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M.Sc. Geo-informatics/DGIS for Science Learners

APPLICATIONS OF GEOINFORMATICS PART-I

DEPARTMENT OF REMOTE SENSING AND GIS

SCHOOL OF EARTH AND ENVIRONMENT SCIENCE

UTTARAKHAND OPEN UNIVERSITY

HALDWANI (NAINITAL)

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CONTENTS

BLOCK 1: APPLICATION OF GEOINFORMATICS IN SOILS

UNIT 1 - FUNDAMENTALS CONCEPT OF SOILS, SPECTRAL CHARACTERISTICS OF SOILS

1.1 OBJECTIVES

After studying this unit, you should be able to:

- Acquire an understanding of the basic concept and fundamentals of soil and recognize the soil's components.
- Attain knowledge of soil formation's basic concepts, factors affecting soil formation, soil structure, soil nutrients, profile and horizons of the soil.
- Discuss the method to analyze soil characteristics and classify the soil based on their characters.
- Get knowledge about the uses of remote sensing and hyperspectral images to interpret the minerals and organic matter of the soil.
- Describe the soil spectral library, reflectance intensity of the curves, principal component analysis, quantification models of soil properties.

Several acronyms have been used throughout the self-learning material, listed at the end of each block for your ready reference.

After studying this course, we hope that you will acquire a basic understanding of the class, or possible classes, of an unknown soil based on spectral information and fundamental concepts of soil.

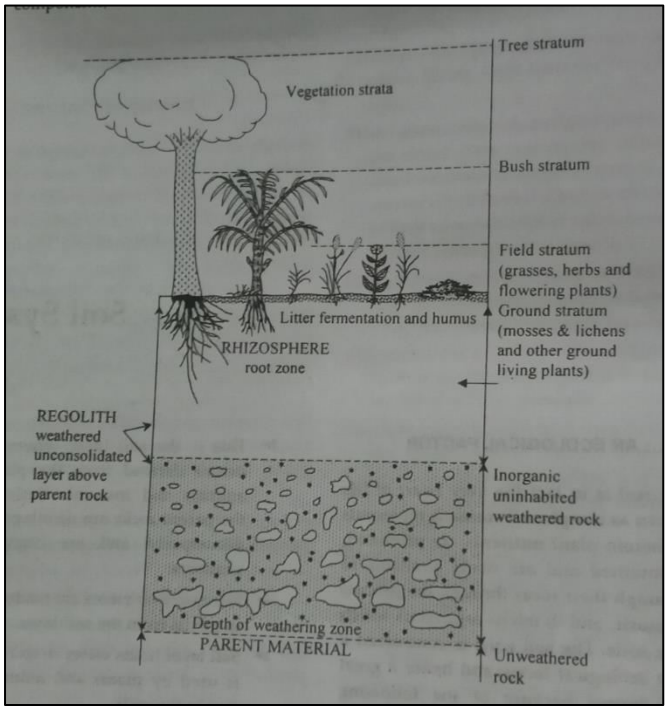
1.2 INTRODUCTION

You know that the soil is, in fact, the very heart of the life layer known as the biosphere because it represents a zone wherein plant nutrients are produced, held, maintained and are made available to plants through their roots through the process of root osmosis, and to micro-organism which lives in the soils. The soil zone is considered a significant ecological factor and hence a tremendous biological factory because of the following reasons:

- The soil layer functions as a medium for energy and matter transfer paths and helps in the biological cycling of nutrients.
- Excellent varieties of organic compounds are generated in the soil layers.
- The soil layer provides habitats and ideal environmental conditions for living organisms of several varieties and numerous species.
- This is the soil layer where organic matter derived from the parent rocks is disintegrated, decomposed, and changed into elements.
- Necessary nutrients are made available to plants and animals which live in the soils.
- Soil is a fundamental medium for food and timber production to human society.
- It is a vital natural exhaustible resource because it cannot be replaced if destroyed or lost through soil erosion caused by anthropogenic activities.

The soil system is the product of environmental and biological processes and is interrelated with climate, vegetation, animals, underlying rocks, topography, and time, affecting the biosphere. The comprehensive study of the soil system in terms of its components, classification, formation processes, and evolution through time is vital because it is an integral part of the biogeography system.

Fig. 1.0 Vertical section through the vegetation and soil system



(Source: P.A Furley and W.W Newey)

The proper soil application in agriculture necessitates a thorough grasp of its chemical, physical, mineralogical, and biological properties. Soil science has worked to create procedures that can assist in describing soil types more accurately. Much recent research has focused on using remote sensing techniques, primarily because these techniques have been proven to produce faster and less expensive characterizations, earning them scientific legitimacy. Remote sensing techniques were first used in soil research in the 1960s and have since grown to include rapid and nondestructive quantification of soil properties, mineralogical measurements, digital soil mapping, precision agriculture, and heavy metal quantification. As a result, constructing a spectral database, or Spectral Library, is a prerequisite for their successful application.

According to Brown et al. (2006), soil reflectance in the visible and near-infrared ranges is a function of soil composition, including organic matter, primary minerals, clay minerals, salts, and partially crystallized elements. These components serve as the foundation for soil management interpretations and are the primary aspects of the North American classification system classes.

Dunn et al. (2002) stated that for spectroscopic techniques to be commercially viable, a wide range of data from various soil types with varying organic and inorganic components must be available. Although current spectrum libraries provide geological spectral curves of soils (Clark, 1999), Shepherd & Walsh (2002) found few examples of spectral libraries containing a wide variety of soils and their physical-chemical information.

According to Viscarra-Rossel et al. (2008), multiple studies on spectral libraries have been published, including those by Dunn et al. (2002), Shepherd & Walsh (2002), and Brown et al. (2008). (2006). There are three essential prerequisites, according to these authors, for establishing a soil spectral library: (a) Samples must be carefully sub-sampled, handled, prepared, stored, and scanned (anything that happens to the sample will affect its spectral curve); (b) samples must be carefully sub-sampled, handled, prepared, stored, and scanned (anything that happens to the sample will affect its spectral curve); (c) samples must be carefully sub-sampled, handled, prepared, stored, and scanned (anything that happens to the sample will affect its spectral curve); and (d) the analytical reference data from the samples that will be utilized in calibrations must be obtained using well-known and reliable analytical processes.

With this brief introductory note on fundamental concepts of soil, spectral characteristics of soils, we further proceed to apprise you of varied soil components.

1.3 FUNDAMENTALS CONCEPT OF SOILS, SPECTRAL CHARACTERISTICS OF SOILS

Now we are discussing the basic idea of soil.

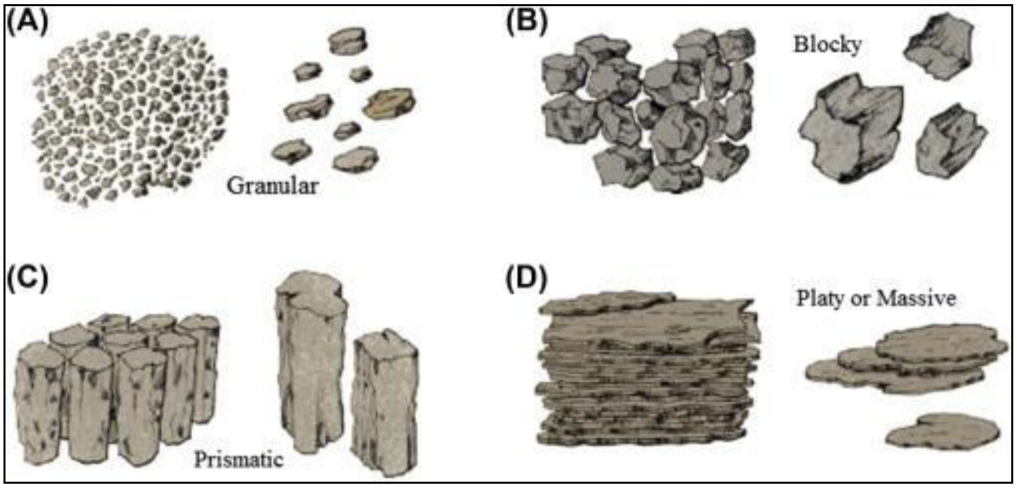
Soil Structure

The aggregation of individual soil particles in the form of lumps of the cluster is called soil structure. A particular soil may have several structures wherein the aggregates or groups of soil particles are separated by natural surfaces of weakness, i.e. cracks. The soil structure is in the physical property of the soil and is thus very agricultural practices because (i) the structural units of the soil indicates the air and water holding capacity of the soils; (ii) soil structure reflects the mineral, and organic contents of the soils, (iii) soil structure determines the nature and lateral movement of water in the soil, (iv) soil structure determines the susceptibility of soil erosion,(v) the ease of cultivation and the capability of the soil for plant growth and management are determined by the soil structures etc.

An individual natural aggregate of soil particles is called a ped, whereas a total of soil particles resulting from the breakage during ploughing of the soils is called a clad. The shape, size and durability in terms of hardness or stability of peds are essential properties of the soil structure. Peds are generally classified into four types based on shape, e.g. (i) platy,(ii) prismatic,(iii) blocky and angular and (iv) spherical or granular. In platy soil structure, peds are composed of plates or thin flat pies arranged horizontally. The prismatic soil structure represents the vertical columnar position of peds. The peds in blocky soil structure are angular in shape and of equal dimension, whereas the peds are more or less rounded in the spherical soil structure.

The peds and even individual coarse mineral grains have the coatings of surface films of materials. Such layers are called cutons. For example, a ped may be coated with clay. This is called cutons caly. The other cutons include coatings of oxides of iron, oxides of manganese on mineral grains and films of organic matter surrounding a ped.

Fig.1.1 Structure of the soil



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Soil profile and horizons

Soil is a display of vertical sections from the ground surface down to the parent rocks. Thus a soil profile denotes the vertical distribution of soil components. The following common properties characterize the soil profile.

(i) On average, there is a gradual decrease in organic matter, the number of living organisms, the activity of living organisms, etc. With increasing depth in the soil profile.

(ii) The level of aeration of soil decreases from the surface downwards in the soil profile.

(iii) There is increasing in the number and variety of parent minerals from the surface downward in the soil profile up to the base of parent rocks.

(iv) There is no definite trend of either increase or decrease in the content of soil water depth because there is a lot of fluctuation in water content. The content of soil water is determined by (i) the location of groundwater,(ii) nature of the movement of groundwater, (iii) frequency and amount of rainfall, (iv) absorptive characteristics of different horizons of the soil profile.

Different soil horizons of a given soil profile with distinctive characteristics are developed due to the action and interactions of a climate, vegetation, animals, and reliefs of a particular area over a long time.

Sometimes the boundaries of a horizon (both upper and lower) are observable and are well defined. In other words, one horizon may be easily differentiated from the further horizon of a soil profile. But sometimes, the changes of a soil property with depth are so slow and gradual that the boundaries of different soil profile horizons are not well marked.

The soil horizons of soil profiles are divided into broad categories, e.g. (i) organic horizons and (ii) mineral horizons.

(i) Organic horizons are the topmost layers of a soil profile, and these contain organic matter, whether dead or alive. These horizons are designated by the capital letter O. These layers are due to the accumulation of organic matter from plants and animals. The organic or O horizon is further subdivided into two layers, e.g. O_1 and O_2 horizon. O_1 horizon is the uppermost layer of the organic horizon and consists of the original form of vegetative matter as fresh litter and partly decomposed or comminuted litter (also called litter layer and distinguished by L for new litter F for partly decomposed litter). Just below the O_1 horizon lies the O_2 horizon, characterized by the altered remains of the plants and animals. The plants and animals are so significantly changed through decomposition and comminution that the original form is beyond recognition without the help of a microscope. The decomposed organic matter of the O_2 horizon is called humus, and the process of humus formation and, therefore, of the development of the O_2 horizon is called humification.

(ii) Mineral horizons contain inorganic minerals of two types, e.g. (i) skeletal minerals (e.g. quartz) and (ii) clay minerals. Besides, the upper layer of mineral horizons also contains a limited amount of organic matter. There is significant variation even within the mineral horizons. Therefore at least three layers are identified within the mineral horizons. These layers/horizons are designated by capital letters A, B and C. Even within A, B and C horizons; there are significant variations. Therefore, various subdivisions are recognized within each mineral horizon. These subdivisions or sub horizons are named by adding numerals with the horizon letters ee. g. A_1, A_2.........B_1, B_2…. etc. It may be pointed that the properties of A and B horizons of soil profiles vary from one type of soil to the other type and from one climatic region to the other region. The following are the common characteristics of different horizons of mineral horizons of the soil profile.

A_1 – These horizons below the O horizon of organic matter are formed at or near the soil surface, characterized by a mixed zone of minerals and organic matter and more biological activity. The horizon is of dark colour.

A_2 – This is the light coloured horizon characterized by maximum eluviations (movement) of silicate clays, oxides of iron and aluminium etc.

A_3 – Transitional to B, but this zone is more like A than B. It is not always present in all soil profiles.

B_1 – Transitional to A but more like B than A. It is not always present in all soil profiles.

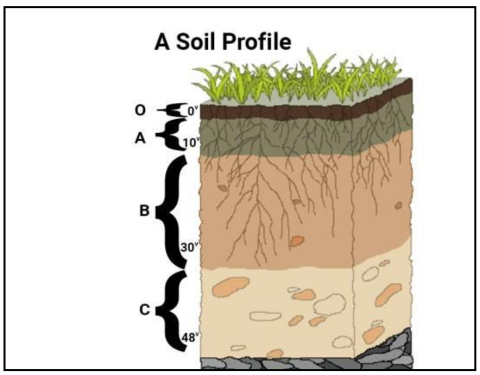
B_2 – This horizon is characterized by maximum illuviation (accumulation) of silicate collate clay minerals or sesquioxides (R_2O_3) (Fe_2O_3+Al_2O_3+MnO_2+P_2O_5) and organic matter.

B_3- Transitional to C but more like B than C. This zone may be present or may be absent.

C- C horizon represents weathered parent materials (called regoliths) which are unconsolidated or weakly consolidated. This horizon is also called the subsurface horizon but lacks the properties of the A_2, A_3, B_2 horizon and retains the characteristics of the structure of the basal parent rocks. This is also called as glay layer.

D or R – D or R layer represents the layer of consolidated hard bedrocks beneath the soils.

Fig. 1.2 Soil profile



(Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.toppr.com%2Fask%2Fcontent%2Fstory%2Famp%2Fsoil-profile-61910%2F&psig=AOvVaw3LtUQYDnybCcoGFFDO1A0L&ust=1634302966431000&source=images&cd=vfe&ved=2ahUKEwiDubaP-8nzAhWe0HMBHaqdBFEQr4kDegUIARCwAg)

It may be pointed out that there are variations within a single sub horizon (e.g. A_1, A_2, B_1, B_2, etc.) due to varying characteristics of sol components. Thus, lowercase letters are added to the capital letters meant for designating major horizons (e.g. A or B) to reveal particular and unique properties of specific soil horizons.

The soil is a dynamic layer of loose end unconsolidated materials because many physical, chemical and biological activities and processes operate simultaneously in the soil layer or profile. There is much variation in the soil-forming processes, ranging from individual, small-scale and rapid events (like exchange of ions) to large-scale complex events and processes that operate very slowly. The formation of the soils in a particular region is the result of i) soil-forming processes and ii) the factors that affect the formation and development of soils.

Soil Forming Processes

The events and processes, whether physical, chemical or biological, which help form soils in a given region are called pedogenic processes or soil-forming processes, classified into four groups. The formation of earth is, in fact, the result of the proportions of these processes over a definite time. The following are soil-forming processes:

- Soil enrichment
- Loss of materials from the soils
- Translocation of materials
- Transformation of materials

Translocations

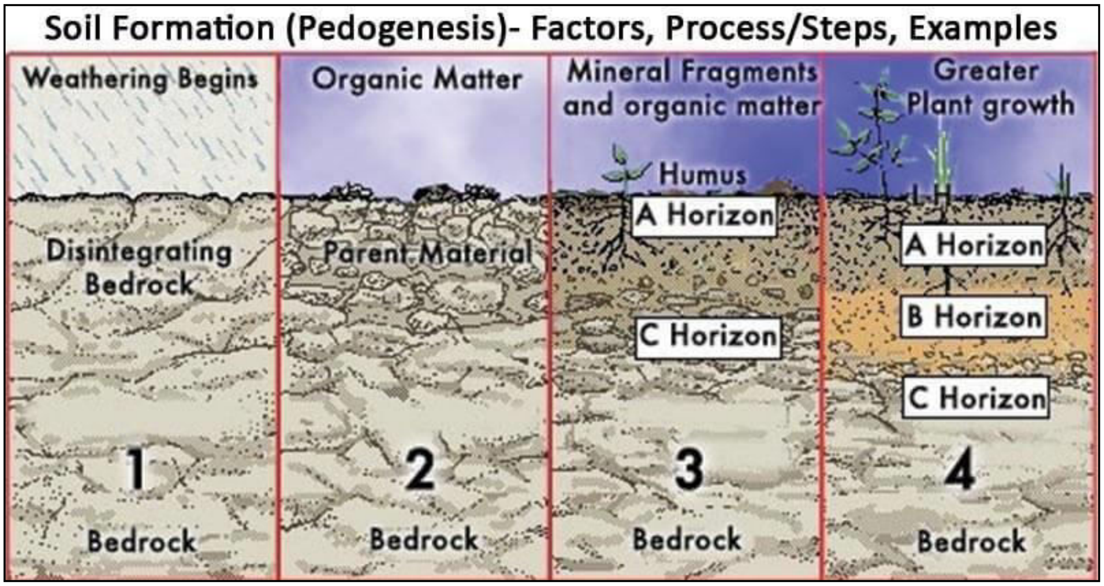
1. **Illuviation:** movement of materials from A horizon and accumulation in B horizon.
2. **Capillary action:** upward movements of dissolved or suspended matter by groundwater.
3. **Upward movements:** of matter by organisms, e.g. earthworms, termites etc.
4. **Melanization:** darkening of the colour of a section of soil profile through organic matter.
5. **Leucinization** (decolouration)**:** lightening the colour of a section of the soil profile, mainly A horizon.
6. **Compaction:** physical reduction of the air content.
7. **Induration:** hardening a section of the soil profile such as kankar pan, iron pan (ferricrete), calcrete, alcrete, silcrete etc.

Transformations

1. **Audification:** accumulation of H ions, mainly in the surface horizon (epipedons)
2. **Neutralization:** counteraction of H ions
3. **Oxidation:** formation of iron oxides
4. **Reduction:** loss of oxygen ions
5. **Solution:** dissolution soluble mineral into solution, e.g. calcium carbonate into bicarbonate
6. **Precipitation:** deposition of dissolved substances in solid form from solution
7. **Hydration:** swelling of minerals through the absorption of water resulting in the formation of new compounds
8. **Dehydration:** loss of water resulting in the return of the mixture to its original form
9. **Hydrolysis:** replacement of cations in a mineral structure by hydrogen ions from the soil solution
10. **Decomposition:** breakdown of mineral and organic materials through biochemical processes
11. **Humification:** formation of humus from original organic materials

12. **Mineralization:** release of minerals in various forms during the process of decomposition f organic matter

Fig. 1.3 Formation of soil



(**Source:**https://www.google.com/url?sa=i&url=https%3A%2F%2Fmicrobenotes.com%2Fsoil-formation pedogenesis%2F&psig=AOvVaw3tVEYU9Ohns5gNpQ0ilkb0 &ust= 163 430 3154735000&source=images&cd=vfe&ved=2ahUKEwjp0Jvp8nzAhUjlEsFHdzhDsIQr4kDegUIARDFAQ)

Soil Classification: The soil of the world has been classified in various ways on different bases. Russian scientists took the initial lead in the development of pedology and the classification of soils. The Russian geologist, V.V Dokuchaiev, related the story of soil to the climate and vegetation of a given region. Thus the Russian scientists based their classifications of soils on the association of soil types with the climatic and vegetation zones in the early twentieth century; G.F Marbut, a U.S. scientist, presented a scheme of a comprehensive system of soil classification 1938, which is recognized as U.S.D.A. (United States Department of Agriculture) system. According to this system, soils at the global level were divided into three orders, e.g. (i) zonal soils, (ii) intrazonal soils, and (iii) azonal soil. The American pedologist presented a new soil classification system named the Comprehensive Soil Classification System (C.S.C.S.) in 1960. This system was initially called the Seventh Approximation because it was seventh in the series of revisions of the system of soil classifications since 1950. The classification system of the C.S.C.S. is also called soil taxonomy. The other significant soil classification at the global level include the schemes of American Soil Taxonomy presented by the Soil Survey Staff in 1975, Soil Type based on bioclimatic zones as presented by E. Bridges in 1978, Soil Orders delivered by H.D Forth in1978, Soil Classification based on diagnostic horizons developed by F.A.O. and UNESCO etc.

