Chapter III

PHYSICAL PROPERTIES AND CLASSIFICATION OF SOILS OF GUJARAT

3.1. INTRODUCTION:
Soil is a vital component in any ecosystem, in fact, our very existence depend on the 6-12 inches underneath our feet. The main functions of soils can be summarized in five major key points:

1- It is the natural medium for plant growth. It provides essential nutrient for plant growth, and supports plant roots.
2- Soil is the environmental sieve that controls the fate of contaminants, and directs water in the various pathways of the hydrologic cycle.
3- Soil is a natural recycling medium. Dead plants tissue and dead bodies of animal and people are decomposed into their basic elements; subsequently, re-assimilated into the life cycle.
4- Soil is a living habitat for microorganisms, insects, reptiles, and small mammals.
5- Soil is an engineering medium for human built ecosystem.

The properties of soil are mainly classified into three groups as shown in the diagram.

![Properties of Soil Diagram]
The soil physical properties influence the way soils function; therefore, decisions concerning suitability of soils for agriculture, hydrology, meteorology, construction and environmental projects depend on the analysis of soil physical properties.

Soil is an extraordinarily complex medium made up of a heterogeneous mixture of solid, liquid and gaseous materials and is composed of layers called horizons, see Figure 3.1. The mineral fraction of soil contains particles of widely varying sizes, shapes and chemical compositions. The solid phase of soil contains particles of vastly different sizes, spanning the lower limits of the colloidal state to the coarsest fractions of sand and gravel.

Now a day, the global worming is becoming a crucial issue for the whole world. The salinization of soil is one of the major reasons causing desertification. Soil degradation and salinization spoil large areas of farmlands, grasslands, and forests especially in arid and semiarid regions. The rise in the sea level, which is sending back the river water in coastal areas, is responsible for increase in salinity. This may be due to decrease in water level in rivers because of tremendous increase in consumption of easily available river water by very fast growing cities, factories, industries, as well as the storage of water in dams to produce electricity reducing the force and quantity of water reaching the sea. The use of improper irrigation techniques is also one of the reasons for increasing salinization of arable land. Thus,
monitoring of salinity and mapping of the extent of the salinized soils are very much important for the health of the arable land.

The water and soil pollution by waste water of large cities as well as the polluted water liberated by industries in the rivers, lakes and underground water streams decrease soil fertility, crop yield and growth by increasing soil contamination. The smoke pollution of cities and industries is also responsible for the increase in soil pollution which may occur in terms of acid rain.

### 3.2. **Classification of Soils:**

Soils are classified into groups of various sizes based on the effective diameter of the particles. The two prominent soil texture classifications that have evolved over the years is the U.S Department of Agriculture (USDA) system and the International Society of Soil Science (ISSS) system. A summary of the two classification systems are shown in Table 3.1.

<table>
<thead>
<tr>
<th>Particle</th>
<th>USDA</th>
<th>ISSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>&lt; 0.002 mm</td>
<td>&lt; 0.002 mm</td>
</tr>
<tr>
<td>Fine Silt</td>
<td>0.002 - 0.006 mm</td>
<td>0.002 - 0.05 mm</td>
</tr>
<tr>
<td>Medium Silt</td>
<td>0.006 - 0.02 mm</td>
<td>0.002 - 0.05 mm</td>
</tr>
<tr>
<td>Coarse Silt</td>
<td>0.02 - 0.05 mm</td>
<td></td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>0.05 - 0.1 mm</td>
<td></td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.1 - 0.25 mm</td>
<td>0.05 - 0.2 mm</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>0.25 - 0.5 mm</td>
<td></td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>0.5 - 1.0 mm</td>
<td>0.2 - 2.0 mm</td>
</tr>
<tr>
<td>Very Coarse Sand</td>
<td>1 - 2 mm</td>
<td></td>
</tr>
<tr>
<td>Gravel/Stones</td>
<td>&gt; 2 mm</td>
<td>&gt; 2 mm</td>
</tr>
</tbody>
</table>

Table 3.1: Particle size classification systems of the U.S. Department of Agriculture and the International Soil Science Society.

