2.1. HISTORICAL 'RESUME'

Man is dependent on the soils and to a certain extent, soils are dependent on man. The quality of soils and the kind and quality of plants and animals grown on them determines man's standard.

The great ancient civilizations grew around great rivers like the Nile, the Tigris, the Euphrates, the Indus, the Yangtse, and the Hwang-Ho. This was made possible by the food producing capacities of the fertile soils of the river valleys civilizations. Periodic flooding of these soils replenished their fertility and provided continued abundant food supplies. It was not until man discovered the value of manures and crop residues that he was able to make extensive use of upland soils for sustained crop culture.

The downfall of some of the civilizations like Euphrates and Tigris due to soil degradation and mismanagement are historical realities.

Towards the end of 19th century, Barron Bertholett, one of the greatest luminaries of French science, accompanied Napoleon on his Egyptian expedition. He was struck by the
fact that solid sodium carbonate occurred on the banks of the Nile. Being one of the founders of Law of mass action, Berthollet believed that sodium carbonate was derived from calcium carbonate present in the soil.

Paul de Mondesir (1888) observed that calcium chloride, present in the aqueous extract of soil situated near sea, was formed by the action of sodium chloride on the soil. Subsequently, reaction with carbonic acid produce sodium carbonate.

The problem of salinization and alkalization in soils is universal among the normal (zonal) soils of arid regions of the earth. The saline-alkaline soils are estimated to comprise about 39 per cent of the world's dry land area. In Asia, they are wide-spread in the eastern and western Siberia, Mangolia, Manchuria, Persia, India, Afghanistan and Pakistan. Their prevalence in eastern part of Trans-Caucasia, Rumania, Hungary, United Kingdom, South-Eastern France, Australia, Western America, some provinces of Canada and North-East Central portion and South Africa is also recognised.

The distribution of the saline and alkaline areas are as follows (Fig. 1).

1- The coastal salt flats, Runn of Kutch.
2- Rajasthan and Madhya Pradesh.
3- The saline marshes of the sea-coast and the deltas of Ganga (Indo-Gangetic alluvial plain), Cauvery and Mahanadi.
4- The uplands of Deccan plateau, especially between Godavari, Tapti and Bhima rivers.
5- The valley and basins of Western India.
6- The Indus valley.

As far back as 1877, a 'Reh Committee' was set up to investigate the causes of land deterioration in Aligarh district. Worth (1891) was, probably, the first to study in some detail the 'reh' soils of Aligarh district. He was followed by Leather (1893), Hill (1903), Auden et al. (1942), Agarwal and Mehrotra (1962), Raychaudhary (1962), Khan and Singhal (1968), Dutt (1968), Singhal and Akhtar (1978) and Singh (1978). While most workers studied the chemical aspects of these soils, Dutt carried out hydrological studies in these soils.

2.2. AGROCLIMATIC CONDITIONS

Aligarh is one of the fifty seven districts of Uttar Pradesh and is situated between 27°28' and 28°10' N Latitudes and 77°29' and 78°38' E Longitudes at an altitude of 187.4 m. It spans 116 km along East-West and 72 km along North-South. The area of the district is 5072 sq. km but varies slightly from year to year owing to changes in the course of the two bordering rivers, the Ganga and the Yamuna (Fig. 2). Aligarh has semi-arid and sub-tropical climate with hot dry summer and cold winters. The winter extends from the middle of October
to the end of March. The mean temperature for December and January, the coldest months are about 15°C and 13°C respectively and the extreme minimum record for any single day is 2°C and 0.5°C respectively.

The average temperature during May-June is 34°C whereas the extreme maximum record is 47°C. The average rainfall is 847.3 mm. But most of it (85%) occurs during June-September and only a little (10%) during the winter which is highly beneficial to 'Rabi crops'.

Aligarh and its surrounding areas are well connected with all-weather roads and railways.

2.3. REVIEW OF LITERATURE

The importance of pedogenic factors in the formation of soil was first recognised by Hilgard (1893) and later by Dockuacheav (1898) who expressed it in the form of an equation in which factors like climate, organisms, parent material and time were included. Jenny (1941) included another factor of relief in addition to those given by Dockuacheav. In later studies by Joffe (1949) and Rieckens (1965) emphasis was placed on the role of these factors under different environmental conditions. Subsequently, a factor of water table was also included in the soil formation (Crocker, 1952; Russel and Rhoades, 1956). Rode (1961) included eight factors in
writing his equation, the additional factor being gravity, water (surface, soil and ground) and man.