There are almost as many classifications and distributions of soils as there are soil scientists. The soil has been classified at global, regional and local levels on various bases, e.g. age of the soils, zonality of the soil distribution, bioclimatic zonation, the character of soil horizons, physical properties of dirt, and associated processes chemical and related processes, biochemical properties. A few schemes of the classifications of world soils are discussed below :

(1) U.S. Department of Agriculture System of Soil classification (U.S.D.A.) has divided the world soils into the following three broad categories:

- Zonal soil
- Intrazonal Soil
- Azonal soil.

Zonal Soils: Zonal Soil represents fully matured soils that have developed under the conditions of good soil drainage. These are the result of the interplay of climate and vegetation over a long period. Zonal soils are characterized by the full development of almost all soil horizons; their number and characteristics may vary according to local conditions and degree of human interference. Within the zonal Order of soils, there are six suborders and 21 great soil groups as follows :

Suborder	Great Soil Groups
1. Soils of the cold zone	1. Tundra soils
2. Light-coloured soils of arid regions	2. Deserts soils 3. Red desert soils 4. Sierozen 5. Brown soils 6. Reddish brown soil
3. Dark coloured soils of the semiarid, subhumid and humid grasslands	7. Chestnut soil 8. Reddish chestnut soils 9. Chernozem soils 10. Prairie soils 11. Reddish prairie soils
4. Soils of the forest grassland transition	12. Deratded chernozem soils 13. Non-calcic brown or shantung brown soils
5. Light-coloured podzolized soils of forested regions	14. Podzol soils 15. Brown podzolic soils 16. Gray-brown podzolic soils
6. Lateritic soils of forested subtropical and tropical regions	17. Yellow podzolic soils 18. Red podzolic soils 19. Yellowish browns laterite soil 20. Reddish-brown lateritic soils 21. Laterite soils

Intra-zonal soils: Intra-zonal soils are formed in those areas where there is water-logging, and therefore there is inferior drainage, regolith is endowed with high content of calcium carbonate, and there is high content of soluble salts and sodium. These soils are divided into two suborders and 12 great soils groups as follows :

Suborders	Great Soil Groups
1. Halomophric soils of imperfectly drained arid regions and litoral deposits	1. Solonchak or saline soils 2. solonetz soils 3. Soloth soils
2. Hydromorphic soils of marshes, swamps, seep areas and flats	4. Meadow soils 5. Alpine meadow soils 6. Bog soils 7. Half bog soils 8. Planosols 9. Groundwaterpodzol soil 10. Groundwater lateritic soils
3. Calomorphic soils	11. Brown forest soils 12. Redzina soils

Azonal Soils: Azonal soils do not have well-developed soil horizons. Instead, there is uniformity in the soils from the top surface to the base. There may be a variety of reasons for the non-development of soil horizon in azonal soil, e.g. (1)lack of sufficient time, (2) steep slopy terrain, (3) renewal of soils every year because of deposition of new materials as in the case of flood plains etc.

The U.S.D.A. System of Soil Classification (1938) was revised in the 1940s because this system was considered by many soils scientists as inadequate. After all, (1) this classification was primarily based on the American experience and examples (2) there was a flood of new information soils due to researches carried out at regional and local levels in the parts of the globe (3) the system could not correctly accommodate and represent the soils of the tropical regions (4) the classification based on assumption between the properties of soils and the roles of climate (5) the lack of precision in definitions (6) more emphasis on undisturbed or virgin soils etc.

Comprehensive soil classification system (CSS), 1975

The U.S.D.A. System of Soil classification (1938) was revised in the 1940s because many soil scientists considered this system inadequate. After all, (1) this classification was primarily based on the American experience and examples; (2) there was a flood of new information on soils due to researches carried out at regional and local levels in the different parts of the globes ; (3) the system could not correctly accommodate and represent the soils of the tropical regions ; (4) the classification was based on assumptions and hypotheses regarding the relationships between the properties of soils and roles of climate ; (5) the lack of precision in definitions ; (6) more emphasis on undistributed or virgin soils etc.

Comprehensive Soil Classification System (C.S.C.S.), 1975

The Soil Survey Staff of the U.S. Soil Conservation Service prepared an exhaustive but scientific scheme of classifying the world soils in 1975. The scheme is known as the Comprehensive Soil Classification System (C.S.C.S.), also called Soil Taxonomy. The C.S.C.S. of soils classification is based on a hierarchy of 6 categories or levels of type.

Levels	Categories (from higher to lower)	Number of soil classes recognized so far
1	Orders	10
2	Suborders	50
3	Great Soil Groups	225
4	Subgroups	1000 (only in the U.S.A.)
5	Families	5000 (only in the U.S.A.)
6	Series	10,000 (only in the U.S.A.)

It may be pointed out that the recognized number of the first three categories of soils (e.g. Orders, Sub- orders and Great groups) may remain almost the same because they include the numbers of the last three categories (e.g. Subgroups, Families and Series) are subject to phenomenal increase if the researches of soil studies at continental, regional and local levels advance and the soils of all the continents are known and are included in the classification.

Order and Suborders of Soils: The world's soils have been classified by the C.S.C.S. into ten rankings of the highest category based on the characteristics of diagnostic horizons of the soil profiles.

The soils at the global level have been grouped into ten orders representing the highest category of the hierarchy of soil classification. The soil orders have been based on the following criteria :

- gross composition of the soils in terms of organic matter or minerals or even both.
- Degree of the development of soil horizons in the soil profiles.
- Presence or absence of diagnostic horizons.
- Degree of weathering of the soil minerals.

Orders of Soils

1. entisols
2. inceptisols
3. histosols
4. oxisols
5. alltisols
6. vertisols
7. alfisols
8. spodosols
9. molisols
10. aridosols

Spectral classification of soils

Now we are discussing the implementation of remote sensing to classify soil**.** As you know, remote sensing and image analysis are very dynamic and effective processes to determine soil characteristics. Many soil scientists are working on it. In this context, we also discuss their contribution.

The presence or absence and the position and shape of specific absorption characteristics on the surface provide spectral reflectance signatures. Soils are complex mixes of mineral and organic elements with spectral fingerprints distinct from those of vegetation. Iron and organic matter concentration and moisture and salt content are the most critical elements affecting the shape of soil spectral fingerprints.

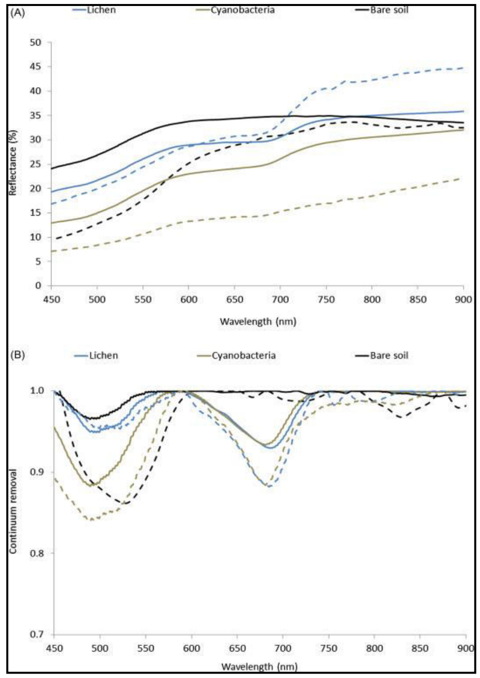
Stoner and Baumgardner (1981) used the spectral range of 0.50 to 2.5 mm to evaluate a vast geographic span of soils (485 soils) and discovered five different soil spectral signatures principally connected to their organic matter and iron oxide levels and influenced by their textures. Because of iron oxide absorptions at shorter wavelengths, soil reflectances tend to increase from 0.4 to 1 mm with an increasing wavelength. Much research has also demonstrated the correlations between soil colour and remotely sensed optical measurements, allowing for integrating widely available soil colour information with remote sensing data—several spectral absorptions caused by the presence of photosynthetic pigments and sunscreen products exuded by biocrusts.

According to Weber and Hill (2016), it resulted in a decrease in reflectivity in the visible region of the spectra (Karnieli and Tsoar 1995; Rodrguez-Caballero et al., 2015b), which was combined with increased surface emissivity at longer wavelengths (Rozenstein and Karnieli, 2015). O'Neill (1994) performed the first extensive spectral analysis of biocrust-covered soils, analyzing various forms of biocrusts from Australia and identifying a standard spectral absorption signature at 675 nm, which was linked to the presence of chlorophyll-a. Several authors later described this absorption in places worldwide covered by various forms of biological soil crusts (Chen et al., 2005; Weber et al., 2008; Chamizo et al., 2012; Casanovas et al., 2015; Fang et al., 2015).

Differences in soil characteristics, such as soil Fe3+ content, which created deeper absorption at a wavelength close to carotenoids (Weber et al., 2008), appear to have a more significant impact on the results reported by Chamizo et al. (2012) than differences in biocrust spectral response. As shown in Fig. 1.4, similar biocrust communities from different regions show similar spectral reactions that differ from the spectral responses of other biocrust types and mask soil spectral properties. Cyanobacteria lower surface albedo and display another important absorption pattern at 500 nm, whereas white lichen-dominated biocrusts show high reflectance values in the VIS-NIR sections of the spectra and an important absorption feature at 675 nm (chlorophyll-a absorption) (carotenoids absorption). On the other hand, Biocrust communities rarely reach 100% coverage (Weber et al., 2015). The spectral response of bare soil covering the open spaces between biocrust forming organisms also affects the final spectral response of biocrust dominated areas, increasing importance as biocrust coverage declines. The bare ground from the Tabernas Badlands had higher reflectance in the VIS-NIR regions of the Spectrum than the soil from Las Amoladeras. In contrast, the lichen and cyanobacteria biocrust from Tabernas had better albedo than the lichen and cyanobacteria biocrust from Las Amoladeras (Fig. 1.4).

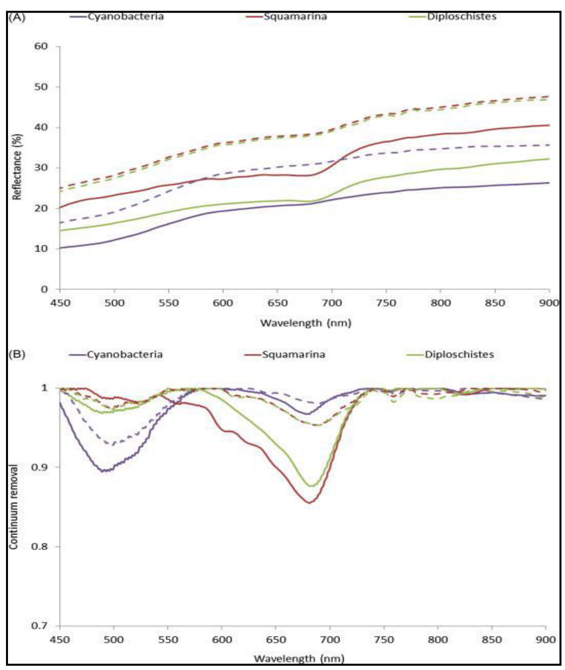
Furthermore, the spectral absorption of bare soils from Las Amoladeras, where soils have a high Fe3+ content, interacts with carotenoids absorption, resulting in deeper absorption of about 500 nm in cyanobacteria-dominated biocrust than is seen in the same biocrust community at Tabernas Badlands, as well as a displacement of spectral absorption to longer wavelengths. Furthermore, when biocrusts are active, their spectral characteristics change rapidly after rainfall or dew episodes. Surface reflectance of diverse biocrust communities dropped from dry to wet, as shown in Fig. 1.5, whereas spectral absorptions increased. The sensitivity of biocrust spectral characteristics to water availability differs between biocrust communities. When cyanobacteria-dominated biocrusts were moist, there was a significant rise in spectral absorption about 500 nm, but this was essentially non-existent in lichen-dominated biocrusts, which showed considerable changes at 670 nm (Fig. 1.5).

Fig. 1.4 Spectral signature (A) and continuum removal (B) of bare soil, lichen- and cyanobacteria dominated biocrusts from two different semiarid areas located in southeast Spain: the Tabernas Badlands (continuous line) and Las Amoladeras (dashed lines).



(Source:https://www.sciencedirect.com/topics/earth-and-planetary-sciences/spectral-reflectance)

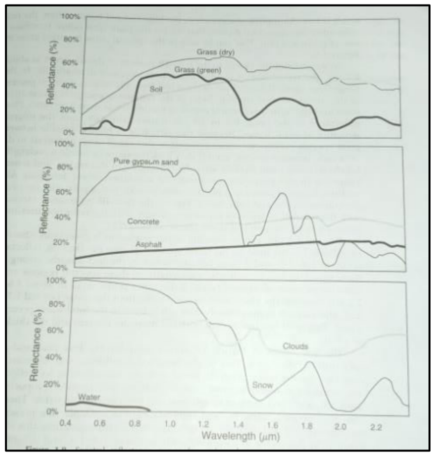
Fig. 1.5 Spectral signature (A) and continuum removal (B) of cyanobacteria dominated biocrusts, and two different lichens dominated biocrust communities (biocrusts mainly composed by the lichen species *Squamarina lentigera and Diploschistes diacapsis*), for wet (continuous line), and dry (dashed lines) conditions.



(Source:https://www.sciencedirect.com/topics/earth-and-planetary-sciences/spectral-reflectance)

As a result, the ability to make general assumptions regarding biocrust impacts on soil surface reflectance is complicated by changes in spectral response between biocrust type and water status (Fig. 1.6) and their interaction with the underlying soil's spectral response (Fig. 1.6). However, when soil or vegetation properties are studied using remote sensing techniques, it is evident that their presence must be taken into account, and mapping methods are required to determine their presence and coverage at the picture scale.

Fig.1.6 Spectral reflectance curves for various features types



(Source: U.S.G.S. Spectroscopy Lab, Johns Hopkins University Spectral Library, and Jet Propulsion Laboratory [J.P.L.]; cloud spectrum from Browker et al., after Avery and Berlin, 1992.)

The soil curve in Fig. 1.6 shows considerably less peak- and- valley variation in reflectance. That is, the factors that influence soil reflectance act over less specific spectral bands. Some of the factors affecting soil reflectance are moisture content, organic matter content, soil texture (proportion of sand, silt, and clay), surface roughness, and the presence of iron oxide. These factors are complex, variable, and interrelated. For example, the presence of moisture in the soil will decrease its reflectance. This effect is most significant with vegetation in the water absorption bands at about 1.4, 1.9, and 2.7 µm (clay soils have hydroxyl absorption bands at about 1.4 and 2.2 µm). Soil moisture content is strongly related to the soil texture: Coarse, sandy soils are usually well-drained, resulting in low moisture content and relatively high reflectance; poorly drained fine-textured soils will generally have lower reflectance. Thus, the reflectance properties of soil are consistent only within particular ranges of conditions. Two other factors that reduce soil reflectance are surface roughness and the content of organic matter. Iron oxide in the soil will also significantly decrease reflectance, at least in the visible wavelengths. In any case, the analyst must be familiar with the conditions at hand. Finally, because soils are essentially opaque to visible and infrared radiation, it should be noted that soil reflectance comes from the uppermost layer of the earth and may not be indicative of the properties of the bulk of the soil.

Sand can have a wide variation in its spectral reflectance pattern. The curve shown in Figure 1.6 is from a dune in New Mexico and consists of roughly 99 per cent gypsum with trace amounts of quartz (Jet Propulsion Laboratory, 1999). Its absorption and reflectance features are essentially identical to those of its parent material, gypsum. Sand derived from other sources with different mineral compositions would have a spectral reflectance curve indicative of its parent material. Other factors affecting the spectral response from sand include the presence or absence of water and organic matter. Sandy soil is subject to the same considerations listed in the discussion of soil reflectance.

Soil spectral reflectance is a comprehensive representation of soil physical and chemical attributes. Its study serves as the material foundation for soil remote sensing and a new method and standard for soil property research. The spectra of soil rooms are highly correlated with those generated from hyperspectral pictures.

As a result, room spectra are critical for soil taxonomy and research. The spectral reflectance in the visible and near-infrared regions of 248 soil samples (black soil, chernozem, meadow soil, blown soil, alluvial soil) collected from Nongan county, Jilin province, was measured with a hyperspectral device in a room to determine the feasibility of soil taxonomy based on topsoil reflectance spectral characteristics. The theoretical foundation for quick soil taxonomy based on remote sensing methods was provided. The models have three layers (input, output, and hidden layer), with "T.R.A.I.N.L.M." as the training function, "LEARNGDM" as the learning function, and "TAN SIG" as the transferring function. (1) There are some differences in spectral properties across different soils, but with equal parental matrix and environment, the spectral differences of soils in Nongan county are not significant. As a result, analyzing soil spectral features based on soil reflectance is difficult. (2) After removing the continuum, the curves improved soil spectral absorption properties and made soil spectral analysis easier. The soil spectral curves in Nongan county mainly have five spectral absorption values at 494, 658, 1 415, 1 913, and 2 206 nm, with the former two vales caused by soil organic matter and mechanical composition, and the latter three due to soil moisture. The differences between soils in the last three vales are not noticeable, and the significant differences are in the former two vales. (3) Soil reflectance is affected by organic matter, soil moisture, Fe, mechanical composition, roughness, and other factors. The sensitivity of soil spectral indices calculated using the continuum removal approach has been reduced. When these indices are used as input variables, the models become more stable and general. Because the input variables were external, the B.P. network model based on the shape characteristics of the first two vales performed better than the model based on reflectance values for all five vales; the primary three soils (chernozem, meadow soil, and blown soil) were classified with greater than 60% accuracy, and the model could be used for soil taxonomy. However, further research is needed, and auxiliary data such as topography, vegetation, and land use should be included to increase classification accuracy.

The programme was used to do a principal components analysis (P.C.A.) to minimize the dimensionality of information and the variability of the spectral data. This was accomplished by preprocessing spectral data, converting it to absorbance and centring it on the mean. P.C.A. (principal component analysis) is one of the most commonly used methods in information analysis (Brown, 1995). It is mainly used to compress data based on the existence of a correlation between different measured variables.

The spectral reflectance of a given soil is determined by the soil's inherent physical and chemical properties—including texture, organic matter, type of clay minerals, salt presence, and moisture content. Some studies have found a good correlation between spectral reflectance and soil properties such as organic matter, moisture content, mineral composition, iron oxide content, colour, brightness, roughness, size and shape of the soil aggregate, and the salt and sodium content. The objective of this study was to analyze the spectral reflectance characteristics of soils across a salinity gradient to determine whether and to what extent spectral reflectance is related to the degree of salinity.

1.4 SUMMARY

In this unit, you have studied the fundamental idea of soil structure, soil formation and soil classification with the help of spectral reflectance. Let us now summarize what we have learned:

- The structure of the soil is a physical property that determines the health of the soil.
- The soil structure also determines water movement.
- Ped and Clad are the primary two divisions of soil particles.
- Granular, prismatic, Platy and blocky are the primary structure of the soil.
- The profile of the soil depends on the slope, vegetation cover, climate and time.
- The O horizon is the topmost and also essential layer because it contains organic matter.
- The mineral horizon is designated by A, B, C and D horizon. These horizons are further subdivided.
- Soil formation is a prolonged and natural process that depends on physical conditions like parent rocks, presence or absence of vegetation and animals, climate, etc.
- There are various processes like illuviation, alleviation, capillary action etc., are involved in soil formation.
- The U.S.D.A. soil classification was revised, and they classified the soil by Order, suborder family etc.
- We can only see the visible portion of the electromagnetic Spectrum, but despite these, several spectral bands are observed by particular types of sensors.
- These several spectral bands like reflected infrared and others are used to classify the soil classification. These data are collected through the remote sensing process.
- Soil has various components like various types of minerals and organic matter, which has multiple reflectances.
- This spectral reflectance is captured and produced hyperspectral images with 10 to 100 bands to analyze the soil characteristic, and based on their character; they are classified into several groups.
- Spectral Library has been made to identify the properties of soil.
- A spectral reflectance curve is used to interpret the mineral and organic composition of the soil.
- 0.50 to 2.5mm reflectance are used to interpret the soil.
- The soil which has iron oxide increases reflectance 0.4 to 1mm.
- The soil which has covered by biological crust has more absorption.
- Sandy soil usually has more reflectance.
- Soil roughness and organic matter are responsible for less reflectance.

- As soil moisture increases, the reflectance of soil decreases at all wavelengths.

1.5 GLOSSARY

1. Biocrust - Aggregated crusts exist on the soil surface of arid environments.
2. Electromagnetic Spectrum - The range of wavelengths or frequencies over which electromagnetic radiation extends.
3. Humification - A process of formation of humic substances
4. Lichen - A simple slow-growing plant that typically forms a low crusty, leaf-like, or branching growth on rocks, walls, and trees.
5. Taxonomy - A scheme of classification

1.6 ANSWER TO CHECK PROGRESS

1) List the horizons of the soil.