In addition to soil particles, organic materials (both decomposed and undecomposed), numerous living organisms and chemical compounds, such as iron and aluminum oxides are found in soils. Both water and air are also important components of soil,
but being transient in nature they are usually not treated as constituents of soil matrix\(^4\).

The clay fraction has a dominant influence on the electromagnetic properties of soil, primarily because the small particles have such a large and reactive surface area and therefore has the ability to retain water. In contrast, the sand and silt fractions typically do not have as much effect due to the small surface area and the inability to absorb or retain water to the extent that clays do. As a result, the sand and silt portions of the soil matrix may be regarded as a passive entity whose influence on soil water is manifested primarily by the geometric arrangement of the particles \(^5\). In wet soil the spaces between the solid particles are fully or partially filled with water and air, which contains various chemicals that may have dissolved from the soil mineral phase or have entered through the soil surface. Water in soil is pulled down by gravitational forces but is also attracted to the surface of the solid matrix. Soil has the ability to retain water and the amount of water retention is based on the forces that act against the water in the soil matrix such as gravitational force, ionic forces from solid surfaces, etc. The most important characteristics of the solid soil phase for our purposes are the sizes and shapes of the individual particles that comprise the soil matrix and the amount of water contained within the mixture.

The physical properties of the soil, including its ability to store water, are very much related to the fraction of the bulk soil volume that is filled with water and air. For plant growth and development, a balance of water and air in pore spaces must be maintained. If water is limited, plant growth may be inhibited by water stress. On the other hand if air is limited, by too much water, then growth may by limited by insufficient aeration.

3.3. **Texture Structure of Soils:**

Soils are assigned unique names based on the concentrations of sand, silt and clay and are conveniently arranged in the soil textural triangle shown in Figure 3.2.
3.3.1 Porosity:

The voids or openings between the particles of soil are called as pore space or porosity of the soil. The ideal soil should have proper assortment of large, medium and small pores. A sufficient number of large or macro pores (with diameters > 0.06 mm), connected with each other, are required for rapid intake and distribution of water in the soil and disposal of excess water by drainage into the substratum or into artificial drains. In absence of water they serve as ducts. Cracks, old root cannels, and animal burrows may serve as large pores. Soils with insufficient functional macro porosity lose a great deal of rainfall and irrigation water as runoff. They drain slowly and often remain poorly aerated after wetting. One of the first effects of compaction is the reduction of the size and number of the larger pore spaces in the soil.

Small pores (diameter < 0.01 mm) are useful to hold water among soil particles. The capillary movement of water takes place through medium-sized pores (0.06-0.01 mm in diameter).
The porosity $P$ of dry soil is defined as $^6$

$$ P = 1 - \frac{\rho_s}{\rho_r} $$

where, $\rho_s$ = the density of dry soil, and

$\rho_r$ = the density of the associated solid rock.

The value of $\rho_s$ for the soil samples considered in this thesis lies in the range from 1.06 to 1.7 g / cm$^3$. The value of $\rho_r$ varies between 2.6 and 2.75 g / cm$^3$ and for simplicity its value assumed as 2.65 g / cm$^3$. The corresponding porosity value of the soil samples varies between 0.35 and 0.6.

3.4. **SOILS OF GUJARAT AND THEIR TEXTURE STRUCTURE:**

The geographical area of the Gujarat state (India) is 19.60 million hectore $^7,8$ and the reporting area is 18.82 million hectare. The forest area of the state is 1.88 million hectare. The barren and uncultivated land is 2.61 million hectare. The proportion of cultivable waste in Gujarat is 2.32 million hectare.

The agricultural production of land depends upon production capability of land, i.e. soil and its moisture conservation. The inherent saline/ alkaline land of about 1.20 million hectare is low in productivity. The coastal strip from Bhavnagar to Una and Malia to Lakhpat covering about 540 km of coastal length is facing grave situation of salinity in ground water due to ingress of sea water at the rate of 0.50 km per year. Nearly 100,000 hectare of fertile land has become unproductive.