Soil genesis can be divided in two phases (i) the preparation and accumulation of soil materials through the agencies of weathering (Polynov, 1937; Henin, et al., 1953; Pedro, 1960) and (ii) the development of soil profile.

To account for different soil types, two initial states of soils can be considered—uniform and variable. (Karale, 1969; Tamhane and Karale, 1967). Factors like climate, topography, biologic and time are variable. Soil formation has been considered in terms of influence by individual factors. The pronounced influence of parent material (Ehrlich, 1955; Namjoshi, op. cit., Karale, op. cit., Mahjoory, 1979), drainage conditions (Gupta, 1952), climate (Sys, 1970 and Rao, 1977), biologic process (Williams, 1949), topography microgeomorphology (Govindarajan and Godse, 1972) and time (Gole and Hawley, 1968; Belzi and Closky, 1977; Ahmad, 1977; Rose et al., 1979).

Climate affects soils by controlling (i) physical and chemical reactions and (ii) organic factor and, to some extent and (iii) the relief. On this account bioclimatic regions have been a basis of classification of soils (Duggal, 1970). The soil variation in northern Indian plains have also been correlated with variation in rainfall (Shankarnarayana and Hirekerur, 1972; Sidhu, 1976).

The pedochemical studies conducted by Yadav (1977) on the soils of lower Vindhyan plateau in Mirzapur district (U.P.)
a well defined catenary relationship between drainage density and colour-texture variation down the slope. According to Prasad (1977) the soilscape at Junagarh (Gujarat) could be the result of both degradational and agradational processes. The intermixing of soils obliterates the inherited characteristics from the parent rocks. Anand and Senegal (1978) studied the relationship between profile development, soluble ions and chemical composition in alluvial soils of Indo-Gangetic plains. They reported that young soils contain greater amount of soluble ions and other chemical constituents in comparison to mature soils.

2.3.1. Soil Formation

The soil forming processes operative in the arid and semi-arid regions can be summed up as follows:

According to Centre (1880) accumulation of salt in Indo-Gangetic basin is due to marine cycles through a sea gulf extending from Sind and Afghanistan in the west of Nainital in the East. Sediments were brought down from Himalayas through rivers to the gulf and a vast plain of alluvial deposits was gradually formed. The receding sea, however, left behind salines. The soil material rested on brakish acquifer. The salts in these soils, according to Leather (1897) can be (i) from a sub-soil salt bed, (ii)
deposited by river water along with alluvium (iii) in situ due to decomposition of minerals, and (iv) from canal water.

Aggarwal and Yadav (1954), Richards (1954) and Varallyay (1967) consider the source of soluble salts in saline and alkali soils to be alumino-silicate minerals in the rocks. Thus a steady supply of bicarbonate and carbonate of the alkali will be available through surface and sub-terranean waters. These will get fixed in the undrained areas under arid climatic conditions (Kovda, 1964). Similar conclusions were arrived at by later workers (Pal et al., 1979; Bhumbla et al., 1980; Chaturvedi et al., 1981; Coyle et al., 1981; Bresler et al., 1981; Rao, 1986).

Egorov (1968) observed that the buried terraces in the piedmont plains of Alpine orogenic zone, showed high salinization in the soils at the lower part of each terrace. According to him, these were the residual soils when the ground water tables were high. Gwande and Tamhane (1970) reported that salt-affected soils of Leh area were derived from the alluvium of Indus river and colluvium of crystalline gneiss under cold continental desert climatic conditions.

In Afghanistan too, Aziz (1980) observed that crustal rocks were the original source of salt deposits. In dry regions, the released salts were carried only short distances and deposited in the valley soils, such as, those in the Helmand valley.
All deep mature soils of the Deccan region (India) have a zone of salt accumulation. High aridity and absence of leaching are the reasons ascribed to it. Auden et al. (1942) attributed salinity in the soils of U.P. to alternating wet and dry seasons. High rate of evaporation has been considered as one of the important factors in the accumulation of salt in soils (Sen, 1958; Bear, 1964; Kaushik and Shukla, 1977; Agarwal et al., 1979; Rose et al., 1979; Bresler, et al., 1982; Fitzpatrick, 1984).

Bhargava et al. (1980) concluded that the location of saline soil area in Haryana state coincide with the rainfall zone of 500-600 mm.

In low-lying areas, soils have higher contents of clay and silt with poor permeability. Obstructed drainage in such areas cause faster accumulation of salts in relation to other areas. This would account for high salinity in the soils of Aligarh, Mahi and Kadana project areas (Gujarat), Tungabhadra area (Karnataka and Andhra Pradesh) and Chambal command area (Rajasthan and Madhya Pradesh) (Bhumbla, 1977).

