FORMATION OF SOIL-PROCESS & FACTOR OF SOIL FORMATION

INTRODUCTION

Soil formation is also termed as pedogenesis, which is the combined effect of physical, chemical, biological and anthropogenic processes working on soil parent material. Basically soil formation is the result of weathering of rocks and minerals. Though it is a slow process and needs hundreds of years.

FACTORS OF SOIL FORMATION

Five main interacting factors affect the formation of soil:

Parent Material– The parent material is chemically and physically weathered, transported, deposited and precipitated, and then transformed into a soil. The typical soil parent mineral materials are Quartz(SiO_2), Calcite ($CaCO_3$), Feldspar ($KAlSi_3O_8$), Mica $\{K(Mg,Fe)_3AlSi_3O_{10}(OH)_2\}$. The types of parent materials and the conditions under which they break down will influence the properties of the soil formed. Parent materials are classified according to how they came to be deposited.

Residual parent materials– are remained at same place for a longer time and soil formation takes long time from such parent materials e.g. igneous rock, Sedimentary rock and metamorphic rocks.

Transported parent material– are those that have been deposited by water, wind, ice or gravity

Every soil "inherits" traits from the parent material from which it formed. For example, soils that form from limestone are rich in calcium and soils that form from materials at the bottom of lakes are high in clay. Every soil formed from parent material deposited at the Earth's surface. The material could have been bedrock that weathered in place or smaller materials carried by flooding rivers, moving glaciers, or blowing winds. Parent material is changed through biological, chemical and environmental processes, such as weathering and erosion

Relief or Topography– This is characterized by the slope, elevation, and orientation of the terrain. Topography determines the rate of precipitation or runoff and rate of formation or erosion of the surface soil profile.

The shape of the land and the direction it faces make a difference in how much sunlight the soils gets and how much water it keeps. Deeper soils form at the bottom of a hill because gravity and water move soil particles down the slope.

Climate– It includes precipitation, temperature, humidity and wind in which rainfall and temperature are most important factors. These influence chemical, physical, and biological processes. Climate is the dominant factor in soil formation, and soils show the distinctive characteristics of the climate zones in which they form, with a feedback to climate through transfer of carbon stocked in soil horizons back to the atmosphere. Soil properties affected by climatic conditions include the nature and composition of clay. Temperature affects the rate of weathering. With a colder and drier climate, these processes can be slow but, with heat and moisture, they are relatively rapid. Evaporation, transpiration and humidity modify the effect of precipitation by reducing or increasing the quantity of water. In scanty rainfall areas, salts are accumulated on soil surface while, in high rainfall areas, salts are leached out into lower horizons thus soil becomes acidic.
Temperature and moisture influence the speed of chemical reactions, which in turn help control how fast rocks weather. Soils develop faster in warm, moist climates and slowest in cold or arid ones.

Organisms– Flora (plants, microorganisms, forest and grasses) play active role in soil formation.

In the same way, plant roots penetrate soil horizons and open channels upon decomposition. Humans impact soil formation by removing vegetation cover with erosion, waterlogging etc. Tillage also mixes the different soil layers, restarting the soil formation process as less weathered material is mixed with the more developed upper layers, resulting increased rate of mineral weathering.

Plants root, animals burrow, and bacteria eat – these and other organisms speed up the breakdown of large soil particles into smaller ones. For instance, roots produce carbon dioxide that mixes with water and forms an acid that wears away rock.

Time- Soil properties may vary depending on how long the soil has been weathered. It is a factor in the interactions of all the above. It has no relevance after the soil reaches its maturity that is why it is a neutral factor.

All of these factors work together over time. Older soils differ from younger soils because they have had longer to develop. As soil ages, it starts to look different from its parent material. That is because soil is dynamic. Its components—minerals, water, air — constantly change. Components are added and lost. Some move from place to place within the soil. And some components are totally changed, or transformed.

Weathering

The weathering of parent material takes the form of physical weathering (disintegration), chemical weathering (decomposition) and chemical transformation. Weathering is usually confined to the top few meters of geologic material, because physical, chemical, and biological stresses and fluctuations generally decrease with depth. Physical disintegration begins as rocks that have solidified deep in the Earth are exposed to lower pressure near the surface and swell and become mechanically unstable. Chemical decomposition is a function of mineral solubility, the rate of which doubles with each 10 °C rise in temperature, but is strongly dependent on water to effect chemical changes. Rocks that will decompose in a few years in tropical climates may remain unaltered for millennia in deserts. Structural changes are the result of hydration, oxidation, and reduction. Chemical weathering mainly results from the excretion of organic acids and chelating compounds by bacteria and fungi, thought to increase under present-day greenhouse effect.

Physical disintegration is the first stage in the transformation of parent material into soil. Temperature fluctuations cause expansion and contraction of the rock, splitting it along lines of weakness. Water may then enter the cracks and freeze and cause the physical splitting of material along a path toward the center of the rock, while temperature gradients within the rock can cause exfoliation of "shells". Cycles of wetting and drying cause soil particles to be abraded to a finer size, as does the physical rubbing of material as it is moved by wind, water, and gravity. Water can deposit within rocks minerals that expand upon drying, thereby stressing the rock. Finally, organisms reduce parent material in size and create crevices and pores through the mechanical action of plant roots and the digging activity of animals.

Chemical decomposition and structural changes result when minerals are made soluble by water or are changed in structure. The first three of the following list are solubility changes and the last three are structural changes.

The solution of salts in water results from the action of bipolar water molecules on ionic salt compounds producing a solution of ions and water, removing those minerals and reducing the rock's integrity, at a rate depending on water flow and pore channels.

Hydrolysis is the transformation of minerals into polar molecules by the splitting of intervening water. This results in soluble acid-base pairs. For example, the hydrolysis of orthoclase-feldspar transforms it to acid silicate clay and basic potassium hydroxide, both of which are more soluble.

In carbonation, the solution of carbon dioxide in water forms carbonic acid. Carbonic acid will transform calcite into more soluble calcium bicarbonate.

Hydration is the inclusion of water in a mineral structure, causing it to swell and leaving it stressed and easily decomposed.

Oxidation of a mineral compound is the inclusion of oxygen in a mineral, causing it to increase its oxidation number and swell due to the relatively large size of oxygen, leaving it stressed and more easily attacked by water (hydrolysis) or carbonic acid (carbonation).

Reduction, the opposite of oxidation, means the removal of oxygen, hence the oxidation number of some part of the mineral is reduced, which occurs when oxygen is scarce. The reduction of minerals leaves them electrically unstable, more soluble and internally stressed and easily decomposed. It mainly occurs in waterlogged conditions.

Of the above, hydrolysis and carbonation are the most effective, in particular in regions of high rainfall, temperature and physical erosion. Chemical weathering becomes more effective as the surface area of the rock increases, thus is favoured by physical disintegration.