This is partly due to poor recharge, accelerated withdrawal of ground water, poor drainage, and consequently, the increase of coastal saline areas. Nearly 270000 MCM water is withdrawn from ground water and only 20% of the total withdrawal is filled by natural recharge.

The 2.32 million hectare wasteland of the state is no man’s land.

The soils of Gujarat are broadly classified into 9 major groups shown in figure 3.3.
There are black soils, mixed red and black soils, residual sandy soils, alluvial soils, saline / alkali soils, lateritic soils, hilly soils, desert soils and forest soils.  

![Figure 3.3: The soils of Gujarat](image)

1. Black soils:  

   There are three types of black soils, namely (i) shallow, (ii) medium and (iii) deep.  

   (i) The shallow black soils:  

   The shallow black soils are developed from basaltic trap in Saurashtra region. These soils are mainly sandy clay loam in nature, and poor in fertility. Deccan trap in extreme eastern part and the remaining strips in Chhotaudepur and Saurashtra districts have developed from granite
and gneiss parent material. They are light gray in colour. In some places they are gravelly but mainly they are sandy clay loam in texture.

(ii) The medium black soils:
They are residual soils having basaltic trap parent material. They are found largely in Sabarkantha and Panchmahal districts, developed from the granite and gneiss parent material. They are calcareous in nature, and a layer of murram (unconsolidated material of decomposed trap and limestone) is found below a depth of about 40 cm, especially in Saurashtra region. The colour of these soils varies from dark grey to light grey, are silty loam to clay in texture, with neutral to alkaline in reaction.

(iii) The deep black soils:
These soils have their origin in trap. They are dominating in the districts of Bhavnagar, Surat, Valsad and South Vadodra. The depth varies from 60 cm to as high as a few meters. The tract of ‘Bhal’ comprising of area between Dhandhuka and Bhavnagar has typical deep black soils formed due to decomposition of trap parent material transported through flow of rivers radiating from the plateau of Central Saurashtra. The ‘Ghed’ tract of Junagadh district covering mainly talukas of Porebander, Kutiyana, Manavadar and part of Mangrol have deep black soils formed due to deposition of basaltic trap material transported by rivers. These soils are also impregnated with quite high amount of free line. The soils are dark brown to very dark grayish brown in colour, containing 40-70% clay, are poor in drainage and neutral to alkaline reaction. These soils are more fertile than other black soils.

2. Mixed Red and Black soils:
These soils are shallow in depth with reddish brown colour at higher elevations and grayish brown at lower elevations. These are clay loam to clay and skeletal in nature, with up to 50% stony material in
subsurface layer, providing ideal drainage conditions to these soils. These soils are highly calcareous in nature and alkaline in reaction.

3. Residual Sandy Soils:
These soils have developed in situ from the parent material originated from red sandstone and shale. These residual soils are shallow in depth, reddish brown in colour with fine weak granular structure, sandy to loamy sand in texture dominated by coarse sand. They are non-calcareous, neutral to alkaline in reaction with poor base saturation. In Kutch district, they are affected due to salt accumulation. These soils are also fertile.

4. Alluvial Soils:
These soils have been formed due to silting by the Indus river system. These soils are very deep, coarse sandy, and are found in Banaskantha and part of Mehsana due to deposition of coarse material from flowing rivers. The alluvial sandy loam to sandy clay loam cover, the entire northern districts of Banaskantha, Mehsana and bordering Sabarkantha. These are non-calcareous, neutral to alkaline in reaction.

The alluvial sandy loam to sandy clay loam are found in Kheda and Gandhinagar districts, eastern part of Ahmedabad district, southern part of Mehasana and western part of Vadodra district.

The coastal alluvial soils are sandy clay loam to clay in texture, neutral to highly alkaline in reaction, and have medium fertility.