2) List the method of soil formation.

3) List some components of soil which are affected soil reflectance.

4) Name a statistical method that is helpful to analyze soil reflectance.

1.7 REFERENCE

- Dr Singh. S(2019), Biogeography, Pravalika publication
- https://www.researchgate.net/publication/309138772
- https://www.sciencedirect.com/topics/earth-and-planetary-sciences/spectral-reflectance
- (1) Henrique Bellinaso(2), José Alexandre Melo Demattê(3) & Suzana Araújo Romeiro(4) Soil Spectral Library and its used in soil classification

1.8 TERMINAL QUESTIONS

1) Describe the horizons of soil.

2) Describe the transformation process of soil formation.

3) Discuss the various spectral reflectance of soil properties.

UNIT 2 - REMOTE SENSING APPLICATION IN SOIL SURVEY AND MAPPING, SOIL MOISTURE ESTIMATION USING GEO INFORMATICS

2.1 OBJECTIVES

After studying this unit, you should be able to:

- To define and categorize soils using a consistent classification system and nomenclature to correlate soils from different areas.
- To depict the distribution of various soil types in the field (soil mapping).
- To give data for interpreting the adaptation of specific soils for agricultural purposes and a variety of other uses (as in soil management).
- Describe the different methods of soil survey.
- Discuss the most popular approach to remote sensing surface soil moisture based on coupled thermal and optical R.S. observations.
- Get a piece of knowledge about L.A.N.D.S.A.T. 8 satellite data and Radar Sentinel-1 data to interpret the soil moisture.
- To describe the uses of air photos to make a soil map.
- Discuss the various range of reflectance which depicts the moisture condition of the soil.
- Application of soil survey, soil mapping in an agricultural field and water management.

Several acronyms have been used throughout the self-learning material, listed at the end of each block for your ready reference.

After studying this course, we hope you will acquire a basic understanding of the class, or possible classes, of an unknown soil-based survey, soil mapping and soil moisture estimation.

2.2 INTRODUCTION

Soil surveying, also known as soil mapping, is the process of identifying soil types and other soil attributes in a specific area and geocoding the data. It uses soil science ideas and depends extensively on geomorphology, soil formation theories, physical geography, and vegetation and land use patterns analysis. Field sampling and remote sensing are used to collect primary data for the soil survey. Aerial photography is the most common small sensing method, but LiDAR and other digital techniques are rising in popularity. A soil scientist used to go into the field with hard copies of aerial photographs, topo-sheets, and mapping keys.

With this brief introductory note on soil survey and mapping and its diverse applications, we further apprise you of the varied components and products.

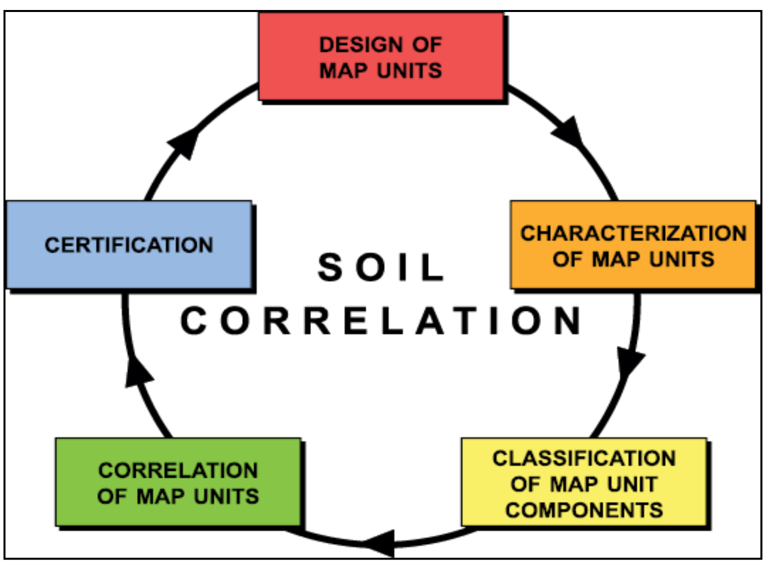
2.3 REMOTE SENSING APPLICATION IN SOIL SURVEY AND MAPPING, SOIL MOISTURE ESTIMATION USE GEO INFORMATICS

Meaning of Soil Survey:

Soil surveying is primarily a field study of soil morphology. Soil surveying includes classifying the area's soils into well-defined units, characterizing soil attributes, mapping their extent and borders on a map, and predicting their adaptability to various applications.

Farmers and ranchers can utilize the information from a soil survey to evaluate if a particular soil type is suitable for crops or cattle and what kind of soil management is required. An architect or engineer can use the technical features of soil to assess if it is suitable for a particular structure style. The information can also be used to manage or build a homeowner's garden, yard, or home.
Soil survey data can be used to anticipate or estimate soil potential and constraints for various applications. A soil survey is an essential piece of data that is utilized to create practical land management plans. To be useful to professional planners and others, the data must be understood. Predictions based on soil surveys make land use and management decisions for areas ranging from tiny parcels to large regions. However, before these projections can be utilized to generate practical recommendations for land use and management, they must be examined alongside economic, social, and environmental factors.
With this background, you will now be able to define soil survey.

Fig 2.0 A diagram that illustrates soil correlation is a continuous process, not a single event. The process is used to facilitate consistent collection, identification, grouping, and transfer of soil information.



(Source: https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcseprd1346229.png)

Soil correlation is a multi-step quality assurance method that provides accuracy and consistency in local and regional soil surveys. It entails designating map units, classifying soils, and providing appropriate interpretations. The goal of correlation is to ensure consistency in the design and naming of map units, ensure adequate information flow to and between users, and allow flexibility between the soil survey standards and the geographic variability scientists see and document.

Objectives and Uses of Soil Survey:

The primary goal is to learn more about soil genesis and to provide information about the area's soil resources. As a result, it serves as the foundation for land use planning and resource management. Land uses, cropping systems, manure and fertilizer application, tillage practises, and water management may benefit from soil survey information.

Other uses for the data include reclamation of problem soils, grass and forestry development, wildlife protection planning for irrigation and drainage, road and rail-track building, and so on.

Types of Soil Surveys:

Surveys are:

(a) Detailed survey

(b) Reconnaissance survey, and

(c) Detailed- reconnaissance survey.

(**a) Detailed Surveys:** Soil boundaries are precisely delineated on maps based on observations gathered across the surveyed region in this method. The geographical distribution of soil is also detailed in this document. Detailed soil surveys are vital because they give the information needed for land use and management planning and agricultural research and extension programmes.

(b) Reconnaissance survey: Soil boundaries are plotted from the observations made at intervals.

(c) Detailed- reconnaissance survey: A portion of the surveyed region is plotted using the exact method, while the remainder is planned utilizing the reconnaissance method. Aerial pictures or accurate topographic maps are used in the mapping of soils. In general, a scale of four inches to 1 mile is used in mapping cultivated regions, although detailed or unique maps are generated on scales of six inches, eight inches, or twelve inches to a mile.

Soil surveys are conducted in India by both central and provincial authorities. Some limited-area surveys have been done for specific aims, such as fertility surveys, soil classification surveys, geological surveys, physicochemical qualities of surface samples, and genetic classification surveys.

Limited areas under the control of large irrigation projects have also been subjected to pre-and post-irrigation surveys to evaluate the nature, quality, and concentration of soluble salts in various soil strata. Under the auspices of the International Society of Soil Science, the Geological Survey of India, and the I.A.R.I. (Indian Agricultural Research Institute), New Delhi, a few generalized soil maps have been developed in India.

Aerial Photo-interpretation for Soil Surveys: Normally, scales of 1: 10,000 or 1: 25,000 are recommended for extensive surveys. The air pictures are an excellent starting point for drawing soil boundaries in such surveys. This is due to the abundance of graphical data accessible in the air photo, which makes orientation and navigation extremely simple. Usually, a pocket stereoscope spends only minimal time demarcating boundaries based on relief and other features. In such surveys, the final soil map and the base photo are created on a large scale.

Fig.2.1 Image of pocket stereoscope

(source:https://5.imimg.com/data5/CI/GE/FD/SELLER-2427214/pocket-stereoscope 500x500.jpg)

Medium and Small Scale Map: In this scenario, aerial photo interpretation is more useful. From medium to small scale, the degree of utility increases. The photo-interpretation process is based on the idea that physiographic units have distinct soil patterns. For semi-detailed reconnaissance surveys, the scales 1: 25,000 to 1: 00,000 and 1: 2, 50,000 are recommended. Relief, slope, geological characteristics, vegetation, tone, textures, pattern, and other elements are used by soil scientists in the same way that geologists and foresters use.

Systematic Photo-interpretation: Delineation of soil borders by air pictures, which are sub-divisions of physiographic units, is the most popular method used by soil scientists. They next choose sample areas that represent all of the photo-delineations interpretations in the next stage.

These are lengthy, narrow sections that cut across as many subdivisions as feasible. In each characterization of the interpretation, detailed soil observations are taken into account. The soils of each unit are categorized and associated with the photo-interpretation team based on the number of such observations. As a result, the soil composition of each unit is determined.

The other aerial pictures are analyzed using the idea of extrapolation of knowledge gathered from the sample area investigations, with the discovery of the sample areas as the starting point. It should be noted that this "modified photo-interpretation" is frequently a partial revision of the office-based pre-field interpretation. A "selected ground inspection" is included in the final phase. This allows the integrity of the altered photo interpretation to be tested. The correct soil boundaries can be found on the resulting field sheet, which consists of air images.

They have detailed soil surveys from a primary source of information about an area. Hence, they are used heavily in such activities as comprehensive land use planning. Understanding soil suitability for various land use activities is essential to preventing environmental deterioration associated with the misuse. In short, if planning to be an effective tool for guiding land use, it must be the premised inventory of the natural resources base; soil data are an essential facet of such inventories.

With this background, you will now be able to describe the types of soil survey and methodology.

Estimation of soil moisture with the help of Geo-informatics

Soil moisture content (S.M.C.) determination is an essential element in biological processes and soil profile change. Furthermore, soil moisture has an impact on vegetation dispersal. As a result, a shortage of water may cause drought and degradation, particularly in rainy areas. Many approaches have been proposed in recent decades to estimate various soil parameters using remote sensing data. Traditional methods are being replaced by remote sensing and G.I.S. techniques, which can cover large areas and offer information about the spatiotemporal fluctuations of S.M.C. In locations with inadequate soil drainage and high water table variations, the soil moisture content is a major environmental stressor affecting crop survival, growth, and yield.

Various authors developed new methods to estimate S.M.C. based on the soil reflectance and the Land Surface Temperature (L.S.T.).

Soil moisture has long been regarded as one of the most critical indicators in hydrology, climate, ecology, etc. Surface S.M.C. can be estimated based on Normalized Difference Vegetation Index (N.D.V.I.) and L.S.T. The land surface temperature-vegetation index (LST-VI) space has extensive sensor information from the visible to the thermal infrared band, and it may accurately describe regional soil moisture conditions. Explained this LST/NDVI relationship as a linear relationship with the S.M.C. Triangle approach was offered as a method to get S.M.C. based on the integration of L.S.T. and N.D.V.I. Because L.S.T. is calculated from thermal emission and N.D.V.I. is calculated from surface reflectance in the red and near-infrared regions of the Electromagnetic Spectrum, these methods are also referred to as optical, thermal, and infrared remote sensing.

The capacity of radar waves to penetrate cloud layers distinguishes them. As a result, the signal can interact with various earth objects. The backscatter qualities of different things vary. In addition, the dielectric constant refers to the soil's essential reflectivity. The quantity of moisture in an object determines the dielectric constant, which ranges from 1 to 100 for most things. The dielectric constant value is affected by the amount of water in the soil. As a result, it is proportional to the moisture content of the object, i.e. soil reflectivity increases as moisture content increases. As a result, radar can measure soil characteristics and biomass (Rancy, 1998). The calculation of S.M.C. using radar is dependent on several factors, including backscatter signal, surface roughness, vegetation cover, and frequency, with lower frequencies being more sensitive.

Sentinel-1 Synthetic Aperture Radar (S.A.R.) systems are characterized by high-resolution backscatter data and are regarded as a possible tool for retrieving S.M.C. It takes 12 days to get around the world. Advanced Synthetic Aperture Radar (ASAR) in the C-band with 1 km ground spatial resolution at the H.H. or V.V. polarisation can be used to assess soil moisture. Microwave remote sensing calculates S.M.C. using a passive radiometer based on backscattering coefficient and soil moisture to measure microwave emission as brightness temperature. Because the volumetric soil moisture content in the upper layer of soil (0–5 cm) is associated with S.A.R. backscatter, S.A.R. data is better suitable for measuring soil moisture content. The link between soil moisture and backscatter is reduced by vegetation cover, which negatively impacts radar reflectivity.

To construct the LST-VI space, 9 pairs of moderate-resolution imaging spectroradiometer (M.O.D.I.S.) products (MOD09A1 and MOD11A2) are used and then the spatial distribution of soil moisture is monitored by the temperature vegetation dryness index (T.V.D.I.). The normalized difference vegetation index (N.D.V.I.), enhanced vegetation index (E.V.I.), and modified soil-adjusted vegetation index (M.S.A.V.I.) are used to create three LST-VI spaces. The correlations between the soil moisture data and the T.V.D.I.s calculated by LST-NDVI, LST-EVI and LST-MSAVI, respectively, were analyzed. T.V.D.I. is found to be a valuable metric for determining soil surface moisture conditions. The LST-EVI space T.V.D.I. (T.V.D.I.E.) had a greater connection with soil moisture than the LST-NDVI and LST-MSAVI areas. It is distinguished from the various stages of the T.V.D.I.E. space that can effectively illustrate the temporal and spatial changes in soil moisture and is an efficient way to monitor soil moisture conditions.

Soil moisture has a negative and positive impact on crop quantity and quality. As a result, estimating S.M.C. using satellite data is a critical component of accurate farm management. Recently, remote sensing has been proposed as a possible solution. The regional distribution of soil moisture is seen in this image. As a result, two radar data and different satellite data received simultaneously Satellite sensors (Sentinel-1) and optical/thermal (Landsat 8) Backscattering coefficients r 0 in dB were used to model soil moisture. Thermal data was also used to determine the moisture content of the soil. Both sorts of data produced good results, according to the findings. The regional distribution of crop Patterns should be considered crucial for estimating soil moisture using remote sensing data.

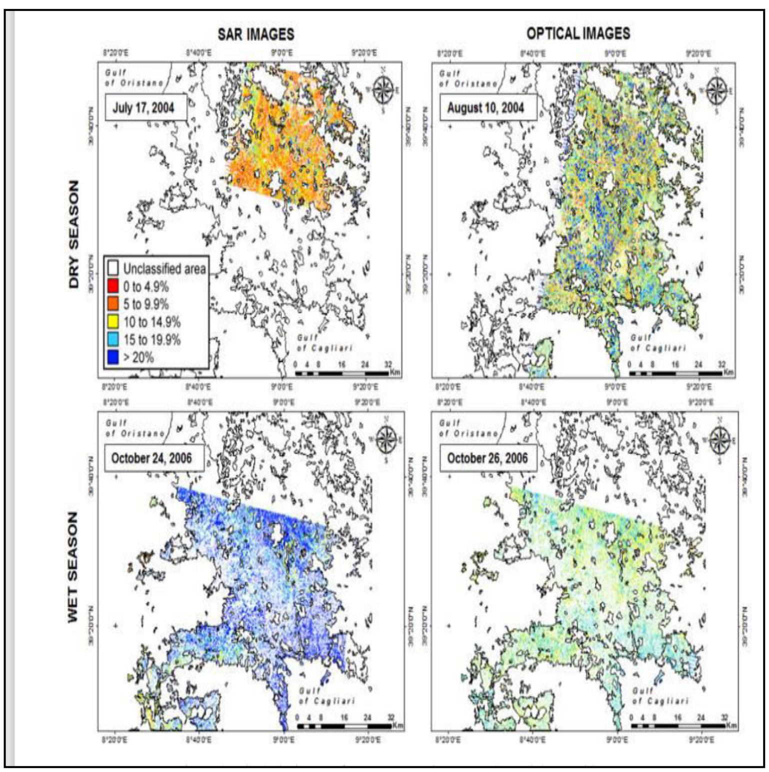
Fig 2.2 Image of spectroradiometer

(Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ci-systems.com%2FSR-5000N-Spectroradiometer&psig=AOvVaw0UHSQHFr-JSLOH6Ctn1mIF&ust=1634722152723000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCLjYn7uV1vMCFQAAAAAdAAAAABAQ)

Importance of surface soil moisture and soil drainage for hydrological modelling and agricultural management: Surface soil moisture (S.M.) is a vital state variable in water resource management because it affects various hydrological processes. Because it regulates interactions between the land surface and the atmosphere, such as infiltration, retention, runoff, percolation, and evapotranspiration, S.M. impacts the planetary boundary layer structure and heat transport. Soil drainage quality is a critical factor that influences the temporal and geographical changes in surface S.M. and the sensitivity of soils to degradation and desiccation, all of which directly affect plant growth. Many hydrological and agricultural applications require monitoring regional and temporal fluctuations of S.M. and other land surface parameters. Surface S.M. is one of the most critical inputs to hydrological models. It updates the model's boundary conditions and drives surface and subsurface water and energy flux partitioning. Early identification of soil drying conditions can help improve irrigation water use, increase agricultural production, and warn of drought situations. This data can be highly beneficial to regional water and agricultural management.

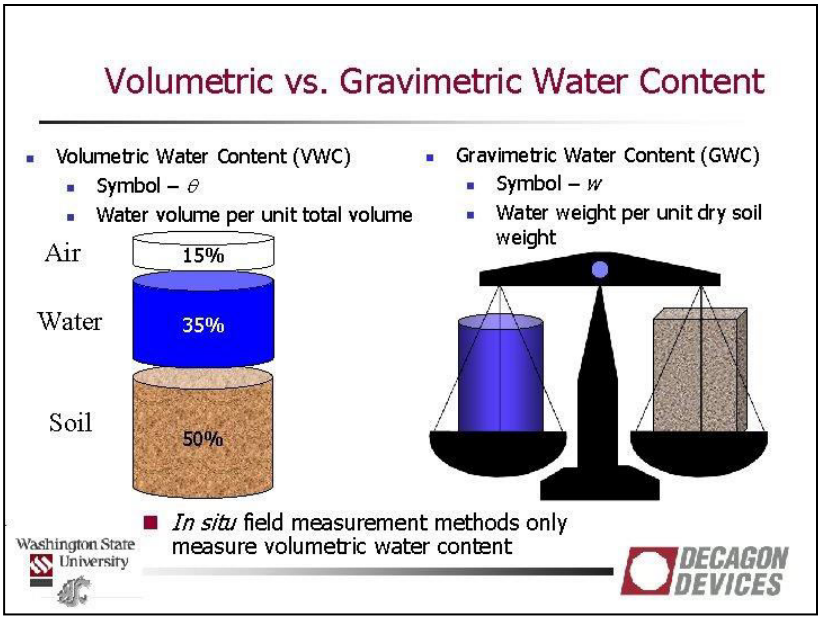
Soil moisture measurement: The goal for soil moisture was to collect the most samples per field possible to calculate a meaningful average value per field. Within three hours of the satellite pass, the sample has to be completed. The temporal domain reflectometry probe (TDR) and the gravimetric sampling method were utilized to detect surface soil moisture. The gravimetric approach entails collecting a soil sample from 0–5 cm or 5–10 cm and placing it in a 100 cm3 steel cylinder. The total weight of this sample is calculated by weighing it immediately after it is collected (wet soil = dirt + air + water). The sample is then heated for at least 24 hours at 110°C before being weighed again (only dry soil). This sample shows how much water is in the ground. The soil density was measured for each field, and the results were used to compute the volumetric soil moisture (per cent). All processes for acquiring soil moisture gravimetric measurements were carried out in A.G.R.I.S. facilities. Each point was sampled three times with the TDR probe: vertically from the surface, 5 cm horizontally (the average of these two values is comparable to one gravimetric measurement 0–5 cm for surface S.M.), and 10 cm horizontally (equivalent to one gravimetric measurement 5–10 cm). The TDR probe method is much faster than the gravimetric measurement, but it needs to be calibrated regularly.

