CHAPTER 1

GENERAL INTRODUCTION
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DEVELOPMENT OF SOIL SCIENCE

Soil science or pedology is a very young branch of science. From the time men emerged from nomadic state and took to agriculture, a vast amount of practical knowledge has been collected by successive generation of agriculturists. "It is very difficult to arrive at a date for the earliest agriculture. It lies somewhere between 6,000 B.C. and 4,000 B.C. Probably the earliest settlement where grains were regularly reaped is that of the so called Natufians on the slopes of Mount Carmel in Palestine."¹

The 'Rig Veda'² composed at about 1500 B.C., contains references regarding soil conditions, cropping systems, forecast of rain, time of sowing and of harvesting, use as manure of nitre from natural deposits, kitchen ashes from burnt cow dung, wood, and all forms of organic waste material (excluding human excreta). As early as the Bible,³ there is a prescription of resting the land once in seven years. The agricultural practices thus built up empirically, gradually attained a degree of efficiency. Agriculture, however, remained an art - rather than a science. The building up of colonial empires where plenty of land and cheap labour were
available led to the neglect of agricultural practices in the mother country. The fall of the Roman Empire has been, to a large extent attributed to its decay in agricultural practices.

The development of the scientific outlook by Francis Bacon (1561-1626) led to a rational approach to the study of natural and applied sciences. Bacon himself believed that water formed the 'principal nourishment' of plants, the purpose of the soil being to keep the plants upright and to protect them from heat and cold. van Helmont (1577-1644) was of the same view. J.R. Glauber (1656) and John Meyo (1674) were of the view that saltpetre is the principle of vegetation. Thus Meyo remarked, "Nitre of the soil is sucked by the plants." This theory was supported by John Woodward by some interesting experiments. When plants were grown with abundance of water which was rendered 'impure' (by addition of salts) the amount of growth increased with the impurity of the water. Thus, vegetables are formed not of water alone but require 'peculiar terrestrial matter.' It has been shown that there is a considerable quantity of this matter contained in rain spring and river water, that the greatest part of the fluid mass that ascends up into plants does not settle there but passes through their pores and exhales up into the atmosphere; that a great part of the terrestrial matter, mixed with
the water, passes up into the plant along with it, and that the plant is more or less augmented in proportion as the water contains a greater or less quantity of that matter; from all of which we may reasonably infer, that earth and not water, is the matter that constitutes vegetables." 7 Boerhaave 8 (1727) believed that "the prime radical juice of vegetables is a compound from all the three kingdoms, viz. fossil bodies and putrified parts of animals and vegetables."

The Edinburgh Society which was established in 1755 for the improvement of arts and manufactures, induced Francis Home 9 (1757) "to try how far chemistry will go in setting the principles of agriculture." The whole art of agriculture, he said, centred on one point the nourishment of plants. Investigation of fertile soils showed that they contained oil, which was therefore thought to be the food of plants. But when a soil was exhausted by cropping, it recovered its fertility on exposure to air. Thus air seemed to supply another food.

The modern period in agriculture was ushered in by Theodore de Saussure (1804). De Saussure 10 grew plants in air or in known mixtures of air and carbon dioxide, and measured the change in the composition of the gas by sudiometric analysis. He was thus able to demonstrate the central fact of plant respiration, the absorption of oxygen and the evolution of carbon dioxide. He further demonstrated the phenomenon of the
decomposition of carbon dioxide and the evolution of oxygen in the presence of light. According to De Saussure, carbon dioxide in small quantities was a vital necessity for plants which perished if carbon dioxide was artificially removed from the air. Carbon dioxide supplies carbon as well as some oxygen. According to him, water was 'decomposed' and fixed by plants. On comparing the amount of dry matter gained from these sources with the amount of material that could enter through the roots even under the most favourable conditions, he concluded, that the soil furnished a very small part of plant food. Small as it is, however, this part is indispensable - it supplies nitrogen which, as he had shown, was not assimilated directly from the air. Baussingault (1834) began a series of field experiments on his farm and drew a balance-sheet of the crops and manures and found out how far other sources such as air, rain and soil were utilized.