It has been noted that soils on slopes contain accumulations of salt and gypsum unlike those at the upper deviations (Maclean and Pawluk, 1975). Bhargava (1980) reported development of typical saline soil at an elevation of 227 m.

The non-saline or weakly-saline to saline soils transform into Solonchak due to uncontrolled irrigation. An inefficient
irrigation system would develop secondary salinization within a few years. The natric horizons in Sakit and Hasanpur Series might have come from basic material aided by salt rich ground water, poor drainage conditions, presence of impermeable 'kankar' pan and prolonged and uncontrolled canal irrigation (Gwande, et al., 1980).

The movement of materials in the soil, appropriately termed as 'pedotranslocation' (Mackeague and St. Arnand, 1966), through infiltrated water in dissolved and suspended form, cause profile differentiation. Sehgal (1972) observed that clay migrated through soil when subjected to perfusion with water under slightly unsaturated conditions.

The dispersal of clay within the soil has been explained due to negative change (Soil Survey Staff Rep., 1975). Such dispersed clay is believed to move with the percolating water and to stop where the water stops. Wetting of dry soil causes dispersion of clay, the cracks help gravitational water or water held at low tension to percolate. Water by capillary withdrawal is favoured by the strong tendency for a dry soil to take up moisture. Clay skins were reported to have formed in Wisconsin soils by deposition of clay carried down in suspension by percolating water from the upper part of solum (Buol and Hole, 1961). According to them the factors that enhance clay illuviation were time, relatively stable root channels, soil aggregates, adequate supply of clay and
percolating water. Goss et al. (1973) concluded that time and conditions of clay movement were functions of availability of clay and quality of precipitation. The formation of argillic horizons in the soils in Las cruces area is thought to be due to percolation of readily available water during Pleistocene period (Gile, 1966; Gile and Hawley, 1966; Ruhe, 1967; Gile and Grosman, 1968; Fitzpatrick, 1984).

Pedotranslocation of clays is a universally accepted phenomenon. Walker and Hutka (1977), state that in illuvial soils (B horizon) the proportion of fine to coarse clay increases with the advancement of pedogenesis.

The chemical processes associated with the reduction and mobilization of Fe and Mn and subsequent oxidation and precipitation are significant for estimating the soil moisture. Studies show that Mn compounds reduce before Fe compounds upon water logging of soils while reverse sequence applies upon aeration (Shelling, 1960; Bouma et al., 1969; Daniels et al., 1971; McKenzie, 1972; Bouma, 1972).

Simson and Boersma (1972), attributed reducing and oxidizing conditions as in Indo-Gangetic soils, to seasonally fluctuating ground water table or the intermittent presence of a perched water table.

The physical significance of soil mottling in terms of reduction and oxidation of iron and manganese compounds have been discussed by many workers. According to Veneman et al. (1976) anaerobic metabolic microbial action in nonaerated
saturated soils causes mobilization of iron and manganese compounds. Clothier et al. (1978) discussed a simple model of soil water drainage that aids interpretation of the pattern of mottling in a soil horizon above a coarse textured layer.

The most striking features of most of the zonal and some of the intrazonal soils in arid and semi-arid regions is the presence of a carbonate-enrich layer at the bottom of illuvial horizon.

Heath (1966) suggested the name 'kankar' for carbonate deposits. It was Bryan (1952) who first introduced the term 'nodule' for rounded irregular shaped mass. Sherman (1959) made an attempt to differentiate between concretions and nodules. The genesis of concretionary layers has been a subject of much discussion (Breazeale and Smith, 1930; Joffe, 1936; Bretz and Horberg, 1949; Brown, 1956; Harper, 1957; Roonwal, 1975; Awasthi and Chopra, 1981; Chaturvedi and Raymahashay, 1981; Wieder and Yallon, 1982). Hilgard (1910) recognised the importance of leaching of calcium carbonate which might accumulate in the sub-soil either as cementing material or around certain centres forming white concretions. Livingstone (1906) and Raman (1911) found that capillary rise of moisture made up soluble calcium carbonate to form layer of lime. Caliche appears to be characteristic of arid and semi-arid regions with alternate periods of wetting and drying. Caliche was thought to have formed by evaporation of ascending ground water as
well as by descending surface water, by plant roots removing water from calcium bicarbonate solution and by evaporation of surface and/or flood waters aided by algae and other plants (Jenny, 1941). According to Darrel et al. (1961), deposition of caliche in the soils of south-western Idaho, probably, resulted from soil forming processes.

