uttar Pradesh* **4** : 65-71.

Bal, D. V. 1935. Some aspects of the black cotton soils of Central Provinces and Berar. *Emp. J. Expt. Agric.* **111** : 261-68.

Basu, J. K. 1937. A review and appreciation of soil survey work in India up-to-date with suggestions for future. *Proc. 2nd Meet. Crops and Soils wing, Bd. Agric. and Anim. Husb. in India* : 226-31.

——— 1950. Problems of saline soils in the Bombay State. *Trans. Intern. Congr. Soil Sci. Amst.* **111** : 169-72.

———and Sirur, S. S. 1932-43. Soils of the Deccan Canals. I. Genetic soil survey and soil classification. Nira Right Bank and Pravara canals. *Indian. J. agric. Sci.* **8** : 637-97.

———and Tagare, V. D. 1943. Soils of the Deccan Canals. IV. The alkali soils, their nature and management. *ibid.* **13** : 157-81.

Champion, H.G. 1936. A preliminary survey of the forest types of India and Burma. *Indian For. Rec. N.S. Silv.* **1** : 1-286.

Dalip Singh and Nijhawan, S.D. 1936. Base exchange studies. *Indian J. agric. Sci.* **6** (2) : 956-72.

Davis, P.W. 1940. Preliminary note on Nilambur soils with special reference to their suitability for teak. *Indian Forester* **66** : 658-71.

Dhamija, O.P., Murthy, R.S. and Raychaudhuri, S P. 1956. Cinchona growing soils of West Bengal. *J. Indian Soc. Soil Sci.* **4** : 275-83.

Desai, A.D. 1942. The nature and relationship of the black cotton soils and red earths of Hyderabad. *H.E.H. Dept. Agric. Bull.* No. 10.

Fox, C.S. 1936. Buchanans laterite of Malabar and Kanara. *Rec. Geol. Sur. India* **6** : 389-422.

Howard, H. 1944. *Post-war Forest policy for India.* Government Press, Delhi.

Kendrew, W. J. 1944. *The Climate of the Continents.* Oxford Univ. Press.

Leather, J. W. 1898. Reclamation of *Reh* or *Usar* lands. *Ag. Ledger* Nos. **7** and **13**.

Mukherjee, B. K. and Das, N. K. 1940. Studies on Kumaon Hill soils. I. Soil survey at the Govt. Orchard Chaubattia. Formation of genetic groups. *Indian J. agric. Sci.* **10** : 990-1020.

———and——— 1941. Studies on Kumaon Hill soils. II. Effect of terracing and cultivation on soil types at Chanbattia. *ibid.* **11** : 941-53.

———and——— 1942. Studies on Kumaon Hill soils. III. Soil type at Dornagiri. *ibid.* **12** : 313-22.

———Agarwal, R.R. and Mukherjee, P. 1946. Studies in Gangetic alluvium of United Provinces I. Cultivated soils of Unao district. *ibid.* **16** : 263-29.

Mukherjee, H.N. 1952. Soils of Bihar and a New Method of determining their Manurial Requirements. *Proc. Bihar Acad. Agr. Sci.* **1** : 58-94.

Mukherji, S.K. 1955. The soil of West Bengal Part II (Murshidabad). *Proc. Nat. Acad. Sci. India* **24** : 1 - 16.

Padoley, G. C. and Tamhane, R. V. 1956. *Proc. Indian Sci. Congr. Assoc. 43rd Ses.* Agra, Part III abstracts.

Raman, P. K. and Satugopan, V. 1935. *Indian Met. Dept. Sci. Notes* **6** : 61.

Raychaudhuri, S. P. 1941. Studies on Indian red soils III. General morphological characteristics of some profiles. *Indian J. agric. Sci.* **11** : 220-35.

——— 1956. *Pres. Add. Indian Sci. Congr. Assoc.* 43rd Session (Agra)

———and Mukherjee, K.C. 1942. Studies on Indian red soils VI. Determination of minerological composition. *Indian J. agric. Sci.* **12** : 323-35.

———and Chakravarty, J. N. 1943. Studies on Indian red soils VII. *ibid.* **13** : 252-54.