In 1840 Liebig made his famous report upon the state of organic chemistry, published as "Chemistry in its Application to Agriculture and Physiology." In this report he emphasised the role of the soil as a store-house for the mineral constituents required by plants. Based upon his ideas, he developed his patent manure. According to Liebig, *The crops on a field diminish or increase in exact proportion to
the diminution or increase of the mineral substances conveyed to it in manure. By the deficiency or absence of one necessary constituent, all the other being present, the soil is rendered barren for all those crops to the life of which that one constituent is indispensable." Liebig considered soil as a "test-tube" which contained the nutrients required by the plants. Hence his concept of soil was static, rather than dynamic. Schlesing and Munz emphasized the role of bacteria in putrefaction processes. Worrington studied the nitrification in soil. Winogradsky isolated two groups of bacteria responsible for putrefaction processes. In 1843, Lewes and Gilbert at Rothamsted started systematic experiments on agriculture which have been continued to date.

The dynamic nature of the soil was emphasised by the famous Russian Scientist Dokuchaev who is considered as an originator of the science of soil or pedology. The early pioneers in this field were Dokuchaev and Clinka in Russia, Remann in Germany and Hilgard in America. Dr. Harbut of the Department of Agriculture contributed extensively to the study of soils in America. According to above workers, soil is a distinct organism with definite morphological and physiological features, and with specific physical properties, chemical composition and biological
make up. Soil is an essential link between the lifeless bodies and the living biological kingdom. Soil must be studied not only in the laboratory but in its natural environment as well. "It is partly alive. It is quite unlike the dead samples of soil stored in the glass jars of chemical laboratories. A soil consists of thousands of compounds, organic and inorganic. Some of these compounds are highly active eventhough present in tiny amounts." Hence in the study of soils great importance is attributed to the study of soil profile, the succession of horizons down to the parent material. Geology, climate, topography etc., are some of the factors which influence the formation of soils. The very definition of soil has undergone continuous changes reflecting continuous progress in the development of the science of soil.

SOIL GENESIS

The soil is formed by the action of various weathering agents on the parent rock material. The weathering processes are divided into different classes:  

(a) Physical weathering which consists of the degradation of parent material by changes of temperature etc.  
(b) The changes brought about by chemical weathering which are more profound in nature consist of processes
like oxidation, hydrolysis, hydration, solution etc.

(e) Biological processes are also responsible for weathering processes. Roots penetrate into rocks and exert tremendous pressure ultimately disintegrating them. The materials secreted by plants exert powerful reaction on soils.

In 1917, Eaman defined soil as "the uppermost layer of the solid crust of the earth; it consists of rocks that have been reduced to small fragments, have been more or less changed climatically, together with the remains of plants and animals that live on it and use it." Hilgard defined soil as "the more or less loose and friable material in which, by means of their roots, plants may or do find a foothold and nourishment, as well as other conditions of growth. Dokuchaev defines soil as "the surface and adjoining horizon of parent material (irrespective of the kind) which have undergone more or less a natural change under the influence of water, air and various species of organisms-living or dead; this change is reflected to a certain degree, in the composition, structure and colour of the products of weathering."

It was Karbut who took a definite step forward in defining soil in terms of soil characteristics instead of soil forming processes: "The soil consists of the outer layer of the earth's crust usually unconsolidated, ranging in thickness from a mere film to a maximum of
somewhat less than ten feet which differs from the material beneath it, also usually unconsolidated in colour, structure, texture, physical composition, biological characteristic, probably chemical processes, in reaction and morphology. According to Joffe: the soil is a natural body of mineral and organic constituents, differentiated into horizons, of variable depth, which differs from the material below in morphology, physical make up, chemical properties and composition and biological characteristics.

The various factors which are responsible for the formation of soils have been called soil formers.

SOIL FORMERS

Dokuchaev proposed that soil is a function of parent material (pm), climate, biosphere, age and topography. According to Joffe the principal factors of soil formation are:

(a) Passive factors:
   (i) Parent material  (ii) topography
   (iii) time factor     (iv) human factor

(b) Active factors:
   (i) precipitation   (ii) temperature
   (iii) wind          (iv) evaporation, transpiration and humidity
(c) Biosphere as a factor:

(i) photosphere
(ii) micro-organisms
(iii) zoospheeres (worms, ants etc.).

SOIL CLASSIFICATION

The natural classification of soils has been attempted on various lines. The problem is perhaps far more complicated than the problem involved in the classification of elements or plants.

The first systematic classification of soils was attempted by Dokuchaev in 1879, who classified soils as follows:

(A) Normal soils (unaffected by other than pedogenie processes.)

Class I Continental humus soils.
(a) Gray northern soils (podsols).
(b) Chernosem (black earth) soils.
(c) Chestnut earths.
(d) Alkaline soils (solonets).

Class II Continental swamp soils.

(B) Extra normal soils.