Fig 2.3 Estimated regional scale S.M. Maps from ENVISAT ASAR and LANDSAT TM5 imagery during the wet and dry season



(Source: https://www.researchgate.net/publication/280866400)

Fig 2.4 A diagram of a volumetric and gravimetric method

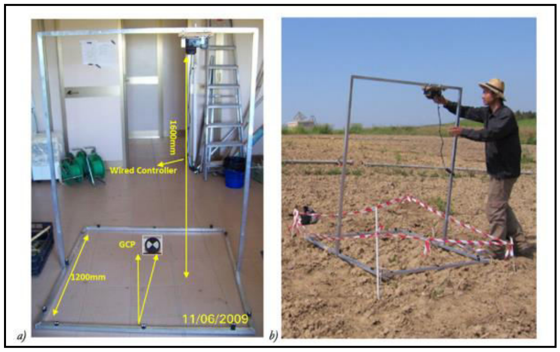


(Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fslidetodoc.com%2Fmasurement-methods-for-soil-moisture-and-plant water%2F&psig= AOvVaw1jVpj Tcg8mj85dx6nd8p5d &ust=1634721724071000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCPC2yJCT1vMCFQAAAAAdAAAAABAS)

Fig.2.5 TDR probe soil moisture monitoring

(Source: https://www.vanwalt.com/equipment/wp-content/uploads/sites/2/2017/11/tdr-Trime-Pico-probes.jpg)

Fig 2.6 Description of various parts of the equipment for the two-dimensional close-range photogrammetric approach



(Source: https://www.researchgate.net/publication/280866400)

This research aimed to see if empirical connections between remotely detected signals (radar backscattering, optical reflectance, and thermal emission) and S.M. values obtained at the field size could be used to generate. They were encouraging estimated soil moisture (ESM) maps throughout an agricultural plain.

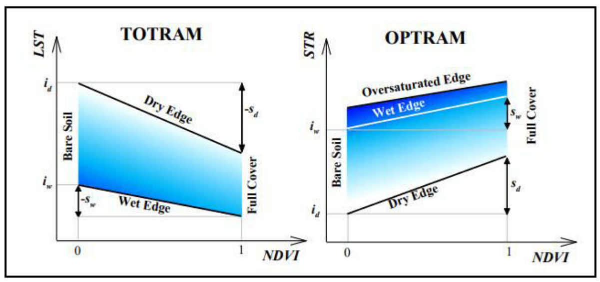
This research suggests a feasible methodology for mapping soil moisture and drainage capacity that could improve irrigation decision-making in essential sites in terms of surface moisture and agricultural soil water retention potential in semiarid conditions. These maps also seek to help researchers choose the best location and time to conduct practical S.M. measurements in the future.

The approach of remote sensing to measure soil moisture: The most prevalent approach to remote sensing (R.S.) of surface soil moisture based on combined thermal (i.e., land surface temperature) and optical R.S. observations is the "trapezoid" or "triangle" model. The model, dubbed Thermal-Optical TRAapezoid Model (T.O.T.R.A.M.), is based on pixel distribution interpretation inside the land surface temperature - vegetation index (LST-VI) space. T.O.T.R.A.M. has two flaws that make it unusable. It does not apply to satellites that do not offer thermal data (such as Sentinel-2), and it necessitates parameterization for each observation date. To overcome these limitations, we present the OPtical TRApezoid Model (O.P.T.R.A.M.), which is based on the linear physical relationship between soil moisture and shortwave infrared transformed reflectance (STR) and parameterized using the STR-VI pixel distribution. The ground truth soil moisture data was compared to the OPTRAM-based surface soil moisture estimations produced from Sentinel-2 and Landsat-8 observations. The results show that O.P.T.R.A.M. and T.O.T.R.A.M. have similar prediction accuracies, with O.P.T.R.A.M. requiring only observations in the past. With local calibration, both models' volumetric moisture content estimation errors were less than 0.04 cm3 cm-3, whereas, without calibration, they were around 0.04-0.05 cm3 cm-3. We also show that for a given site, O.P.T.R.A.M. only requires a single universal parameterization, which is a significant improvement that opens up a new path for soil moisture remote sensing.

Because microwaves may penetrate through the vegetation canopy and underlying soil, especially at lower frequencies, microwave R.S. approaches have demonstrated more potential for monitoring global-scale soil moisture dynamics. On the other hand, microwave satellite observations are not well suited for small-scale applications (e.g., field-scale) because of their coarse resolution. Because of their higher spatial solutions (i.e. metre scale), optical and thermal satellite measurements are frequently used to close the scale gap.

One of the most generally used ways to R.S. of soil moisture utilizing both optical and thermal data is the so-called "trapezoid" or "triangle" model. The Thermal-Optical TRAapezoid Model (T.O.T.R.A.M.) interprets the pixel distribution inside the LST-VI space, where L.S.T. is the land surface temperature, and VI is an RS-based vegetation index.

Fig.2.7 Sketch illustrating parameters of the traditional thermal-optical trapezoid model



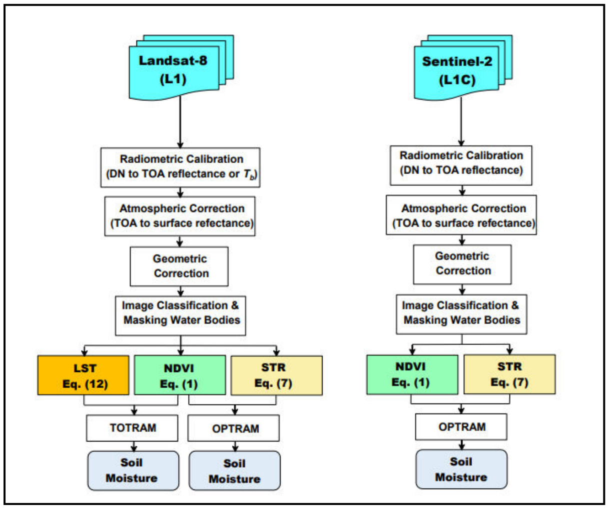
(Source: The Optical Trapezoid Model: A Novel Approach to Remote Sensing of Soil Moisture Applied to Sentinel-2 and Landsat-8 Observations Morteza Sadeghi1*, Ebrahim Babaeian2, Markus Tuller2 and Scott B. Jones1)

This study's new OPtical TRApezoid Model (O.P.T.R.A.M.) proposes a revolutionary satellite-based surface soil moisture remote sensing technique. The linear physically-based relationship between STR and surface or root zone soil moisture in bare or planted soils was used to develop O.P.T.R.A.M. The pixel distribution within the STR-NDVI space (or with least-square regression of the model to field observations) can be used to derive O.P.T.R.A.M. parameters for a specific area. O.P.T.R.A.M.'s prediction accuracy is comparable to that of the traditional trapezoid model (T.O.T.R.A.M.), which uses paired LST-NDVI data. The O.P.T.R.A.M. has two distinct advantages over the T.O.T.R.A.M.:

- Because O.P.T.R.A.M. does not require thermal data, it can be used with satellites that provide optical data, such as the E.S.A. Sentinel-2 spacecraft.
- Because the STR-soil moisture relationship is unaffected by ambient environmental parameters (e.g. air temperature, wind speed), O.P.T.R.A.M. can be parameterized for any location.

Compared to T.O.T.R.A.M., O.P.T.R.A.M. has a higher sensitivity to oversaturated and shaded pixels, which is a drawback. Solving for the wet edge requires some refinement when the optical trapezoid contains too many oversaturated pixels. However, because a single universal model parameterization is feasible, this may not be a severe limitation.

Fig 2.8 Flowcharts illustrating the sequence of Sentinel-2 and Landsat-8 data analyses steps for mapping surface soil moisture with T.O.T.R.A.M., and O.P.T.R.A.M.



(Source: The Optical Trapezoid Model: A Novel Approach to Remote Sensing of Soil Moisture Applied to Sentinel-2 and Landsat-8 Observations Morteza Sadeghi1*, Ebrahim Babaeian2, Markus Tuller2 and Scott B. Jones1 1Department of Plants, Soils and Climate, Utah State University, Logan, UT 2Department of Soil, Water and Environmental Science, The University of Arizona, Tucson, AZ *Corresponding author at 4820 Old Main Hill, Logan, UT 84322-4820)

Method of soil mapping based on soil moisture

Detailed soil surveys are the product of an intensive study on resources by trained scientists. The delineation of soil units has traditionally utilized air photo interpretation coupled with extensive fieldwork. Soil scientist traverses the landscape on foot, identify soils, and delineate soil boundaries. This process involves examining numerous soil profiles (cross-section) and identifying and classifying soil units. The soil scientist's experience and training are relied on to evaluate the relationship of soils to vegetation, geologic parent material, and landform and landscape position. Air photo interpretation has been utilized since the early 1930s to facilitate the soil mapping process. Typically, panchromatic aerial photographs at scales ranging from 1:15,840 to 1:40,000 have been used as mapping bases.

Agricultural soil survey maps have been prepared for portions of the United States of the U.S.D.A. since 1900. Most of the soil surveys published since 1957 contain soils map printed on a photomosaic base at a scale of 1:24,000, 1:20,000, or 1:15,540. Beginning in the mid-1980s, soil survey map information for many countries has been made available as line maps, and digital files can be incorporated into geographic information systems. The original purpose of these surveys was to provide technical assistance to farmers and ranchers for cropland and grazing operations. Soil surveys published since 1957 contain information about the suitability of each mapped soil unit of various uses. They have information for such purposes as estimating yields of common crops; evaluating rangeland suitability; determining woodland productivity; assessing wildlife habitat conditions; judging suitability for various recreational uses; and determining appropriateness for various developmental services; such as highways, streets and roads, building foundations, and septic tank absorption fields.

The U.S.D.A. Natural Resources Conservation Services (formerly the Soil Conservation Service) provides soil survey maps in digital form for many areas of the United States. Since 1994 it has provided nationwide detailed soil information using the National Soil Information System, an online soil attribute database system.

A portion of a 1:15,840 scale U.S.D.A. soil printed on a photomosaic base is shown in Fig 5.10. The Table shows a sampling of the soil information and interpretations contained in U.S.D.A. soil survey reports. This map and Table show that the nature of soil conditions and, therefore, the appropriates of land areas for various uses can vary significantly over short distances. As with soil map data, much of the interpretive soil information is available in computer-based files.

The reflection of sunlight from bare soil surfaces depends on many interrelated factors, including soil moisture content, soil texture surface roughness, the presence of iron oxide, and the organic matter content. A unit of bare soil may manifest significantly different image tones on other days, depending predominantly on its moisture content. Also, as the area of vegetated surfaces (e.g. leaves) increases during the growing season, the reflectance from the scene is more the result of vegetative characteristics than the soil type.

Fig 2.9 plate 8 oblique color infrared aerial photographs illustrating the effects of date of photography : (a) June 30; (b) 1; (c) July 2; (d) August 11; (e) September17; (f) October 8. Dne Country. Wl. The approximate horizontal scale at the photo centre Is 1:7600 (Source: Liles and M. Thomas, Kiefer W. Ralph, Chipman W. Jonathan 2018, Remote sensing and image interpretation)

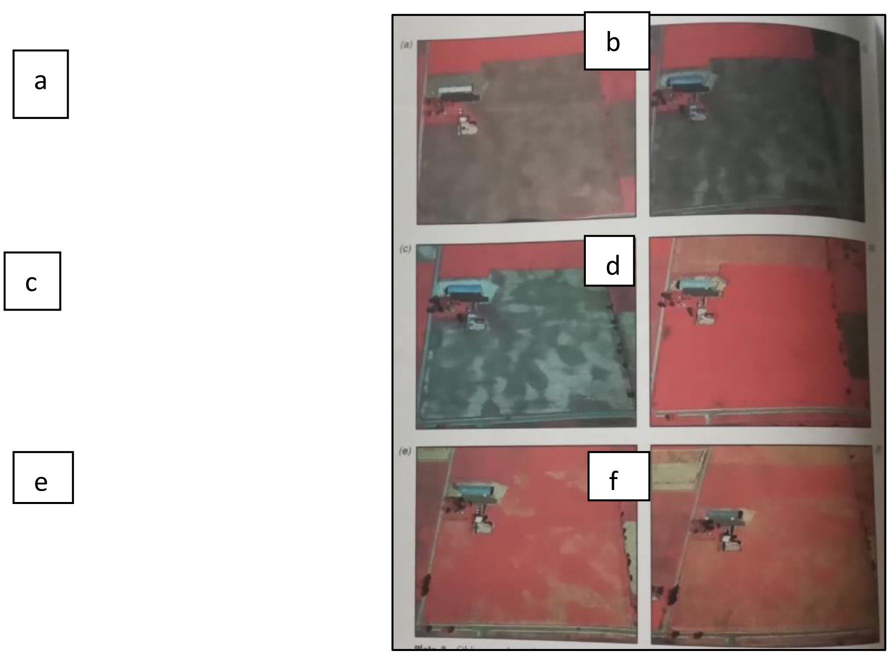
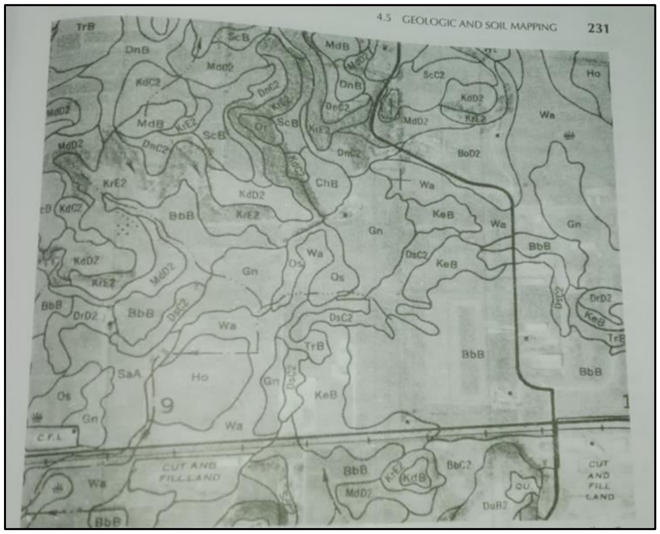


Fig.2.10 Portion USDA-ASCS soil map, Dane Contry, Wl. Original scale 1:15,840



(Source: U,S Department of Agriculture,1977)

Fig 2.9 Plate 8 illustrates the dramatically different appearance of one agricultural field, approximately 15 ha in size, during one growing season. Except for a small area at the upper right, the entire field is mapped as one soil type by the U.S.D.A. (map unit BbB, as shown in Fig 2.10 and described in Table). The soil parent materials in this field consist of glacial meltwater deposits of stratified sand and gravel overlay bt 45 to 150cm of loess (wind- deposited silt). Maximum relief is about 2 m, and slope ranges from 0 to 6 per cent. This field was planted to corn (Zea mays L.) in May and harvested in November.

Map unit Fig 2.10	Soil name	Soil description	Depth to groundwater table(cm)	Predicted corn yield	Septic tank absorption fields	Dwellings with Basements	Sites for golf course fairways
BbB	Batavia silt loam, gravelly substratum, 2-6%	100-200cm silt over stratified sand and gravel	>150	8700	Moderate	Slight	Slight
Ho	Houghton muck, 0-2%	Muck at least 150cm deep	0-30	8100 (when drained) Not suited	Very severe	Very severe	Severe
KrE2	Kidder soils, 20-35%	About 60 cm silt over sandy loam glacial till	>150	Not suited	severe	severe	Severe
MdB	McHenry Silty loam,2-6%	25-40cm silt over sandy loam	>150	7000	Slight	Slight	Slight

		glacial till					
Wa	Wacousta silty clay loam, 0-2%	Silty clay loam and silt loam glacial lakebed materials	0-30	7000	Very severe	Very severe	Severe

Table Soil information and interpretation for five soils shown in Fig 2.10.

Fig 2.9 Plates 8a,b, and c illustrate the change in surface moisture patterns visible on the cultivated soil over 48 hours in early summer. During this period, the corn plants were only about 10cam tall, and consequently, most of the field surface was bare soil. The area received about 2.5 cm of rain on June 29. On June 30, when the photo in Plate 8a was exposed, the moist soil had a nearly uniform surface tone. By July 2 (8c), distinct patterns of dry soil surface (light image tone) could be differentiated from areas of wet soil surface (darker image tones). The sites have relatively high infiltration capacity and are slight mounds of 1 to 2 m relief. These topographic highs have very gentle slopes. Rainfall that does not infiltrate into the soil on these areas runs off onto the lower portion of the landscape. These lower areas remain wet longer because they have relatively low infiltration capacity and receive runoff from the higher regions in addition to their actual increment of rainfall.

Plates 8d,e and f, illustrate changes in the corn crop's appearance during the growing seasons. By August 11 (8d), the corn had grown to a height of 2m. Vegetation completely covered the soil surface, and the field had a very uniform appearance. However, by September 17 (8e), distinct tonal patterns were again evident. Very little rain fell on this field during July, August and early September, and the corn's growth during this period depended on moisture stored in the soil. In the dry areas, Shown in light tan yellow, the leaves and stalks of the corn were drying out and turning brown. In the wetter regions, pink and red colours, the corn plants were still green and growing. Note the striking similarity of the damp and dry soils pattern in (8c) versus the 'green' and brown areas of corn (8e). The pattern seen in the September photograph (8e) persists in the October photograph (8f); however, there are larger areas of dry corn in October.

Based on these photographs, a soil scientist divided the soil moisture conditions in this field into four classes; as shown in Fig, Field inspection of selected sites in each of the four units produced the information in Table. Note that the corn yield is more than 50% greater in unit 2 than in unit 4.

This sequence of photographs taken during one growing season illustrates that certain times of the year are better suited to image acquisition for soil mapping (and crop management) purposes than others. The most appropriate dates will vary widely in any given region and season, depending on many factors, including temperature, rainfall, elevation, vegetation cover, and soil infiltration characteristics.

Application of soil survey and soil mapping:

- To produce land use and land cover map of an area soil survey is an important part.

- To check soil health, we need to survey the specific field.
- To interpret the condition of the soil and moisture content, we need to produce a soil map.
- For the water management purpose, we need to monitor the capacity of the soil water.
- To monitor the vegetation health, a soil moisture survey is essential,
- Watershed analysis comprises soil survey and soil mapping.
- It is helpful to analyze the crop pattern.
- Help to make an irrigation strategy.
- Soil Moisture Mapping helps analyze climate change.

2.4 SUMMARY

In this unit, you have studied the fundamental idea of soil survey, soil mapping and estimation of soil moisture with the help of Geo-informatics. Let us now summarize what we have learned:

- Soil survey is a part of geomorphology and pedology.
- Many tools are used for soil survey like toposheets, satellite imagery, aerial photographs, LIDAR data etc.
- Among these, aerial photo interpretation is the most popular method.
- Soil survey has various applications like land use management, watershed management, architect engineering, agricultural field etc.
- The type of the soil survey is 3. you can get more information about it from the sub unit 2.3
- Primarily you can extract the soil boundary from aerial photos with the help of a pocket stereoscope.
- Relief, soil texture, vegetation, slope etc., parameters are needed to survey.
- To produce a standard soil survey, you should follow the soil correlation method.
- Soil Moisture Content is estimated by soil spectral reflectance, Normalized Difference Vegetation Index and Land Surface Temperature.
- This NDVI AND LST method can be analyzed by visible and thermal infrared wavelength.
- Optical, Thermal and Infrared Remote sensing is used to calculate S.M.C.
- The dielectric constant, which has a broad wavelength between 1 to 100m, is affected by water in the soil.
- Soil reflectivity increases when the amount of water in the soil also increases.
- Backscatter signal, soil roughness, vegetative cover and frequency gives an effect to calculate S.M.C.
- Sentinel-1 Synthetic Aperture Radar high resolution and Advanced Synthetic Aperture Radar (ASAR) in the C-band prepare S.M.C.
- Spectroradiometer is used to monitor the spatial distribution of soil moisture.
- TDR probe, gravimetric and volumetric methods are used to measure the soil moisture. Even the TDR probe is more efficient equipment among all of these.
- With the help of S.M. values, you can generate an estimating soil moisture map which is very helpful for an agricultural plan.

- "Trapezoid" or "triangle" model based on soil moisture survey combines optical R.S observation and thermal method.
- The trapezoid or triangle method is interpreted by pixel distribution.
- The U.S.D.A. Natural Resources Conservation Services, International Society of Soil Science, the Geological Survey of India, and the I.A.R.I. (Indian Agricultural Research Institute) conduct soil surveys and produce soil maps.

2.5 GLOSSARY

- Aerial photograph- It involves taking photos from elevated platforms such as humanized or remote-controlled aircraft or helicopters.
- Calibration- Each of a set of graduations on an instrument.
- Evapotranspiration- The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.
- Geocoding- Provide geographical coordinates corresponding to (a location).
- Infrared- It is a region of the electromagnetic radiation spectrum where wavelengths range from about 700 nanometers (nm) to 1 millimetre (mm).
- Photomosaic- It is a photographic reproduction of a series of aerial photographs put together in such a way that the detail of one photo matches the point of all adjacent photographs
- Spatiotemporal- It belongs to both space and time or space-time.
- Stereoscope- It is a device for viewing a stereoscopic pair of separate images, depicting left-eye and right-eye views of the same scene as a single three-dimensional image.
- Stressor- Something that causes a state of strain or tension

2.6 ANSWER TO CHECK YOUR PROGRESS

1) List the three types of soil survey methods.