The calcite in soils might have two possible origins, viz., 'primary', inherited from the parent rock, and 'secondary', formed in the soil itself. Sehgal and Stoops (1972) considered that calcite in Indo-Gangetic alluvium was of secondary origin. Roonwal (1975) too concurred with this view.

Alternate dry and wet seasons in semi-arid regions would account for calcitic nodules, often surrounded by neoferous material formed under to reducing condition (Shegal and Stoops, 1972). The carbonates of alkaline earth have been explained due to pluvial activity (Dhir, 1976). Thus the presence of alkaline earths in soils suggest a seasonally wet but an overall dry climate.

It has been observed that saline-alkali soils of Karnal are characterized by a zone of calcium carbonate (nodules) whereas the normal soils were very low in carbonates (Sen, 1953; Kanwar and Sehgal, 1962; Raychaudhury, 1963). The high CaCO₃ observed in the lower layers of most salt-affected soils of Kaira district (Gujarat) could possibly be due to displacement of calcium from the upper layers to lower layers (Pathak and Patel, 1980).
Since there is a good correlation between soil types and topography, aerial photographs from Landsat imagery have been used to demarcate salt affected soils of Haryana and other areas (Manchanda et al., 1983; 1984; Ahuja et al., 1985).

Mineralogical study of various types of soils of India was undertaken like red lateritic soils (Raychaudhury and Mukherjee, 1942), black cotton soils (Tamhane and Namjoshi, 1959), some soils of M.P. (Gwande, et al., 1963), some soils of Chhotanagpur of Bihar (Sinha and Mandal, 1963) and some soils of Rajasthan (Singh and BHandari, 1964).

Roy (1954) reported epidote, hornblende, garnet, kyanite, zircon, mica and tourmaline among the heavies and mostly feldspar among the light fractions from the soils of Delhi and Karnal.

The ratio of light to heavy fractions may be used as a measure of degree of weathering (Ruhe, 1956). The soils of Bihar are reported to contain greater amount of easily weatherable minerals (Sinha and Manda, 1963). The soils of north Gujarat contain more resistant minerals, such as, zircon, garnet and tourmaline indicating transported nature of soil (Barde and Goworkar, 1965). Roonwal et al.,(1967) investigated the fine sand fraction of the soils of Hissar district and reported biotite, chlorite, epidote, garnet, sphene, zircon, tourmaline and iron oxides among the heavies and quartz, muscovite and feldspar among the light minerals. They concluded
that these are drift soils derived from sedimentary or para-
metamorphic areas of Himalayas. Singh (1974) reported amphiboles
in addition to above. The soils at Aligarh were reported to
contain quartz, calcite, mica, biotite and some dark brown
particles of ferruginous and manganiferous material (Singhal

The subsurface alluvium of Lucknow contains quartz
(dominant), garnet, epidote, hornblende, kyanite, tourmaline,
apatite, zircon and chlorite probably of metamorphic and
granitic provenance of Himalayas (Singh, 1975).

The soils from Punjab, Pundeer (1978) is reported to contain
quartz and muscovite as dominant light minerals and biotite,
tourmaline, garnet, kyanite and sphene as the major heavy
minerals. Thus a dominant metamorphic and subsiding acid
igneous source areas are suggested.

Sehgal (1973) reported that the dominant mineral associa-
tion in salt-affected soils of Sangrur (Punjab) was hornblende-
epidote and garnet with occasional parametamorphic mineral.
Manchanda (1978, 1982) reported the predominance of quartz
followed by muscovite and with calcite. The mineralogical
composition of clays in soils depend on weathering. There is
a predominance of illite and kaolinite in the saline alkali
'Reh' soils of Lucknow (Raychaudhary, 1952-53), of kaolinite
in the soils derived from granites and pegmatites and of
illite from those derived from slates and shales (Mukherjee,
1958), of illite and montmorillonite in the soils of the lower Gangetic basin (Gupta, 1961), of illite and chlorite from the soils of western U.P. (Gupta, 1968; Khan and Singhal, 1968; Chatterjee and Gupta, 1970) and of illite, chlorite and kaolinite in soils of Aligarh district (Jadava and Gupta, 1972; Ghani and Ansari, 1984; Ansari, 1984). Yadav and Gupta (1974) have also reported smectite from moderately alkalic soils of U.P. Raman and coworkers (1975) reported the occurrence of illite, chlorite, vermiculite, smectite and traces of kaolinite from some soils of U.P. Bhargava (1981) reported illite, smectite, vermiculite and chlorite from the soils of Haryana. Intersтратification of illite-chlorite and illite-vermiculite is common in the salt affected soils of India (Kapoor et al., 1981). Chlorite, smectite, kaolinite and mixed layer minerals are reported from the soils of Jammu (Gupta, et al., 1986). The alkaline soils of Gujarat are reported to contain mainly smectite followed by vermiculite, chlorite, mica, kaolinite and allophane among the clay minerals (Kaswala and Deshpande, 1986). According to Rhoades (1976), clay minerals exert considerable influence on the salinity and fertility of soils.