Class III Denuded or eroded soils.

Class IV Alluvial and lacustrine soils.

This classification is far from completely satisfactory. Subsequently, Ramann, Glinka, Gedroits, Lang, Vilensky, Sigmond, Marbut, Robinson and Soil
Survey of U.S.D.A. have suggested different ways of classifying soils. Sigmoid's classification of soils is as follows:

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<th>Stage I</th>
<th>Stage II</th>
<th>Stage III</th>
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<td>Main groups.</td>
<td>Sub-groups.</td>
<td>Soil orders.</td>
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<tr>
<td>1 Organic soils.</td>
<td>1 Raw organic soils i.e. Turfy soils.</td>
<td>1 Turfs, poor in bases.</td>
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<td>2 Turfs, rich in bases but not salty.</td>
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<td>3 Salty turfs.</td>
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<td></td>
<td>2 Humified organic soils</td>
<td>4 Acid peat soils.</td>
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<td>5 Neutral peat soils.</td>
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<td>6 Salty peat soils.</td>
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<td>2 Organic mineral soils.</td>
<td>3 Raw organic mineral soils.</td>
<td>7 Endodynamic soils.</td>
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<td>8 Ectodynamic soils.</td>
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<td>9 Pseudodynamic soils.</td>
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<td>4 Humic siallitics</td>
<td>10 Hydrogen soils.</td>
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<td>11 Calcium.</td>
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<td>12 Sodium.</td>
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<td>5 Ferric siallitics</td>
<td>13 Brown earth.</td>
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<td>6 Allites.</td>
<td>16 Pure allites.</td>
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<td>17 Siallitic allites.</td>
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<td>18 Beauxite allites.</td>
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<tr>
<td>3 Purely mineral soils.</td>
<td>7 Raw mineral soils.</td>
<td>19 Soils of mixed rock debris.</td>
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<td>20 Soils of mineral grit.</td>
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<td></td>
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<td>21 Soils of fine mineral dust.</td>
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</table>
8 Mineral soils with some decomposition.
9 Mineral soils with the end products of decomposition.
22 The calcium of the mineral matter partly mobilised.
23 The silica of the mineral matter partly mobilised.
24 Soils with easily soluble salt crust.
25 Soils with slowly soluble salt crust.

On the other-hand, according to American (United States Department of Agriculture) system of classification soils are first divided into three great groups:

(a) Zonal groups are primarily influenced by climate in which they have developed.
(b) In the Intrazonal group local factors such as drainage also contribute to the nature of the soil.
(c) Azonal soils are without profile characteristics.

These groups have again been divided into various subdivisions.

The above divisions of soil are still far from satisfactory. According to Robinson, the relative weight to be assigned to geology, climate and topography cannot be uniform over all the countries.

CLASSIFICATION OF INDIAN SOILS

The classification of Indian soils has been attempted from time to time. Leather (1893) distinguished four major groups of the Indian soils viz.
(1) Black soils
(2) Red soils
(3) Alluvial soils
(4) Laterite soils

Shokalsky\textsuperscript{25} (1929) prepared a soil map of India. The soil survey work in India is still in a process of evolution. The Indian Council of Agricultural Research formulated a scheme of collecting and collating data on Indian soils and the final report was submitted in 1953. Raichaudhary\textsuperscript{26} classifies Indian soils as follows:

(i) Red soils which may be classified as Red earth, Red loam, yellow earths etc.,

(ii) Laterite and Lateritic soils.

(iii) Black soils of varying types, including the black cotton soil or 'regur'.

(iv) Alluvial soils (ill-defined).

(v) Forest and Hill soils.

(vi) Saline and Alkaline soils.

(vii) Desert soils.

(viii) Peaty and Marshy soils.

It is interesting to observe that the soil survey of India\textsuperscript{27} is to be undertaken jointly by India and U.S. Soil Survey and is to be carried out on climatic basis at different centres in India divided into six zones. Upto July 1955 work has been started in 20 centres.
SALINE AND ALKALI SOILS

The saline and alkaline conditions reduce the productivity of the soils. Such soils belong to the Intrasonic soils of the U.S.D.A. classification. Saline soils are widely prevalent in the world. It has been estimated that 39% of the world's dry land area is covered by these soils. Such soils occur extensively in different parts of India.