2) List the interpretation method of the soil survey.

3) List components that affect the soil moisture calculation.

4) Name some instruments which are helping to monitor soil moisture capacity.

2.7 REFERENCE

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- Liu, S., Roberts, D.A., Chadwick, O.A. and Still, C.J., 2012. Spectral responses to plant-available soil moisture in a Californian grassland. International Journal of Applied Earth Observation and Geoinformation, 19, pp.31-44.
- Remote sensing and image interpretation published by John Willey & Sons, Inc Thomas M. Lilesand, Ralph W. Kiefer, Jonathan W. Chipman (2018).
- The Optical Trapezoid Model: A Novel Approach to Remote Sensing of Soil Moisture Applied to Sentinel-2 and Landsat-8 Observations Morteza Sadeghi1*, Ebrahim Babaeian2, Markus Tuller2 and Scott B. Jones1 1Department of Plants, Soils and Climate, Utah State University, Logan, UT 2Department of Soil, Water and Environmental Science, The University of Arizona, Tucson, AZ *Corresponding author at 4820 Old Main Hill, Logan, UT 84322-4820.

2.8 TERMINAL QUESTIONS

1) Describe the process to calculate the Soil Moisture content.

2) Discuss the application of soil survey and soil mapping.

3) How aerial photographs are used to produce the soil map?

4) What is the most popular approach of remote sensing in recent years to estimating soil moisture.

UNIT 3 - SOIL EROSION TYPES AND THEIR PROCESSES, RS IN CHARACTERIZATION OF LAND DEGRADATION TYPES AND THEIR PROCESSES, SOIL EROSION MODELING USING GEO INFORMATICS

3.1 OBJECTIVES

After studying this unit, you should be able to:

- At first, we are discussing the history of soil erosion.
- You will get to know about the factors of soil erosion.
- Describe the agents of soil erosion and their process of decay.
- Discuss the landforms which evolved due to soil erosion.
- Then you can compare water and wind erosion.
- Describe the land degradation and its type.
- Approaches of remote sensing to analyze land degradation.
- Describe the model which can study soil erosion using Geoinformatics.

Several acronyms have been used throughout the self-learning material, listed at the end of each block for your ready reference.

After studying this course, we hope you will acquire a basic understanding of the class, or possible classes, of unknown soil erosion and how to measure soil erosion using remote sensing.

3.2 INTRODUCTION

Earth abounds in resources. Among them, the soil is considered to be the most essential. By soil is meant that layer of the earth's surface with a thickness of 18 to 20 c.m.A thin layer is the primary source of food, shelter, clothing, and other consumer goods. The quality of soil is the basis of human civilization. That is why the old world civilizations like Nile civilization, Babylonian civilization, Hwang Ho civilization, Mohenjodaro civilization were grown on the fertile alluvial soils of the river basins. Soil is the basis of agriculture.

The land surface becomes corroded when running water moves over it or the wind blows over it. The soil particles become agitated, loose, and uprooted. The particles move in suspension or by rolling over the ground. Under natural conditions, the removal is low then the amount of soil by soil-forming processes acting over parent materials. This type of removal of dirt is called Normal erosion or Geological erosion. Soil erosion is a normal process. By this process, some areas get eroded, and some areas receive those eroded materials and get filled up or silted up. Erosion lowers the mountains or highlands, and lowlands become filled up with eroded materials and develop alluvial plains or loess plains.

When the lands are titled, and there is no vegetation, the soil becomes entirely exposed to water or wind actions. The removal of soils is hastened. The rate of reduction becomes so high that the new soil formation cannot replenish the amount. This accelerated removal is called Soil erosion. It is essential to check this erosion for the survival of human civilization.

This phenomenon of soil erosion is not a result of recent age. This problem has been initiated with the initiation of agriculture. And as more lands are being brought under agriculture with the increase of population, soil erosion increases.

Soil erosion is a dangerous phenomenon. It brings down the productivity of land, brings famines. When it occurs abundantly, human civilization comes under danger or even extinction. This process has lost many cultures. Because of the need for the production of crops, tilling is necessary. As tilling is done, the possibility of soil erosion initiates and increases and increases with time. However, with suitable measures, soil erosion can be checked to a reasonable extent. At least civilization can be saved from complete ruin. Although the danger of soil erosion was first left in the U.S.A., most of the world's countries have been aware of this today. India is also adopting measures to check it and make the people more aware of this.

3.3 SOIL EROSION TYPES AND THEIR PROCESSES, RS IN CHARACTERIZATION OF LAND DEGRADATION TYPES AND THEIR PROCESSES, SOIL EROSION MODELING USING GEO INFORMATICS

Soil erosion is an extreme form of soil degradation in which natural Geomorphological processes are accelerated so that soil is removed at rates and sometimes several thousand times faster than case under the conditions of natural vegetation and much quicker than rates in which new soil forms.

Factors and causes of soil erosion

The factors of soil erosion include the following:

(1) Climatic Factors:
   (a) Rainfall intensity
   (b) Quantity of rainfall
   (c) Duration of rainfall
   (d) Rainfall distribution
   (e) Terminal velocity of raindrops
   (f) Kinetic energy

   (ii)Temperature

   (iii)Wind

(2) Topographic Factors :
   (i) Relative reliefs
   (ii) Gradient and slope segments

(iii) Slope profile length
(iv) Slope aspects

(3) Lithological Factors :
(i) Rock types
(ii) Chemical and physical properties

(4) Vegetation Factors :
(i) Types of vegetation cover
(ii) Density of vegetation
(iii) Nature of parent rocks

(5) Soil Factors :
(i) Soil erosivity
(ii) Soil erodibility

(6) Human Factors :
(i) Land-use changes
(ii) Farm practice changes
(iii) Construction and building activities
(iv) Mining and excavation
(v) Management measure

1. **Climatic Factor:** Climatic factors influencing runoff and soil erosion include precipitation, mainly rainfall, temperature and wind. The intensity, amount (quantity), duration, and distribution of rain are the most critical components of the rainfall factor that determine the nature and magnitude of soil erosion. A large amount of rainfall (with high-intensity persistence of rain for a relatively longer duration) causes maximum soil erosion if other factors also favour soil erosion. Still, high intensity of rainfall for a short time (and hence the low amount of total rainfall) causes little erosion caused by the parameters of precipitation is dependent mainly on vegetation because vegetation determines infiltration runoff ratio, which ultimately determines the nature and magnitude of soil erosion.

   Overland flow is caused by rainfall intensity (the total amount of rainfall received per unit time, mainly per hour) exceeding infiltration rate (amount of rainwater percolating into soil horizons or ground surface per unit time). Densely vegetated primarily forested areas allow maximum rainwater infiltration because it reaches the ground surface slowly in aerial streamlets through the branches and stems of trees. Thus the resultant overland flow is either absent or is insignificant, and hence soil erosion in the presence of forest cover is negligible. On the other hand, bare arable soils generate maximum overland flow and allow the least infiltration of rainwater because of compaction of the soils caused by the use of agricultural equipment (such as tractors, harvesters, combines etc.). This results in maximum erosion of soils exposed to falling raindrops in the absence of any vegetal cover.

2. **Topographic factors:** Topographic factors include relative reliefs, gradient, slopes segments, length of slope profile, slope aspects etc. These factors are more critical for geological erosion, which is not our concern here. Still, the slope is closely related to soil erosion and soil loss because a steep gradient increases the flow velocity and kinetic energy of surface runoff which accelerates the rate of soil erosion and transport of eroded materials. The studies have shown that the rate of soil loss increases with increasing slope angle. Similarly, the longer slope length accounts for more soil erosion because of greater depth and velocity of overland flow than the shorter slope profile.
3. **Lithological factor:** Lithological factors include rock types and their chemical and physical characteristics. These factors are, in fact, related to geological erosion of all kinds of geomaterials and are not related to soil erosion.
4. **Vegetation factor:** Vegetation factor is a dominant control factor of soil erosion because it (i) intercepts the rainfall through its canopy and thus protects the ground surface from direct raindrop impact, (ii) allows maximum infiltration of rainwater because the rainwater reaches the ground surface very slowly through the leaves, branches and stems as aerial streamlets,(iii)decreases surface runoff because of more infiltration and reduces the velocity of runoff because of obstructions offered by the stems of plants, (iv) reduces the rate of the detachment of soil particles and their transportation, (v) its roots increase soil strength, granulation and porosity (vi) acts as an insulator of soils against high and low temperature and thus prevents the development of cracks, and (vii) markedly reduces the speed of the wind and thus prevents soil erosion by wind.
5. **Soil factor:** The soil factor is related to soil's erodibility, which refers to the resistance of the soil to erosion or its vulnerability to soil erosion. Soil characteristics such as its physical and chemical properties (e.g. practical size distribution, structure, organic matter content, permeability, root content, shear strength, aggregate ability, the tendency to surface crusting etc.) and management practices (such as crop management and land management) affect erodibility of soils which in turn together with eroding power of the processes (erosivity) determines the nature and magnitude of soil erosion.
6. **The human factor:** Human factor has recently become the essential factor of accelerated soil erosion because its multi-facet activities change and modify all of the natural elements (as listed and discussed above) which control soil loss and soil erosion. The human activities leading to an accelerated rate of soil erosion may be grouped under three categories:
   - **(i)** **Land-use** changes include removal of forest and grassland covers for various purposes viz. for an increase in agricultural land, for meeting out ever-increasing demand of space for industrial expansion and urbanization, for the development of mining, for constructional purposes such as roads, rails, dams and reservoirs etc.:
   - **(ii)** **Farm practice changes** such as greater use of farm machines leading to the more significant impact of wheeled traffic on the land (used of tractors, harvesters,

combines etc.), frequent changes in nature of farming such as the shift from field crops to orchard farming or change from field crops to cattle ranching etc., and

(iii) **Management measures** include both crop management and land management. The ever-increasing application of farm machines and chemical fertilizers has essentially modified soils' physical and chemical characteristics.

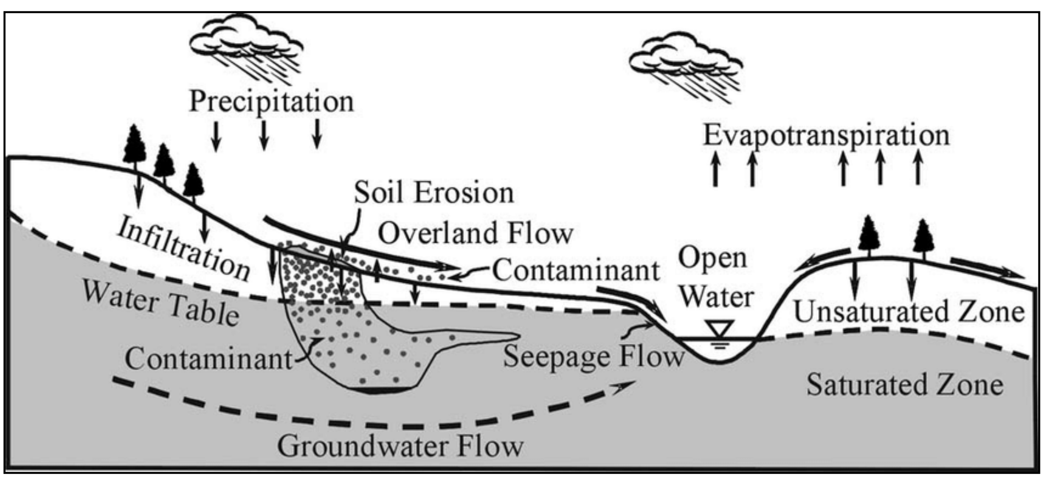
Man induces and accelerates soil erosion by modifying the natural factors of soil erosion through his activities in a variety of ways, as given below:

- Through modification and changes in climatic factors by removal of forest and grassland covers.
- Through modification and characteristics by constructing contour bunds on hilly slopes of agricultural purposes, quarrying and mining, constructing roads, digging canals and drainage ditches, etc.
- Changes in physical and chemical properties of soils by de vegetation ploughing, increased use of machines, fertilizers etc.
- Increase in soil erosion due to extensive grazing by sheep, goats, cattle etc.

Soil erosion involves mainly two processes as follows:

- Loosening and detachment of soil particles from the soil mass, and
- Removal and transport of loose soil particles.

Fig. 3.0 Process of soil erosion

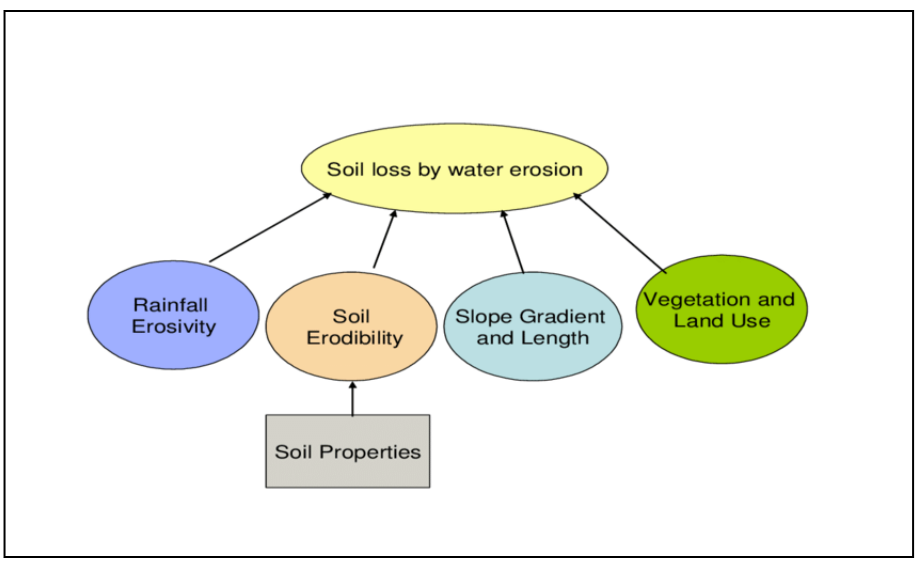


(Source: https://www.researchgate.net/profile/Zhiguo-He-5/publication /239389583 /figure/fig8/AS:668624025055244@1536423798453/Sketch-of-flow-soil-erosion-and-contaminant-transport-in-a-watershed.ppm)

Agents of soil erosion: Main agents of soil erosion are (1) Water and (2) Wind. Although there are differences in their work, their primary function is to remove soil material with the increase in the velocity of water and wind. The rate of soil erosion increases. It is possible to mitigate their effects by building hurdles in their pathways. The fundamental difference between water and wind erosion is soil erosion due to water with the rise in slope. But in the case of wind, there is no direct relationship between pitch and wind erosion.

1. **Soil erosion due to water action:** When soil removal occurs due to rainwater, ice, or waves, the erosion is called water erosion. Erosion due to water action is the most widespread means of soil erosion in the world. It occurs in most parts of the world. As a result of water Action, Mountains and hills are lowered and smoothened on the one hand and valleys, plains and details are originated by deposition of eroded materials on the other hand. In that score, it is both destructive as well as constructive.
   Mechanism of water action: The phenomenon of water erosion can be discussed under two stages viz.- (a) Loosening and detachment of soil particles from soil mass by raindrops which is a preparatory work to transportation, and (b) Transportation of soil. This transportation may be affected in various ways – (i) In suspension, (ii) By rolling over the ground, (iii) Displacement of practices by the splash action of raindrops and (iv) Displacement of particles by the displace particles.
   It is to be mentioned here that the influence of raindrops on soil erosion is very significant. Not only the soil particles or peds are detached or removed. They may be broken up. It has been experimentally observed that raindrops can vertically rise to 0.7 metres from the ground after striking it and may be displaced horizontally to the extent of 1-2 metres on slopping lands or when the wind blows at incredible velocity, these types of displacement perhaps even more.

Fig 3.1 Factors of soil loss by water



(source:https://www.researchgate.net/profile/MuradAburas/publication/299597953/figure/fig4/AS:668925088002065@1536495577706/Factors-that-contribute-to-soil-erosion-and-their-relation-to-soil-properties.png)

Different types of erosion due to water: There are three types of water erosion. However, these three types are interrelated to one another, and their differentiation can hardly be done. In most cases, more than one type can continue simultaneously and develop one over the other. Generally, land erosion is of four types viz. –(a) sheet erosion, (b) rill erosion, (c) gully erosion and (d) ravine.

(a) Sheet erosion: When a thin layer of soil is uniformly removed from the uniformly sloping area, the type of soil erosion is called sheet erosion. In this case, the same amount of soil is removed from all points lying at right angles to the slope direction. This type of erosion is invisible; however, due to the removal of topsoil rich in organic matter, the colour of the soil decreases.

On bare lands, the amount of erosion differs depending upon a few geographical factors. The greater the amount of rainfall more significant is the removal of soil.

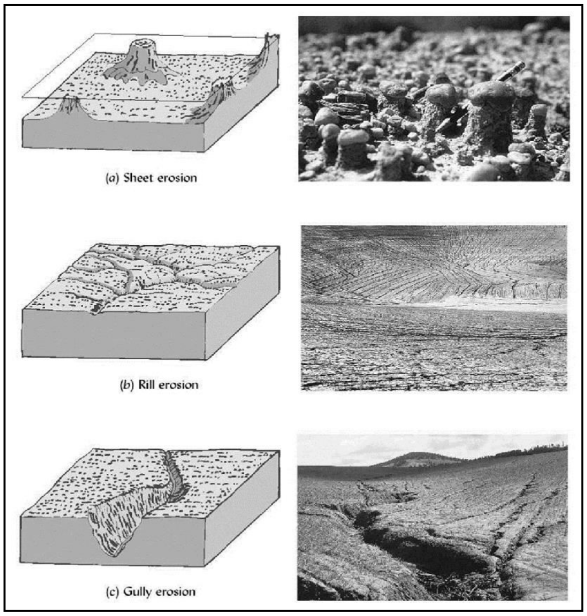
The nature of the soil is another important factor: the loose alluvial or sandy soil, mainly where the impervious subsoil layer is a more significant erosion hazard. Soils with minor organic matter are eroded more. Under areas of sheet erosion, the following water becomes muddier.

Characteristics of soil erosion: Sheet erosion is a prolonged process. So, farmers can not feel its effect readily. The soils gradually become lighter in colour, and in some cases, the underlying parent material becomes exposed. If sheet erosion continues for a long time, there develop some notches. These fine notches are the initiation of riils.

(b)Rill erosion: When the soils without being removed uniformly along slopes and flow small and well defined fine channels, the amount of erosion is more. These channels are called Rills. Rills are less dangerous. These can be overcome by ploughing across the rills. In areas where rainfall is more significant, the media become more vivid, and soil erosion becomes greater. When the snow melts rapidly, then soil erosion becomes greater.

(c) Gully erosion: When the slope of the land is more significant, and the running water flows collectively, then the fine channels become more pronounced. These relatively deep but narrow channels ways are called Gullies, and this type of erosion is called Gully erosion.

Fig. 3.3 Images of landform developed due to the soil erosion by water



(source:https://www.researchgate.net/profile/Safdar-Bashir/publication/ 320729156/ figure /fig3/AS:555440053460992@1509438636094/Types-of-water-erosion-a-Sheet-erosion-b-Rill-erosion-c-gully-erosion-Modified-from.png)

Origin of narrow gullies: The gullies are originated in various ways. Over relatively sloppy areas, the flow of water is concentrated, and the channels become deeper. In the event of taking insufficient measures, those channels gradually become more profound. However, all gullies are4 not originated by water action. Sometimes along the pathways of cattle, hare, and mice etc., gullies may develop. Even gullies can be formed due to the movement of wheels of agricultural implements. Once narrow channels are created, they become increasingly broad and deep by water flows and ultimately develop gullies. The nature and erodibility of the soil and the type of rock they produce are also crucial in their development.

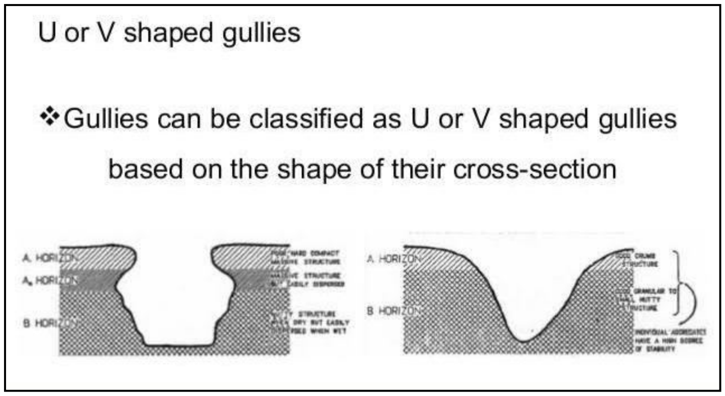
The shape of the gullies: The shape of the gullies may be of three types viz. (i) V-shaped, (ii) U shaped and (iii) Mixed shaped of V and U.