——— and Mathur, L. M. 1954. *Nat. Inst. Sci. India, Bull.* 3 : 111-14.

Satyanarayana, K. V. S. 1955. Laterite of Kutch. *Proc. Nat. Acad. Sci. India* **24** : 17-20.

Scholasky, Z.J. 1932. *Contributions to the knowledge of soils of Asia. Soil survey and soil work in Uttar Pradesh* (1951) **1.**

Taylor. E. M. *et al.* 1935. A study of the soil in the hill area of the

Kulu division, Punjab Part I. *Indian For. Rec. Silv.* **1** (2): 289-346.

TROUP, R.S. 1921. *Silviculturc of India. Trees.* **I** : 17.

VISWANATH, B. and UKIL, A.C. 1944. Comparative studies on Indian soils I. Regional and environmental factors associated with Indian soils. *Indian J. agric. Sci.* **14** : 333-44.

VOELKAR, J. A. 1893. *Improvement of Indian Agriculture.*

WADIA, D.N., KRISHNAN, M.S. and MUKHERJEE, P. N. 1935. Introductory note on the geological formation of the soils of India *Rec. Geol. Survey India* **68** : 363-91.

I.C.A.R. REVIEW SERIES PAMPHLETS

No.	Title	nP.
1.	Agricultural Implements for Indian Farmers *by* R.V. Ramiah and C.P. Srivastava ...	50
2.	Organic Manures *by* C.N. Acharya ...	37
3.	Phosphate Fertilization of Legumes *by* S. Sen and W.V.B. Sundara Rao ...	37
4.	Agricultural Practices in Ancient India *by* S.P. Raychaudhuri ...	50
5.	Buyers' Guide for Indian Agricultural Implements *by* R.V. Ramiah ...	50
6.	Green Manuring *by* T.J. Mirchandani and A.R. Khan ...	37
7.	Dry Farming *by* P. Krishna Rao and S.B. Priyavritha Rao ...	37
8.	Double Cropping *by* P.C. Raheja ...	37
9.	Control of Helminth Parasites with Special Reference to Livestock Farms *by* R.N. Mohan ...	50
10.	Virus Diseases of Potato and Their Control in India *by* R.S. Vasudeva. ...	60
11.	Thirty Years of Statistics in India *by* V.G. Panse ...	65
12.	Crop Rotation in India *by* T.J. Mirchandani and S. Sen ...	62
13.	Wheat Varieties *by* G.S. Murthi ...	75
14.	Dairying in India ...	25
15.	Principles of Feeding Farm Animals *by* K.C. Sen and S.C. Ray ...	37
16.	Camels and Their Management *by* P.N. Nanda ...	75
17.	Livestock Products *by* H.S. Bawa ...	50
18.	Diagnosis of Tuberculosis in Animals *by* J.M. Lall ...	30
19.	Contagious Caprine Pleuro Pneumonia *by* P.R. Krishna Iyer ...	25
20.	Fisheries and Fishing Industry in India *by* B.N. Chopra ...	37
21.	Establishment and Operation of the Farm *by* Arjan Singh ...	50
22.	Farm Management, Extension and Research *bv* Arjan Singh ...	25
23.	Banana in India *by* T. Gopalan Nair ...	1.25
24.	Shifting Cultivation Practices in India *by* D.C. Kaith ...	1.25
25.	Soils of India *by* S.P. Raychaudhuri ...	60
26.	Incidence of Anaerobic Infections in Sheep *by* M.R. Dhanda and G.L. Sharma ...	55
27.	Swine Husbandry and Piggery Products *by* R.L. Kaura ...	1.30
28.	The Menace of Heart Rot Fungi to Forest Trees, their causes and effects *by* S.K. Bagchee ...	85
29.	Urea as a Fertilizer *by* P.C. Raheja and K.S. Yawalkar ...	1.00
30.	Effect of Residual Phosphorus on Crop Production *by* P.C. Raheja and S.S. Bains ...	60
31.	Nutrition and Lactation in Diary Cattle *by* K. C. Sen ...	85