The literature on saline soils is very extensive, although the problem of such soils is still far from being completely understood. Even the nomenclature for this problem soil is in a formative stage. In 1892 Hilgard published a report on the relation of soil to climate in which he discussed his studies on alkali soils which were started by him in 1888. Vilensky and de 'Sigmond cite references to alkali soils dating back right up to the 18th century. Hilgard divided the alkali soils into two groups, white alkali soils and black alkali soils; the former contained sulfate and chloride of sodium and sometimes of magnesium; while the latter contained carbonate of sodium. In 1912, Gedrois presented his views on the genesis of the soils based upon the phenomena of exchangeable cations. Saline soils have been investigated by many workers amongst whom may be mentioned Vilensky in Russia, de 'Sigmond in Hungary,
Hissink in Holland and Kelley, Joffe and the workers of the U.S. Salinity Laboratory in America.

The properties of such soils including methods of investigation etc., have been extensively treated in the following publications:

(i) Pedology by J.S. Joffe (1949).
(iv) Diagnosis and Improvement of saline and Alkali soils, U.S. Regional Salinity Laboratory (1954).

According to Russian workers, the alkalinisation of the soil takes place in the following three stages:

The first stage is the process of salinisation, i.e. the accumulation of soluble salts at the surface. Such soils are known as solonchak.

The second stage consists of desalinisation whereby the soluble salts are removed and the soil complex becomes progressively saturated with sodium ion. Such soils are known as solonetzs.

In the third stage soluble salts are completely removed and as a result of hydrolysis the silicates are split and SiO₂ is released, such soils are known as solodi.

Sigmoid considers the alkali soils as sodium soils and divides them into the following categories:
(1) Saline Soils:

The first stage consists of the accumulation of sodium salts.

(2) Salty-Alkali Soils:

In the second stage of alkali soil formation, the nature of the absorbing complex is changed by the sodium salts.

(3) Leached Alkali Soils:

The third stage of alkalinization is due to the intensive leaching of the salts, when the soil becomes of the solonetz type.

(4) Degraded Alkali Soils:

In the fourth stage of alkali soils, the leaching down of water soluble salts is followed by the hydrolysis of the sodium complex. This results in sodium being replaced by hydrogen and the soil reaction becomes acidic.

(5) Regarded Alkali Soils:

If owing to some reason water level rises up again, the degraded alkali soils become regraded and the soils become saline again.

According to U.S. Salinity Laboratory saline and alkali soils are divided as follows:

(i) Saline Soil

(ii) Saline Alkali Soil and

(iii) Non-Saline Alkali Soil.
(i) Saline Soil: A non-alkali soil containing soluble salts in such quantities that they interfere with the growth of most crop-plants. The electrical conductivity of the saturation extract is greater than 4 mhos per centimetre (at 25°C) and the exchangeable-sodium percentage is less than 15. The pH reading of the saturated extract is less than 8.5.

(ii) Saline Alkali Soil: A soil containing sufficient exchangeable sodium to interfere with the growth of most crop plants and containing appreciable quantities of soluble salts. The exchangeable sodium percentage is greater than 15, and the electrical conductivity of the saturation extract is greater than 4 mhos per centimetre (at 25°C). The pH reading of the saturated extract is usually less than 8.5.

(iii) Non-Saline Alkali Soil: A soil that contains sufficient exchangeable sodium to interfere with the growth of most crops plants and does not contain appreciable quantities of soluble salts. The exchangeable sodium percentage is greater than 15 and the electrical conductivity of the saturation extract is less than 4 mhos per centimetre (at 25°C). The pH reading of the saturated soil paste is usually greater than 8.5.
The Imperial Department of Agriculture was established in 1881. Dr. J.A. Voelcker (1889-1891) initiated the systematic study of Indian Agriculture. In 1892, the Imperial Institute of Agricultural Research (now the Indian Agricultural Research Institute, New Delhi) was established under J.W. Leather. In 1947 Dr. A.W. Stewart published a report on soil fertility investigations in India with special reference to manuring. In this report he examined critically the results of investigations by various workers. Important problems in connection with soil research have been studied by the irrigation authorities in the Punjab. Studies of the conservation of soil and soil moisture have been conducted at Nagari in Madras and at Raichur in Hyderabad. In 1935 Wadia, Krishan and Mukherjee published a soil map showing the geological formations under Indian soils.