(i) **V-shaped:** If for any reason the lower part of the soil becomes stiff clays or hard rocks, the down-cutting of the valleys becomes less. The narrow valleys which develop over there become V-shaped. It should be remembered that the valleys produced in these areas develop very slow since they develop over hard materials of B horizon.

(ii) **U-shaped gullies : The gullies' valleys that develop over soft loes or alluvium become U-**shaped, and their sides become almost vertical.

(iii) **Mixed type of V and U**: These gullies are developed where the upper part of the soil is composed of more complex materials. As a result, its shape appears V in the initial stage. But sometimes, below the hard top layer, softer rocks or materials may remain. Under these circumstances, if it touches the more delicate fabrics below, then the rate of valley development hastens, and the valley sides become vertical. So in the upper section of the gully, it becomes V-shaped, and the lower team takes the shape of U. Thus, are mixed gullies developed?

Fig. 3.4 Image of different types of gullies



(Source: https://1toz.in/wp-content/uploads/2020/08/IMG_20200809_121026.jpg)

(d) Ravine: The rate of water erosion over lands with more excellent slopes and bare vegetation becomes excessively high. As a result, the narrow gullies rapidly transform into vast and deep valleys whose sides are nearly vertical. These deep valleys with steep sides are called Ravines. However, their depth is less than the canyons. At Gangani of West Medinipur district, this type of ravines has developed.

(e) Badland topography: The landscape composed of gullies and ravines developed under treeless or almost treeless land is called Badland topography. In this case, the valleys of the gullies and ravines become pretty deep. Between two adjacent gullies and ravines become gullies and ravines the land sharp-edged, knife-shaped. These regions are not at all suitable for farming. French tourists in the Dakota state of the U.S.A. were the first to observe this type of topography. In French, they named this type of landscape mauvaises terres, a traversen or lousy land to cross.

This type of landscape is frequently observed in the Chotonagpur region of Jharkhand. This region's erosion rate is high due to a greater slope, although rainfall is relatively high. So, due to over draining erosion is remarkably high and develops badland topography by widespread erosion. These landscapes are shown in the topographical maps by a particular symbol.

Fig 3.5 Badland of river Yamuna, Chambal and Mahi

(Source: https://new-img.patrika.com/upload/mediafiles/2015/12/22/badlands-of-chambal-5678f938e988a_1_835x547.jpg)

2. **Soil erosion due to the wind:** Like water, winds are another agent of soil erosion, and it is no less important than water erosion. Wind erosion is significant over plains with low and uncertain rainfall, i.e. under arid and semi-arid areas. This type of erosion is also dominant near the coasts and over high altitudes. Sometimes wind erosion is also observable in regions of water erosion.

   Types of wind erosion: Unlike water erosion, it is challenging to classify wind erosion. Because in case of wind erosion, the difference in the degree of erosion. Because in the case of wind erosion, the difference in the degree of deterioration is more important than the variation in the type of erosion. From the point of view of comprehensiveness, wind erosion may be localized or widespread, affecting large areas.

   When any place remains covered by natural vegetation, the amount of wind erosion is negligible. That amount may be reciprocated by the building of the same amount of soil from the parent rocks. The type of erosion is called Normal erosion or Geologic erosion. But due to violent winds resulting from depressions, soil removal becomes so great that soil formation cannot reciprocate the amount. This type of removal of soil that can be replenished is called Wind erosion.

Favourable conditions of wind erosion: When the amount of vegetative cover in the land decreases due to the felling of trees or overgrazing, the soils become exposed. Not only is that, soils deprived of the binding effects of organic matter and plant roots. Under such conditions, the soil becomes loose, and the soil particles are carried along the surface and may be intercepted by highlands or hedges or buildings and deposited there.

The nature of soil also determines the amount of soil removal. Some soils are naturally resistant to wind erosion. The winds may quickly erode some soils. The erosion of soil depends on the erodibility of soil, structure of the soil, size of the soil particles and also on the organic matter content of the soil. Experiments have shown that sand particles, under their greater size and clay particles by their structure-building capacity, are less susceptible to erosion. So, the amount of decay is less. Even if the soils are ploughed, they are not easily eroded. Organic matter determines the amount of soil erosion—the greater the amount of organic matter, the lesser the soil erosion or vice versa.

Soil erosion due to the wind is also dependent on the velocity of the wind. Violent winds affect heavy soil loss. Winds with a low-velocity effect less soil loss. Dry wind affects more erosion than moist wind.

The moisture content of the soil is another important factor. Moist soils are generally heavy. They are less susceptible to wind erosion than dry soils.

Influence of wind erosion: No doubt wind erosion is a global problem. Winds remove fertile topsoil and reduce the productivity of the land. Crop yield decreases. However, winds carry and deposit the eroded materials at greater distances and give birth to losses Plains. It has been observed that the wind bounce materials are deposited at great lengths, even at a distance of hundreds or thousands of kilometres. Soils from China's Gobi desert have been deposited in the Hwang Ho river valley and formed extensive loess plains. Similar deposits are observed in Western North America and Argentina of South America. These loess plains are very fertile.

Comparison between water and wind erosion: There is some fundamental difference between water and wind erosion, viz. (a) water erosion is directly related to the land's slope. The eroded materials are carried through the well-defined valleys and reach the seas or lakes. In wind erosion, the eroded materials are carried by the winds and deposited in varying directions. In this case, the heavier and larger particles are not taken for long distances. Only the finer particles are carried for long distances. In the case of the movement of more extensive and heavier particles, the slope has some limited role to play.

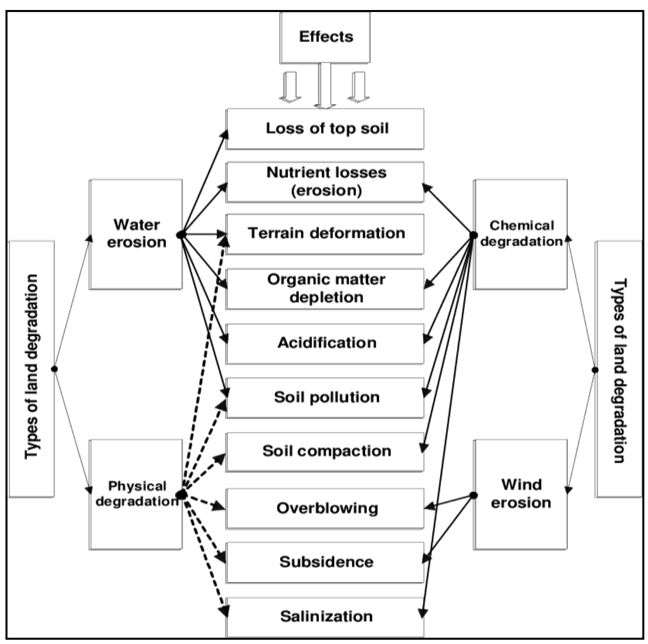
(b) In case of water erosion, the eroded materials are carried in suspension with water. But in case of wind erosion, except the sands of the light coloured soils, none is taken in saturated conditions.

Land degradation and its types: There are different definitions of land degradation, but they all share the premise that land degradation has happened due to the various ways land has been developed and exploited. The term 'degradation' is used to describe changes that occur in addition to those that occur naturally, and it connotes unwelcome alteration brought about by humans. On the other hand, land degradation refers to changes in land's chemical and biophysical properties that degrade its quantity and quality. These changes are frequently linked to a decrease in land's productive potential and economic worth.

The term "land" refers to rocks, soils, and minerals, as well as the vegetation and animal habitats they sustain; the combination of all of these elements creates landscapes. The concept of ecosystems – the interactions and linkages between the living and non-living components of the environment – is invoked by the state of land, or 'land health.' The altered ecosystems of degraded land, where ecosystems have been transformed, continue to function but have a diminished potential to supply the products and services we need, such as food, habitat for threatened species, and landscape amenity.

In addition to meeting the physical demands of growing populations, land has spiritual and cultural value for many people, especially Indigenous people. In many parts of Australia, changes in land conditions following European arrival in 1788 have reduced these values. However, some older cultural sites have recently been discovered due to disturbance by the new immigrants.

Fig. 3.6 Schematic diagram of land degradation



(Source :https://www.researchgate.net/profile/Thomas-Cochrane-2/publication/ 294 868 64/ figure/fig2/AS:669557266071556@1536646300110/Types-of-land-degradation-and-their-effects-on-soil.png)

Extent and Type of Degraded Land: But most importantly, since fertile land is one of several commodities whose scarcity threatens our ability to feed a growing world population, which is expected to top 9 billion by 2050. Julian Cribb notes out in his book 'Coming Famine' that a quarter of the 1.5 billion hectares of global cropland is seriously degraded, up from 15% two decades ago. When we learn that the worldwide need for food is expanding at a rate many times faster than the amount of land available for farming, the gravity of the situation becomes evident.

Soil erosion, soil salinity, soil acidity, and soil pollution are the four main types of land degradation. Nutrient loss and soil structure deterioration are also emphasized while discussing these issues.

Already we are discussing soil erosion. So, now we are talking about other types of land degradation.

Soil Salinity: Salinity in the soil is not a new phenomenon. Over millions of years, rain, wind, and marine ingressions (land that was once buried beneath the sea) deposited salt from the oceans, which was subsequently leached through soils into underground aquifers and groundwater until natural equilibrium was created.

There are two types of salinity – dryland salinity and salinity caused by irrigation practices.

(1) **Dryland salinity:** Geology and hydrology mix at various points throughout the landscape to generate a place where water enters and flows underground. The equilibrium between evapotranspiration (the transfer of water from soils via plants and subsequently evaporation from the leaves into the air) and the quantity of water naturally flowing underground down the slope is disrupted when these recharge regions are removed of deep-rooted vegetation. The amount of water travelling through the soil profile increases, and the dissolved salts in the water table rise. Soil waterlogging is frequently a precursor to salinity.

(2) **Salinity caused by irrigation practices:** Irrigation-Induced Drought When irrigation water percolates through the soil, it exceeds the dispersal capacity of subsurface aquifers and drainage systems, causing salinity. When dissolved salts in groundwater rise to within a meter of the soil surface, the growth of the most diminutive salt-resistant plants are hampered.

(3) Soil Acidification: When anions such as nitrate (NO_3^-) from nitrogenous fertilisers and the nitrate-producing process in legume-based pastures leach through the soil profile with positively charged cations (e.g., K^+, Ca^{++}), leaving an excess of positively charged hydrogen ions (H^+) (the more hydrogen ions, the lower the pH), induced acidification occurs. Changes in soil acidity can happen quickly, but because plants thrive in the pH range of 5-8, it can take decades for productivity to decline. When the pH falls below 4, fine fractions in some soils are mobilised in the soil profile, leaving barren coarse sands at the surface. Other factors contributing to acid soils include increased organic acids due to stored organic matter and the elimination of alkaline plant products, making soils acidic. The most straightforward answer to acid soil problems is to add lime. However, this is costly and does not address the underlying issues.

(4) Contaminated Soils: We know that fertilisers include heavy metal contaminants, with cadmium being the most concerning because it is the one that goes the fastest from soils to edible food crops. Pesticide residues have been found in agricultural goods in the past. Still, some people believe that the benefits of pesticide use exceed the dangers, especially now that the risks are better understood, consumption is better regulated, and integrated pest management strategies are more extensively adopted. However, there is a growing interest in growing and eating pesticide-free crops.

Approaches to assessing land degradation: Gibbs and Salmon (2015) identified four main approaches to mapping the global extent of degraded lands in a review of different methods and attempts to map global land degradation: expert opinions satellite observation of vegetation greenness – for example, remote sensing of Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Plant Phenology Index (PPI); biophysical models; and inventories of land use/condition. They provide a reasonably comprehensive assessment when taken together, but none of them measures the process's complexity on its own.

Although there are still knowledge gaps to be filled and the problem of baseline values, there is widespread agreement that remote sensing and field-based methods are critical for assessing and monitoring land degradation, particularly over large areas (such as global, continental, and sub-continental).

Remote sensing can provide valid land degradation proxies in terms of severity, temporal development, and area. Several indexes used to measure land conditions and monitor changes in land conditions, such as the extent of gullies, severe forms of rill and sheet erosion, and deflation, are examples of these proxies of land degradation. The availability of open-access, quality-controlled, and regularly updated global databases of remote sensing data is priceless because it is the only way to monitor enormous areas consistently over decades. Because it represents land cover, an essential aspect for soil preservation, the NDVI is one of the most often used ways to estimate land degradation as a proxy for Net Primary Production (NPP). Although NDVI is not a direct measure of vegetative biomass, NDVI integrated throughout a season and in situ NPP have a strong relationship.

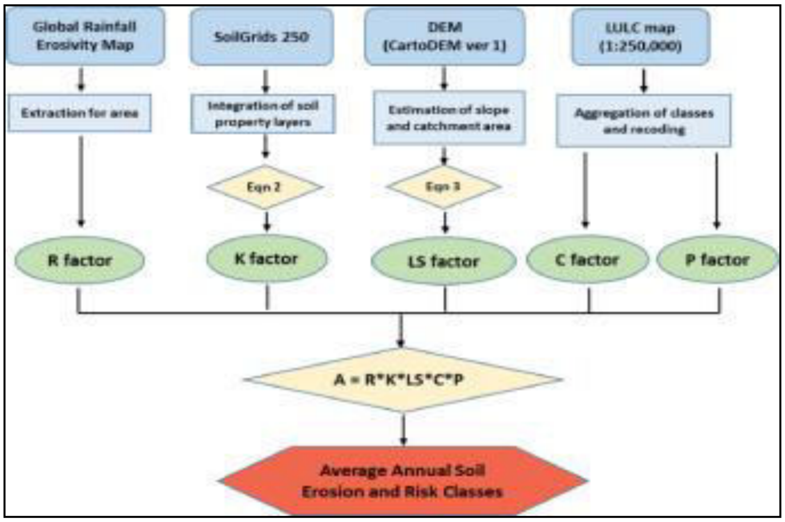
Even though remote sensing has a lot of potentials, applying it to land degradation and recovery is difficult because structural changes often occur at scales too small for most remote sensing technology to detect. Furthermore, if remote sensing is dependent on vegetation index data, other types of land degradation, such as nutrient depletion, changes in soil physical or biological properties, and loss of human values, cannot be inferred directly. Improved estimates of carbon stocks and tree biodiversity can be obtained using a mix of remotely sensed pictures and a field-based technique.

Furthermore, the bulk of trend methodologies used would only detect the most severe deterioration processes, making them useless as a degradation early-warning system. Additional investigations utilizing higher-resolution data, such as that provided by the Landsat and SPOT satellites, would be ideal for delivering more localized information on the trends seen. New methods for assessing land degradation with a high spatial resolution are being developed, although development is slow due to time series. SAR data has been demonstrated to help estimate soil surface parameters, particularly surface roughness and soil moisture, and identify and measure selective logging. To be able to quantify land deterioration using remote sensing entirely, more research is needed.

In conclusion, because land degradation is such a complicated and global process, there is no approach for objectively and consistently estimating land deterioration over huge areas (very high confidence). However, there are various methods for assessing different aspects of land degradation or providing proxies. When combined with other data types (for example, field observations, inventories, and expert views), remote sensing is the only way to provide geographically detailed and internationally consistent data over periods relevant to land degradation (several decades).

Soil erosion modelling using geo-informatics: Computer simulation models can be employed alone or combined with remote sensing measurements to estimate land degradation. To some extent, the Revised Universal Soil Loss Equation (RUSLE) can be used to forecast long-term average yearly soil loss due to water erosion. The product of rainfall-runoff erosivity, soil erodibility, slope length and steepness factor, conservation factor, and support practice parameter have all been used in RUSLE to assess soil loss. The inability to account for soil loss through gully erosion or mass wasting events and the fact that it cannot anticipate sediment paths from hill slopes to water bodies are inherent limitations of RUSLE. Because RUSLE models only offer gross erosion, a new module in the RUSLE system is required to estimate the sediment production from the modelled hill slopes. WaTEM/SEDEM, a regionally distributed sediment delivery model, has been extensively tested throughout Europe. Another aspect that must be considered in the modelling of soil erosion is wind erosion. To account for the constraints of the RUSLE models, new models must be built.

Fig 3.7 The different datasets used in the study were integrated into the RUSLE model in a GIS environment



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The Revised Universal Soil Loss Equation (Renard, 1997) is improved from of USLE (Wischmeier and Smith 1965, 1978), used to estimate average annual soil erosion potential, $A = R \times K \times L \times S \times C \times P$ …(1)

Where, A = computed average annual soil loss (tons/ha/year), R = rainfall-runoff erosivity factor, K = soil erodibility factor, L = slope length factor, S = slope steepness factor, C = cover-management factor, P = conservation practice factor However, over the period each component was further revised.

Rainfall-runoff erosivity factor: Annual Relationship: $R_a = 81.5+0.380P_a$ …(2) Seasonal Relationship : $R_s = 71.9 + 0.361P_s$ …(3) Where, R = average erosion index, P = average rainfall (mm), Subscript a and s stands for annual and seasonal.

Soil erosion is principally controlled by rainfall and water flow. Soil erosion due to climate is dependent on several conditions such as-

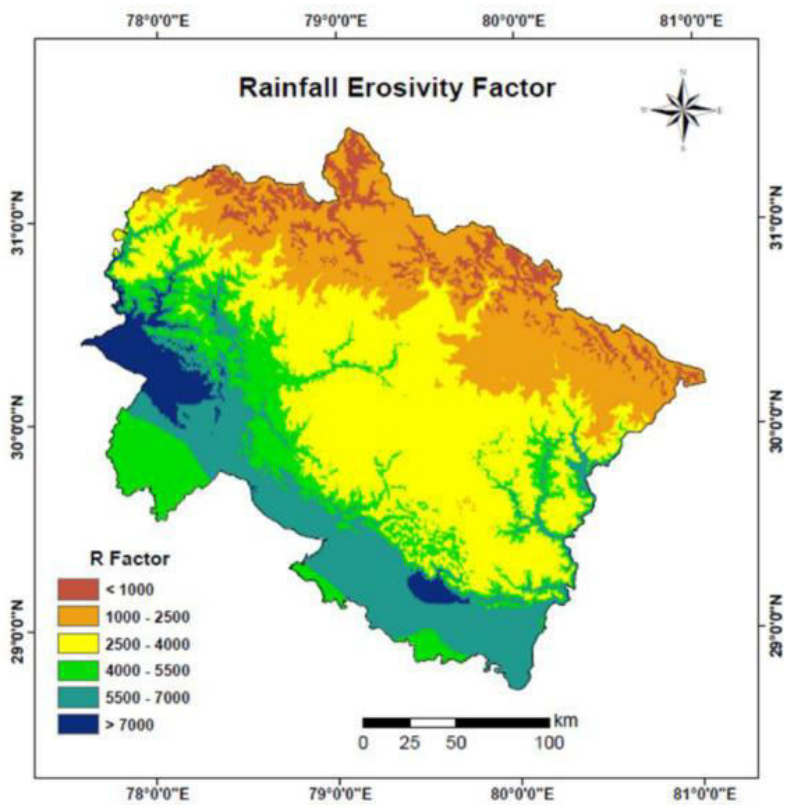
(i) Generally, the greater the rainfall is the scope of soil erosion. However, one must remember that the intensity of rains, i.e. how much precipitation occurs in an hour, is more important than the total amount because few showers of rainfall over time are less effective in soil erosion than violent rain occurring within a short time. It is for this reason that soil erosion is greater in deserts.

(ii) It is also crucial whether rainfall is occurring in a particular season or occurring throughout the year. The possibility of soil erosion will be greater if the precipitation occurs heavily in a specific season than uniformly disturbed throughout the year.

(iii) In monsoon regions, if rainfall occurs heavily just after dry summer, the degree of erosion will be more remarkable because the surface remains mostly bare of vegetation during that period. Besides, if heavy rainfall occurs just after tilling the land, the degree of soil erosion becomes greater because the soil remains loose after tilling.

(iv) During tornadoes or hurricanes, or norwester's, the erosion remains at its highest level generally.