5. Laterites:
In the Dangs district, due to abundant forest vegetation and high annual rain fall laterities are developed. They are yellowish red in upper horizon, with thickness ranging from 20-40 cm. These are neutral to slightly acidic in reaction.
6. Hill soils:
   These soils occur in the hilly areas of Surendranagar, Amreli, Jamnagar, Bhavnagar and Junagadh districts of Saurashtra, Kuttch and eastern strip of mainland Gujarat. They are shallow in depth, composed of undecomposed rock fragments and are poor in fertility.

7. Desert Soils:
   The two ranns (deserts) of Kuttch, viz. little runn and greater runn, have these soils formed as a result of geological process of Pleistocene age in Indogangetic depression. They are fairly deep, light gray in colour, sandy to sandy loam, with silty clay loam texture in some areas. The salt content in these soils is very high with NaCl as the dominant salt.

8. Forest Soils:
   The soils of Junagadh forest contain more sand and are neutral. The soils of Dangs forest have higher silt fraction and are acidic. Organic matter and lime contents are high in Junagadh soils compared to Dangs soils.

9. Saline soils:
   Salt affected soils occur in majority of soil groups identified in the state. The major areas affected are due to the desert soils in Kuttch and those affected along the sea coast due to ingress of sea water. The Bhal tract is the area with flat topography formed due to the Alluvial deposits brought by the rivers like Narmada, Mahi, Sabarmati, and Bhogavo flowing in to the gulf of Cambey. The rivers Bhadar, Ozat, Minsar, Madhuvanti etc. have formed a delta which is known as Ghed. Water loagging for a long time has created saline conditions.

To determine the dielectric properties of soils at radio and microwave frequencies soil samples were collected from different regions of Gujarat state having different soil texture. Referring to the soil map of Gujarat 5, 6 (Figure 3.3), the soil samples were taken from the Sabarmati river bed at Ahmedabad, field at Amiapur (Gandhinagar
district), field at Kheralu (Palanpur district), field Jamnagar dist., field at Navsari (Valsad district), Amreli district and field at Sayla (called Bhagat nu gaam) (Surendranagar district) as well as from the sea bed near the Somnath temple (Veraval).

The texture analysis was done by the KBM Engineering Company, Ahmedabad. The texture analysis of these soil samples is listed in table 3.2. According to this table the soils were mainly sand, sandy loam, silt loam and silty clay loam. The photograph of the soil samples is shown in the figure 3.4.

**Table 3.2:- The texture structure of soil samples.**

<table>
<thead>
<tr>
<th>Location (Region)</th>
<th>Soil texture (%) of Soil</th>
<th>Soil type</th>
<th>Density of Dry Soil g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sand</td>
<td>Silt</td>
<td>Clay</td>
</tr>
<tr>
<td>Sabarmati River Sea bed</td>
<td>96</td>
<td>3.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Sabarmati River Bed, Ahmedabad</td>
<td>93</td>
<td>6.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Palanpur dist.</td>
<td>82</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Surendranagar dist. (Sayla)</td>
<td>69</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>Gandhinagar Dist.</td>
<td>65</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>Amreli Dist.</td>
<td>11</td>
<td>78</td>
<td>11</td>
</tr>
<tr>
<td>Valsad Dist.</td>
<td>7</td>
<td>62</td>
<td>31</td>
</tr>
<tr>
<td>Jamnagar Dist.</td>
<td>12</td>
<td>50</td>
<td>38</td>
</tr>
</tbody>
</table>
Figure 3.4: Soil samples Collected from different locations of Gujarat State, India

- Gandhinagar District, Sandy Loam Soil
- Sabarmati River bed Sand, Ahmedabad
- Somnath Sea bed, Sand
- Surendranagar District, Sandy Loam
- Gandhinagar District, Sandy Loam
- Valsad District, Silty Clay Loam
- Amreli District, Silt Loam Soil
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1. Environmental quality lab manual draft, Agriculture and Biological Engineering Department, Prude University, Soil Properties, September 15 (2003).


7. Joshi Sujan, Agriculture in Gujarat, Progress and Potential, Helios Enprint Ltd.