2.3.2. Soil Nutrients and Amendments

The modern concept of soil fertility is based on the capacity of the soil to buffer the ionic environment against
changes in ion activity caused by nutrient removal. The capacity of soil to release potassium from the non-exchangeable form is a function of micaceous clay fractions (Mulford and Jockson, 1966). Feldspar, micas, and K-bearing minerals play important role, in this respect. Joshi et al. (1982) observed that low potassium fixation is due to higher K-saturation.

Since SiO\textsubscript{4} and PO\textsubscript{4} tetrahedra are interchangeable, the phosphate fixing ability of acid and alkali soils of Punjab were attributed to free sesquioxides. The finer soil fraction contributes significantly towards forms and availability of phosphorus (John and Gardner, 1971).

Sodic soils are deficient in both soluble and exchangeable calcium. Plants grown in sodic soils die more often from lack of Ca than from toxic effects of Na. The availability of Ca depend upon soil ESP, root CEC and plant species (Poonia and Bhumbla, 1972). The wide-spread occurrence of calcium related physiological disorders, in fruits have also been reported (Bangerth, 1979; Lougheed et al., 1979).

The observed 'zinc deficiency' in salt affected soils is due to low organic content and high pH and CaCO\textsubscript{3} (Bhumbla and Dhungra, 1964; Kanwar and Randhawa, 1974; Misra and Pandey, 1976; Katyal et al., 1980). The heavy metal cations - copper, cobalt and zinc are susceptible to exchange reactions with clays (Jone, 1936), with copper bound more strongly than zinc (Peech, 1941). Similar behaviour has been reported for cobalt (Zende, 1954).
The available nitrogen in sodic soils decrease with increasing pH (Paliwal and Maliwal, 1975) and depth (Laura, 1973). High pH and increased pollution cause micro-organisms, including nitrogen-fixing bacteria, to die as a result nitrogen is not available to the plants (Bhardwaj, 1975; Akhtar, Ansari and Khan, 1983).

An excess of certain ions, like, \( \text{Cl}^- \), \( \text{SO}_4^{2-} \), \( \text{HCO}_3^- \), \( \text{Na}^+ \), \( \text{Ca}^{2+} \), \( \text{Mg}^{2+} \) and, occasionally, \( \text{NO}_3^- \) and \( \text{K}^+ \) may make soils toxic to plants. Carter and Myers (1963) found that \( \text{NaCl}, \text{CaCl}_2 \) and \( \text{Na}_2\text{SO}_4 \) inhibited the production of chlorophyll and carotene in the leaves of grape fruit.

Miyamoto (1977) proposed addition of sulphuric acid (a waste by-product in many industrial areas) to irrigation water to check precipitation of CaCO\(_3\) in the root zone.

Reclaiming saline and sodic soils is a challenging problem. Carter and Fanning (1964) compared ponded leaching with periodic applications of small quantities of water by sprinkling. They (1964 and 1965) applied surface mulches to reduce evaporation at the soil surface and to enhance infiltration. Benz et al. (1967) found that straw mulches effectively reduced evaporation from dry land-cropped soil.

Gypsum (\( \text{CaSO}_4\cdot2\text{H}_2\text{O} \)) has been utilized for many years with varying success as a source of \( \text{Ca}^{2+} \) to replace \( \text{Na}^+ \) from the soil. Oster and Frenkel (1980) suggested that gypsum requisite for sodic, calcareous suits be increased by a factor
of 1.1 to 1.3 depending upon the final exchangeable sodium percentage desired.

In India, the Ganges basin is the largest, densely populated, fertile and intensively irrigated grain bowl of India. But it is beset with serious pollutional problems. There is a progressive increase in pH, salinity, alkalinity and heavy metal contamination. No systematic data on pollution is available for the soils of Aligarh.