Fig.3.8 Rainfall erosivity factor



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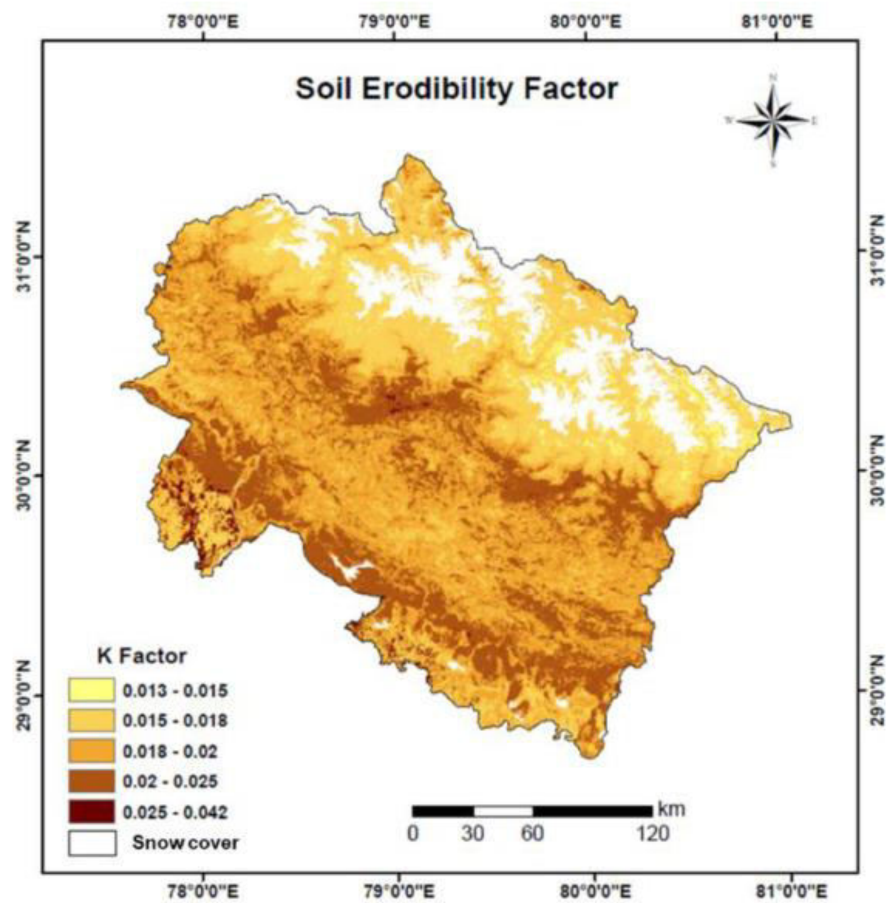
Soil Erodibility Factor K In RULSE, K is assumed to be constant throughout the year. Tables of K values are available in Soil Conservation Service Offices for most soils in the U. S. In the absence of published data, a widely used relationship for predicting erodibility is a nomograph by Wischmeier et al. (1971). Soil erodibility in the nomograph is envisioned as a function of soil and soil profile parameters:

- Percent silt (MS; 0.002-0.05 mm)

- Percent very fine sand (VFS; 0.05-0.1 mm)
- Percent sand (SA; 0.1-2 mm)
- Percent organic matter (OM)
- Soil structure code (s)
- Soil permeability code (p).

Fig 3.9 Soil erodibility factor



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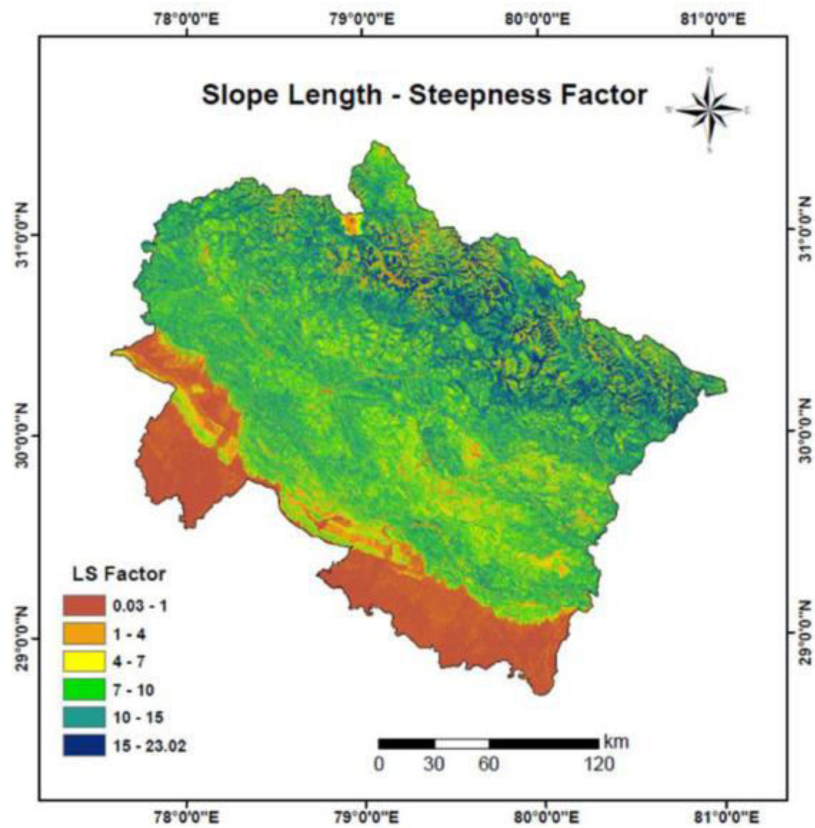
Slope Length and Slope Steepness Factor LS The effect of topography on erosion in RUSLE is accounted for by the LS factor. The slope length factor (L) is calculated using the following equation,

$L = (\lambda/22.13)^{m}$

Where, 22.13 = the RUSLE unit plot length (m) and m = a variable slope-length exponent. Slope length λ is defined as the horizontal distance from the origin of overland flow to the point where (1) the slope gradient decreases enough that deposition begins or (2) runoff becomes concentrated in a defined channel.

The length of the slope of the land influences the degree of soil erosion. The degree of erosion is proportional to the length of the slope. Researches have shown that if the length of the slope is doubled at an area of 7% slope, the erosion will be increased by 2.6 times.

Fig 3.10 Slope length- steepness factor



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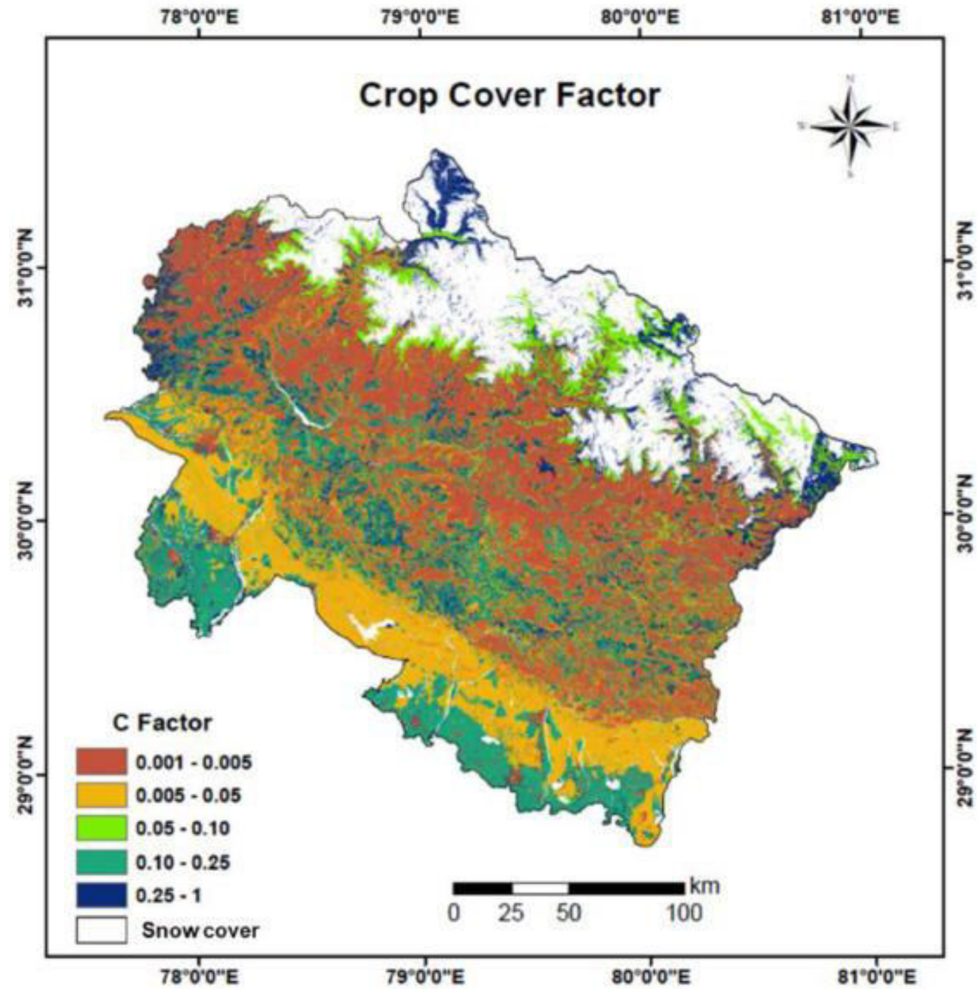
Cover-Management Factor C The cover-management factor is the ratio of soil loss from an area with specified cover and management to an exact location in continuous tilled fallow. In his PhD thesis, De Jong (1994) described vegetation indices to extract vegetation parameters for erosion models. Based on his work following statement can be assumed to be valid in general: i) NDVI and RULSE C-factor is correlating; ii) There is a linear relation between NDVI and RULSE C-factor Based on these assumptions, the NDVI map can be analyzed to formulate the linear equation between NDVI and C factor. The NDVI values less than zero (0) indicate the water and snow, so the negative values should not be considered in preparing the C factor equation. With these boundary conditions, the regression equation for the C factor can be developed.

Fig 3.11 Cover management factor



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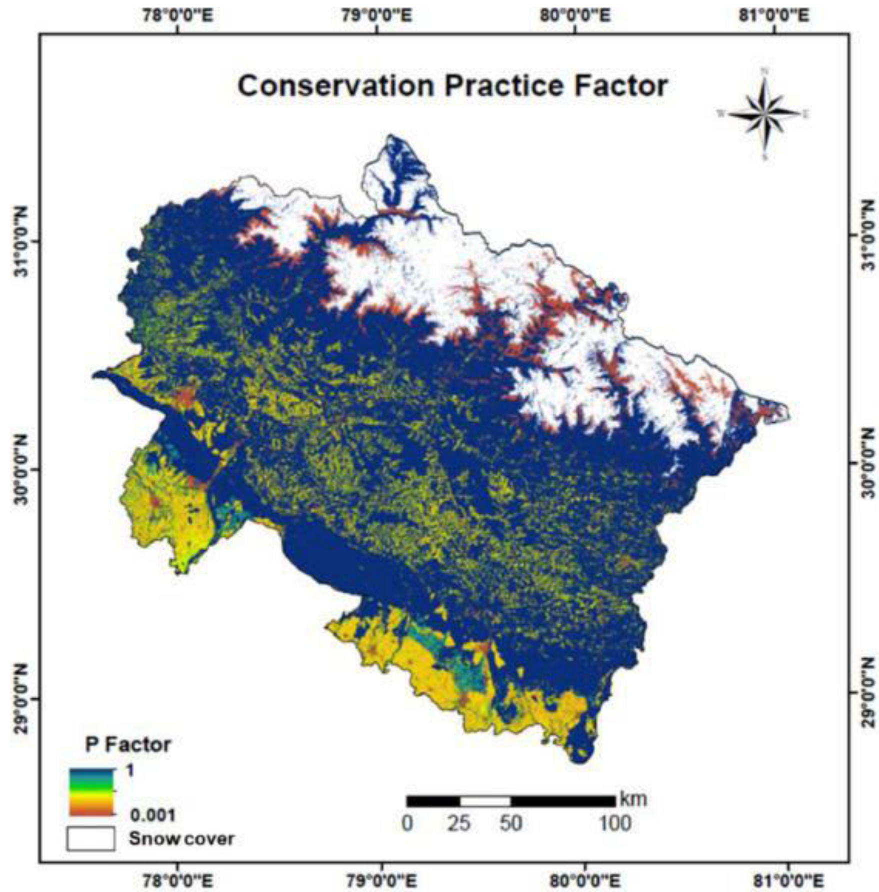
Conservation practice factor(P): It is observed that cultivation is essential for the necessity of man. And whenever lands are ploughed, they become subject to soil erosion. But adoption of proper measures reduces the propensity of erosion so that the yield of a crop is not unduly hampered. Even cultivation of crop over slopy lands become possible without much soil damage. The measure is (a) Contour cropping, (b) contour strip cropping, (c) Terrace cultivation, (d) Cultivation of grass along diversion channels or drainage channels, (e) construction of check dams along river valleys etc. Adoption of these measures reduces the velocity of water flow and this reduction moderates soil erosion.

Fig 3.12 Conservation practice factor



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Soil erosion remained a significant issue. Pimentel et al. (1995) estimated that one-third of the world's agricultural lands had been lost to erosion in the previous 50 years, with about 1.0 106 ha of additional agricultural land lost annually as a result of accelerated soil erosion, in a study conducted near the end of the twentieth century. In the United States and Europe, erosion losses were predicted to be 17 Mg ha1 year1, while in Asia, Africa, and South America, losses were assessed to be 35 Mg ha1 year1 (Pimentel et al., 1995). Soil erosion is expected to cost the United States $27 billion in onsite expenditures and $17 billion in offsite costs per year, for a total of $44 billion per year, or nearly $100 per hectare of agriculture and pasture. It was predicted that avoiding erosion would cost $8.4 billion per year. In 2015 dollars, these figures would be $68.5 billion per year, $156 billion per year, and $13 billion per year, respectively (US BLS, 2016). In every way, these figures pointed to a significant environmental issue that needed to be addressed to achieve long-term sustainability.

By the end of the twentieth century, the United States was likely the only country with long-term soil erosion data collected using standardized procedures; other countries had intermittent and shorter-term data coverage. According to Morgan and Rickson (1990), as the twentieth century drew close, no single European country's annual extent of erosion was recognized. However, erosion issues were identified and documented in various parts of the world (Morgan et al., 1998a), even though the total effort did not have the same level of national coordination as in the United States. While agriculture has been practiced in Europe for millennia, it was not until the second part of the twentieth century that widespread concern about the consequences of erosion and other agriculturally related environmental problems became widespread (Morgan and Rickson, 1990; Stoate et al., 2001).

3.4 SUMMARY

In this unit, you have studied the fundamental idea of soil erosion, land degradation and a model to measure soil loss by Geoinformatics with the help of spectral reflectance. Let us now summarize what we have learned:

- Soil erosion is a natural phenomenon, but sometimes it increases with the interference of humans.
- There are so many factors that involve soil erosion like climatic, topographical, human factors etc.
- Water and wind are the main two agents of soil erosion.
- Several landforms evolved due to water and wind soil erosion.
- Favourable conditions like sloppy land, bare land are responsible for a faster process of soil erosion.
- Land degradation is a decade of land potentiality.
- Soil salinity, soil pollution and many other things are responsible for land degradation.
- NDVI, EVI, PPI and RUSLE are major models to analyze soil erosion model.

3.5 GLOSSARY

- **Erodibility-** It is a measure of the inherent resistance of geologic materials (soils and rocks) to erosion.
- **Erosivity-** The potential of raindrop impact on soil.
- **Equilibrium-** A state in which opposing forces or influences are balanced.
- **Indigenous-** It is originating or occurring naturally in a particular place; native.
- **Kinetic energy-** Is the energy of motion
- **Suspension -** It is a type of wind erosion that involves the movement of dirt and dust particles through the wind.
- **Terrace-** Bench or step that extends along the side of a valley and represents a former level of the valley floor.

3.6 ANSWER TO CHECK PROGRESS

1) List the factors responsible for soil erosion.

2) List the approaches which are used to measure soil erosion.

3) List the landscape which is evolving due to water soil erosion.

4) List the favourable condition for wind erosion.

3.7 REFERENCE

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3.8 TERMINAL QUESTIONS

1) Compare between water soil erosion and wind soil erosion.
2) How does human interference increase soil erosion?
3) How are ravines formed?
4) What are the components of RUSLE?

BLOCK 2 : APPLICATIONS OF GEOINFORMATICS IN GEOMORPHOLOGY

UNIT 4 - CONCEPTUAL FRAMEWORK-INTERFACES GEO INFORMATICS WITH GEOSCIENCES, BASIC GEOMORPHIC PROCESS, AND FEATURES

4.1 OBJECTIVES

After studying this unit, you should be able to:

- Define Geoinformatics and geosciences
- Identify various components of the geomorphic process
- Easy to understand geomorphologic features by using Geoinformatics
- Develop a concept about various Geoinformatics tools
- Discuss the advantages and diverse application of Geoinformatics in geosciences

4.2 INTRODUCTION

Geoinformatics has been described as "the science and technology dealing with the structure and character of the information about earth, its capture, its classification and qualification, its storage, processing, portrayal, and dissemination, including the infrastructure necessary to secure optimal use of this information" or "the art, science or technology dealing with the acquisition, storage, processing production, presentation and dissemination of Geoinformation.

The term Geoinformatics consists of two words, geo (Earth) and informatics (the study of information processing). Hence, Geoinformatics can be understood as the union of Geosciences and Informatics. We can say that Geoinformatics broadly deals with information technology for the collection, analysis, storage, retrieval, representation, and dissemination of information about the Earth.

The term 'Geoinformatics' is believed to have come into existence just a few decades back due to integrating three disciplines: photogrammetric, remote sensing, and geographic information systems.

There is another term, i.e. 'Geomatics', which was first used in Canada at Laval University in the early 1980s to describe the disciplines mentioned above, realizing the concept of that increasing potential of computing which was revolutionizing surveys and representation sciences. According to the Department of Geomatics Engineering, University of Calgary, "Geomatics Engineering is a modern discipline, which integrates acquisition, modelling, analysis, and management of spatially referenced data, i.e. data identified according to their locations".

Geomatics Industry Association of Canada (GIAC) defines Geomatics "as a technology and service sector focusing on the acquisition, storage, analysis, dissemination, and management of geographically referenced information for improved decision-making".

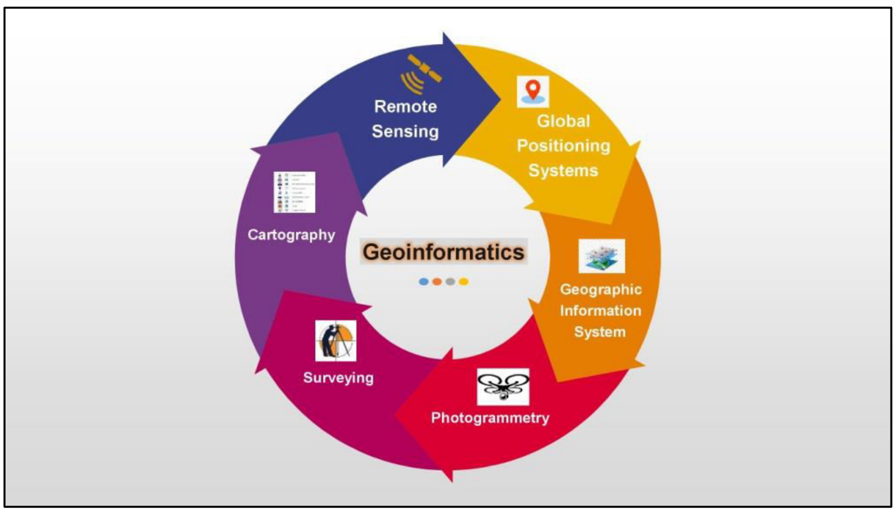
Geomatics is derived from the French word Ge'omatique, which Dubuisson, a French Photogrammetric, coined. The term Geomatics is more commonly used in North America. In contrast, Geoinformatics seems to be more prevalent in Europe, such as in the Netherlands, where there is a Geoinformatics Department at the famous I.T.C. (International Institute for Aerospace Survey and Geosciences').

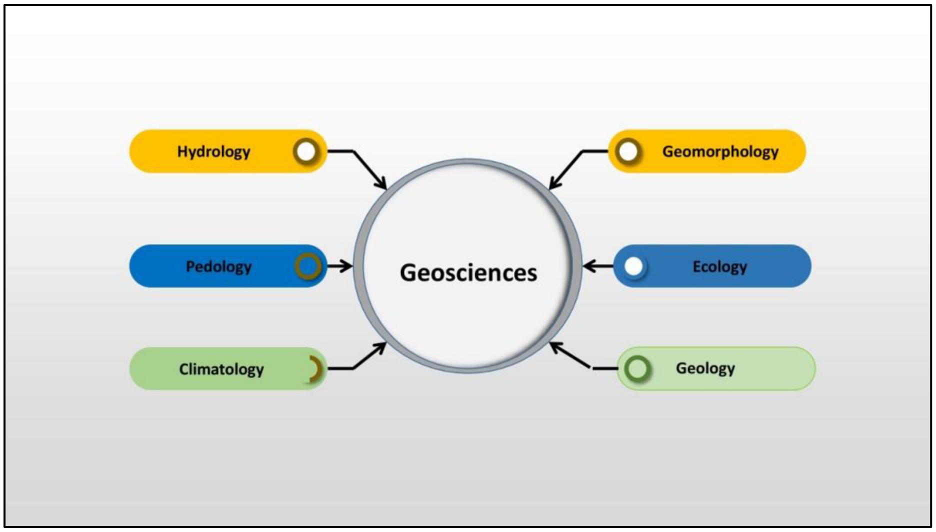
Michalak (2000) considers the term 'geomatics' to be interchangeable with 'Geoinformatics'. However, some people think that both Geomatics and Geoinformatics include and rely heavily upon geodesy's theory and practical implications. There is a difference in the meanings that the terms Geomatics and Geoinformatics convey.