A considerable body of information is now available on the profile characteristics of major groups of Indian soils, mainly as a result of the zeal of individual soil scientists. These profile studies have centred round either, the elucidation of major groups of soils, or, a soil survey with an agronomic purpose, or in relation to the problems of saline and alkaline soils. They vary in scope and objective but mark the beginning in India of the scientific study of soil as
'a natural body' which is subject to operations of
dynamic factors and thus to change with time. The more
extensive of these studies are by Basu and coworkers
on soils of the Bombay Deccan; by Dilip Singh on soils
of some areas of the Punjab; by Hoon on the soils of
the Kulu valley of the Punjab; by Mukherjee, Agarwal and
coworkers on the soils of the Kumaon Hills and several
other areas of Uttar-Pradesh; by Mukherjee, Datta and
Das on the coastal soils of Bakharganj now in East
Pakistan; by Venkataratnam, Vishwanath and Karunakar on
soils of some areas of Madras; by Narayanam on the soils
of Irwin Canal tract; by Krishna on soils of some areas
of Hyderabad and by Bal on the black soils of Madhya
Pradesh. Basu et al developed a classification into
soil types of soils investigated by them and prepared
a soil map showing their boundaries which is being used
for advisory work.\textsuperscript{39}

In accordance with the recommendation of Planning
Commission of the Government of India, a Central Soil
Conservation Board was set up in the Central Ministry
of Food and Agriculture. Soil conservation stations are
established all over India. It is estimated that in the
second five year plan (1956 to 1961), seven million
acres of land will be surveyed, of which 4 million acres
will be put to some form of soil conservation. The
second five year plan is a part of the 30 year programme
in which it is estimated that conservation measures will
be applied to 200 million acres of land at a cost of Rs. 1,200 crores. The Soil Conservation Society of India was established in 1952 with a view to bring together workers on various problems in connection with soil conservation. The society has started a quarterly, Journal of Soil and Water Conservation in India.

**STUDY OF ALKALINE SOILS IN INDIA**

Saline and alkali soils occur fairly extensively in India in the following areas: throughout the Indus valley; the valleys and basins of western India and Pakistan, the Ganges valley west of about 80°E long.; on the uplands of the Deccan plateau, especially between the Tapti, Godavari and Bhima rivers; the saline marshes of the sea-coast and of the river deltas of the Ganges, Indus, Cauvery and Mahanadi; the coastal salt flats along the Rann of Cutch.

In different parts of India (and Pakistan) a number of local terms are in use to designate alkali soils, viz. uppu, reh, thur, kollar and usur. Lona and kharar are the terms generally used in the Bombay state. The problem was recognized as early as 1876 when the Reh Commission was appointed to investigate the cause of deterioration of land in the Aligarh district. It is estimated that there were 2,000,000 acres of such soils in the whole of India in 1903. Such soils have
been investigated by Leather and Auden\textsuperscript{41} in the United Provinces and by Basu\textsuperscript{42,43,44} and his associates in the Bombay Deccan area. The Punjab Irrigation Research Institute has published several important publications relating to the salt problem by Mehta\textsuperscript{45} Puri\textsuperscript{46} and other workers.

Gorrie\textsuperscript{47} has published a treatise on soil conservation in Punjab. A very interesting publication in this connection is the famous report "The Origin of Salt Deposits in Rajputana" by Holland and Christie\textsuperscript{48}. According to Holland and Christie, the huge quantity of salt occurring in Rajputana may be traced to the wind-borne sand particles containing salt.

**GROUND WATER RESOURCES**

The UNESCO publication\textsuperscript{49} has devoted a special chapter on the utilization of ground water in India. Nearly the quarter of the irrigated land in India and Pakistan is watered by wells. Nearly three-fourth of the well irrigated area in India lies in the Gangetic plain. An ambitious programme of supplementing the water resources of the region by digging tube wells has been undertaken by the Bombay State. It is claimed that in some of the districts of North-Gujarat, a large number of tube wells have been successfully dug and the work is still in progress. The main work of boring
the wells is done by a semi private agency called Famine Relief Commission. It is feared that the sites of many of these wells have not been selected on scientific lines. It is interesting to record that the services of a water diviner were officially requisitioned by the government for selecting well-sites in the Badhanpur area. Information from Government sources, however, is not easily forthcoming and systematic analysis of these waters if carried out is not available to the public. Under the circumstances, the importance of non-government agencies carrying out survey of ground water resources by analysis of waters from different wells cannot be under-estimated. In the present investigation, waters from a number of tube-wells have been investigated.

In 1955, under the auspices of the Central Board of Geophysics, (ministry of Natural Resources and Scientific Research) a symposium on "Ground Water" was held in February at New Delhi. The paper entitled 'Chemical Properties of Ground Water in North Gujarat' was contributed. The proceedings of the symposium will be published in the near future.
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