Let us come back to the definition of Geoinformatics. Wikipedia defines Geoinformatics as "…the science and the technology which develops and uses information science infrastructure to address the problems of geography, geosciences and related branches of engineering".

Geoinformatics has been described as "the science and the technology dealing with the structure and character of spatial information, its capture, its classification, its storage, processing, portrayal, and dissemination, including the infrastructure necessary to secure optimal use of this information" or "the art, science, and technology dealing with the acquisition, storage, processing, production, presentation and dissemination of Geoinformation" (Oledzki, 2004). The Conceptualization of the Geoinformatics can be illustrated as in Fig. 4.1.

Fig. 4.1 Conceptualization of Geoinformatics (a) Geoinformatics representation and, (b) Geosciences broad classes





Oledzki (2004) believes that the term Geoinformatics is more easily understood and better at conveying the essence of spatial research focusing on informatics. With this background, you will now be able to define Geoinformatics.

Geosciences' (also called Earth Science) is the study of Earth. Geosciences include so much more than rocks and volcanoes; it studies the processes that form and shape Earth's surface, the natural resources we use, and how water and ecosystems are interconnected. Geosciences' uses tools and techniques from other science fields, such as chemistry, physics, biology, and math!

Geoscientists can be seen working in many STEM (Science, technology, engineering, and mathematics are all examples of STEM disciplines.) related fields, but they all study our planet somehow. Individual studies can focus on anything from climate change or volcanic activity to how the environment and human societies interact with each other, as highlighted by the American Geosciences Institute (A.G.I.). Borrowing perspectives, processes, and frameworks from different scientific disciplines like chemistry and physics, geosciences allows you to study the nature of our planet and the issues that threaten it through multiple lenses.

The following fields of science are generally categorized within the Earth sciences:

- Geology describes the rocky parts of the Earth's crust (or lithosphere) and its historical development. Major sub-disciplines are mineralogy and petrology, Geomorphology, palaeontology, stratigraphy, structural geology, engineering geology, and sedimentology.
- Physical geography focuses on geography as an Earth science. The seasons, climate, atmosphere, soil, streams, landforms, and oceans of the Earth are all studied in physical geography. Physical geography can be divided into several branches or related fields, as follows: geomorphology, biogeography, environmental geography, palaeogeography, climatology, meteorology, coastal geography, hydrology, ecology, glaciology. Geophysics and geodesy investigate the shape of the Earth, its reaction to forces, and its magnetic and gravity fields. Geophysicists explore the Earth's core and mantle and

the tectonic and seismic activity of the lithosphere. Geophysics is commonly used to supplement the work of geologists in developing a comprehensive understanding of crustal geology, particularly in mineral and petroleum exploration. Seismologists use geophysics to understand plate tectonic shifting, as well as predict seismic activity.

- Geochemistry is defined as the study of the processes that control the abundance, composition, and distribution of chemical compounds and isotopes in geologic environments. Geochemists use the tools and principles of chemistry to study the design, structure, processes, and other physical aspects of the Earth. Major sub-disciplines are aqueous geochemistry, cosmochemistry, isotope geochemistry, and biogeochemistry.
- Soil science covers the outermost layer of the Earth's crust that is subject to soil formation processes (or pedosphere). Major subdivisions in this field of study include edaphology and pedology.
- Ecology covers the interactions between organisms and their environment. This field of study differentiates the study of Earth from other planets in the Solar System, Earth being its only planet teeming with life.
- Hydrology, oceanography, and limnology are studies that focus on the movement, distribution, and quality of the water and involve all the components of the hydrologic cycle on the Earth and its atmosphere (or hydrosphere). "Sub-disciplines of hydrology include hydrometeorology, surface water hydrology, hydrogeology, watershed science, forest hydrology, and water chemistry.
- Glaciology covers the icy parts of the Earth (or cryosphere).
- Atmospheric sciences cover the gaseous parts of the Earth (or atmosphere) between the surface and the exosphere (about 1000 km). Major sub-disciplines include meteorology, climatology, atmospheric chemistry, and atmospheric physics.

Remote sensing is the base behind the informatics that has been used in numerous fields, including geography, land surveying and most Earth Science disciplines (for example, hydrology, ecology, meteorology, oceanography, glaciology, geology); it also has military, intelligence, commercial, economic, planning, and humanitarian applications.

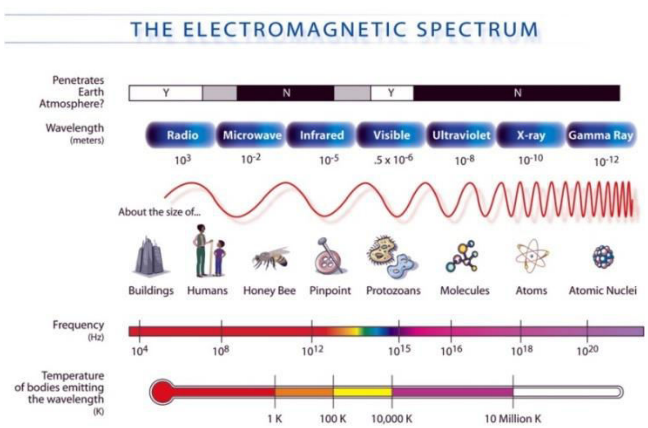
"Remote Sensing is the non-contact recording of information from the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum through instruments such as cameras, scanners, lasers, linear arrays, and/or area arrays located on platforms such as aircraft or spacecraft, and the analysis of acquired information through visual and digital image processing." The source of energy could be from passive source like sun and active source like the microwave energy.

Electromagnetic Radiation: The incident energy from sun comes as Electromagnetic radiation (EMR). EMR is the radiant energy released by specific electromagnetic processes. Visible light is electromagnetic radiation; other familiar electromagnetic radiations are invisible to the human eye, such as radio waves, infrared light and X-ray Classically, electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields that propagate at the speed of light, which, in a vacuum, is commonly denoted c. Inhomogeneous, isotropic media, the oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy and wave propagation, forming a transverse wave. The wave front of electromagnetic waves emitted from a point source (such as a light bulb) is a sphere. The position of an electromagnetic wave within the electromagnetic Spectrum can be characterized by either its frequency of oscillation or its wavelength. Different names call electromagnetic waves of different frequencies since they have various sources and effects on matter. To increase the frequency and decrease wavelength, radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays.

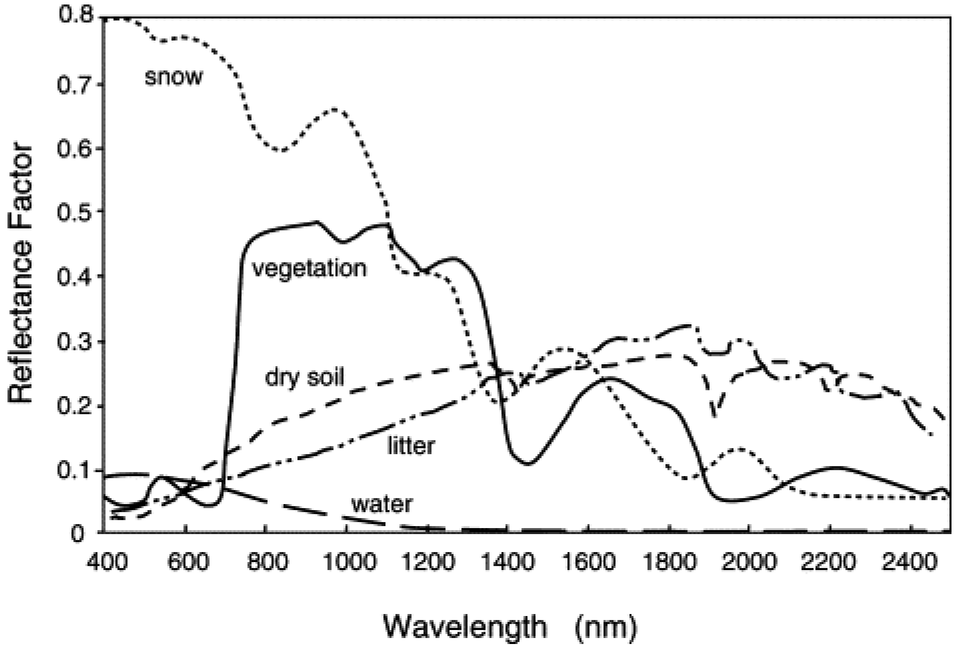
Electromagnetic Spectrum, The distribution of the continuum of all radiant energies, can be plotted either as a function of wavelength or frequency in a chart known as the electromagnetic Spectrum. The electromagnetic Spectrum is the collective term for all known frequencies and their linked wavelengths of known photons. The electromagnetic Spectrum has a different meaning and is instead the characteristic distribution of electromagnetic radiation emitted or absorbed by that particular object.

The sequence from the longest wavelength (radio waves) to the shortest wavelength (gamma rays) is likewise an energy series from lowest to highest. Keep in mind that waves transmit energy from one location to another. A radio wave has low energy content, but a gamma ray has high energy content. The reflectance of EMR for various surfaces dependent of physical, chemical and biological properties of the substance and varies with respect to the different wavelength of the spectrum.

Figure 4.2: (a) EMR and, (b) the Spectral reflectance signatures



(Source: https://commons.wikimedia.org/)



With this background, you will now be able to define geosciences.

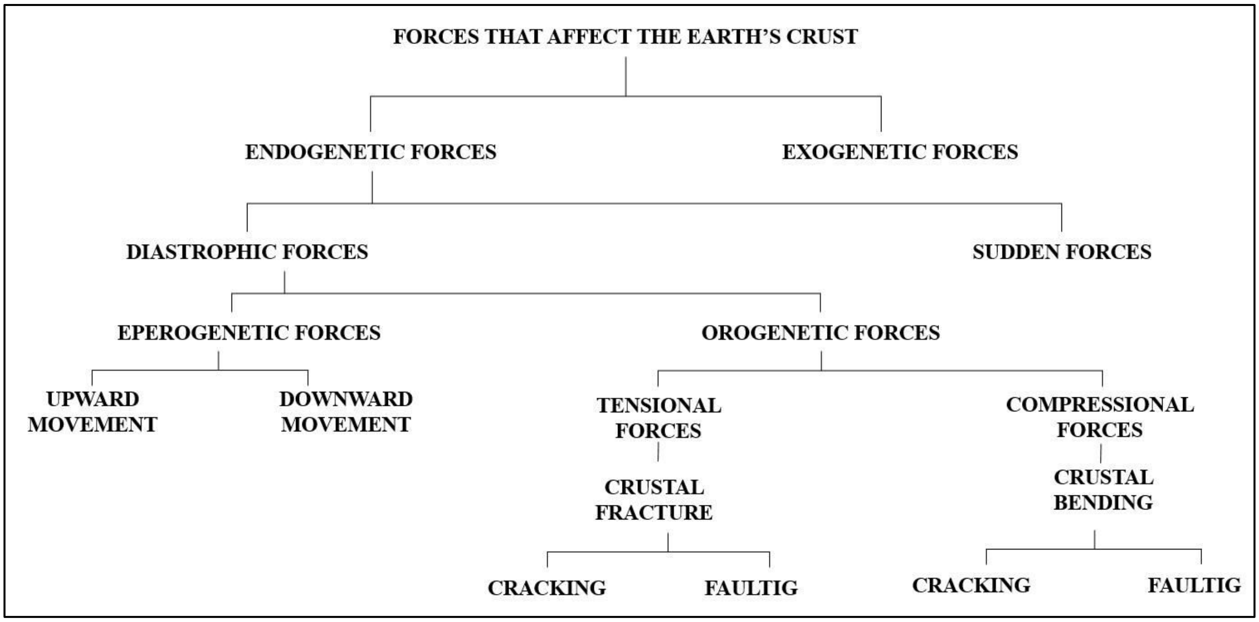
4.3 CONCEPTUAL FRAMEWORK –INTERFACE OF GEOINFORMATICS WITH GEOSCIENCES, BASIC GEOMORPHIC PROCESS, AND FEATURES ,APPLICATION OF GEOINFORMATION IN GEOMORPHOLOGY

You would be introduced to the major disciplines later in the relevant courses. However, let us get a brief idea about the various Geoinformatics fields with geosciences and basic conceptual geomorphic processes and features.

Basic geomorphic process and features

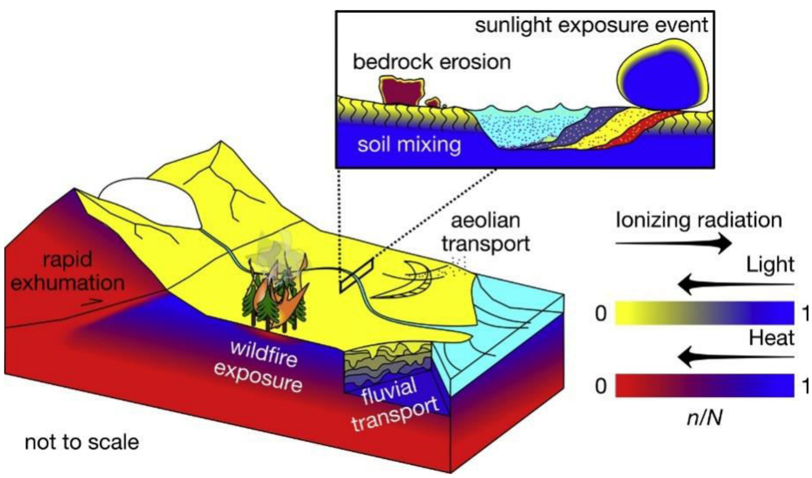
The study of forces affecting the crust of the Earth or geomorphic processes is of paramount significance. These forces and resultant movements are involved in the creation, destruction, recreation, and maintenance of geomaterials and numerous types of relief features of varying degrees magnitudes. These forces very often affect and change the Earth's surface. The change is a law of nature. The geomorphic process has two types, e.g.(i) long period changes and (ii) short-period changes. Long-period changes occur so slowly that man is unable to notice such changes during his life –period. On the other hand, short-period changes occur so suddenly that these are detected within a few seconds to a few hours,e.g. seismic events, volcanic eruptions, etc. The forces, which affect the Earth's crust, are divided into two broad categories based on their sources of origin, e.g. (1) endogenetic forces and (2) exogenetic forces.

Schematic Presentation of Forces Affecting the Earth's Crust



(Source: Singh, 2019)

Fig.4.3 Geomorphic Process presentation

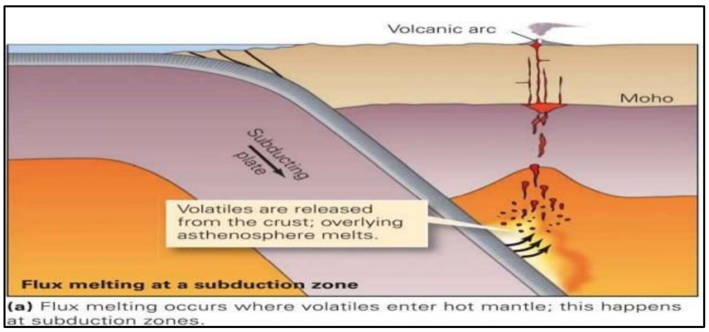


(Source: Brown, 2020)

Endogenetic Forces

The forces coming from within the Earth are called endogenetic forces, which cause two types of movements in the Earth, viz (i) horizontal movements and (ii) vertical movements. These movements motored by the endogenetic forces introduce various kinds of vertical irregularities that give birth to numerous relief features on the Earth's surface (e.g. mountains, plateau, plains, lakes, faults, folds, etc.).Volcanic eruptions and seismic events are also expressions of endogenetic forces. Such movements are called sudden movements, and the forces responsible for their origin are called sudden forces. We do not know precisely the mode of the endogenetic forces and movement because these are related to the interior of the Earth, which our scientific knowledge is still limited. On average, the origin of endogenetic forces is associated with the thermal conditions of the Earth's interior. Generally, the endogenetic forces and related horizontal and vertical movements are caused due to contraction and expansion of rocks because of varying thermal conditions and temperature changes inside the Earth. The displacement and readjustment of geomaterials sometimes occur so rapidly that earth movements are caused below the crust. The endogenetic forces are divided, based on intensity, into two major categories, viz. (i) Diastrophic Forces and (ii) Sudden Forces.

Fig.4.4 Showing the Process of Endogenetic Forces



(Source: class. in)

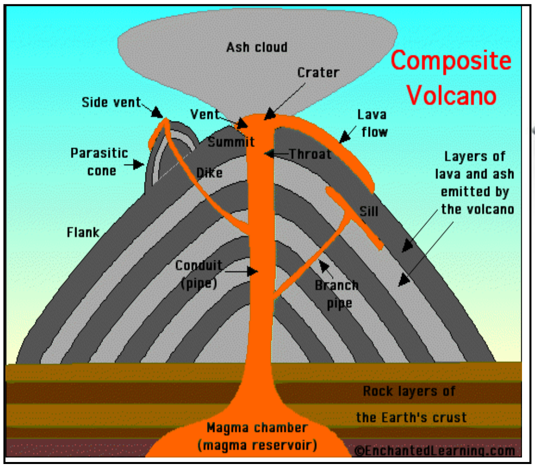
(1) Sudden forces and movement

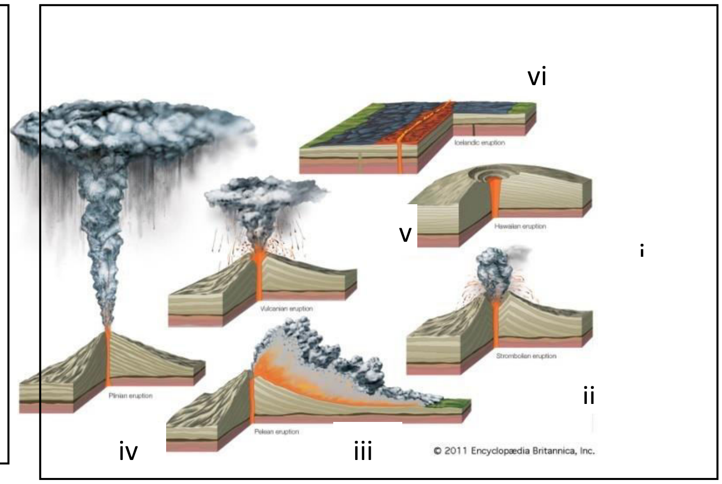
Sudden movements, caused by sudden endogenic parties coming from deep within the Earth, cause such sudden and rapid events that cause massive destructions at and below the Earth's surfaces. Like volcanic eruptions and earthquakes, such events are called 'extreme events and become disastrous when they occur in densely populated areas. These forces work very quickly, and their results are seen within minutes. It is important to note that these forces are the result of long-period preparation deep within the Earth. Geomorphologically, these sudden forces are termed 'constructive forces because these create certain relief features on the Earth's surface. For example, volcanic eruptions result in the formation of volcanic cones and mountains. At the same time, fissure flows of lavas from extensive lava plateau (e.g. Deccan plateau of India, Columbian plateau of the U.S.A., etc.) and lava plains. Earthquakes create faults and fractures, lakes, etc.

Create faults and fractures, lakes, etc.

Fig.4.5 showing the process of Volcanism

Fig. 4.6 Showing various types of volcano mountains (i-HawaiianType, ii-Strombolian Type, iii- PeleanType, iv-Visuvia Type





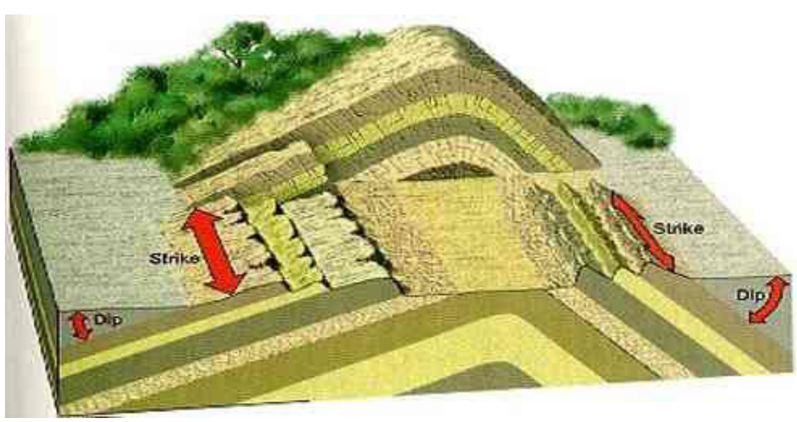
(Source: enchantedlearning.com)

Source: https://encrypted-tbn0.gstatic.com

(2) Diastrophic forces and movement

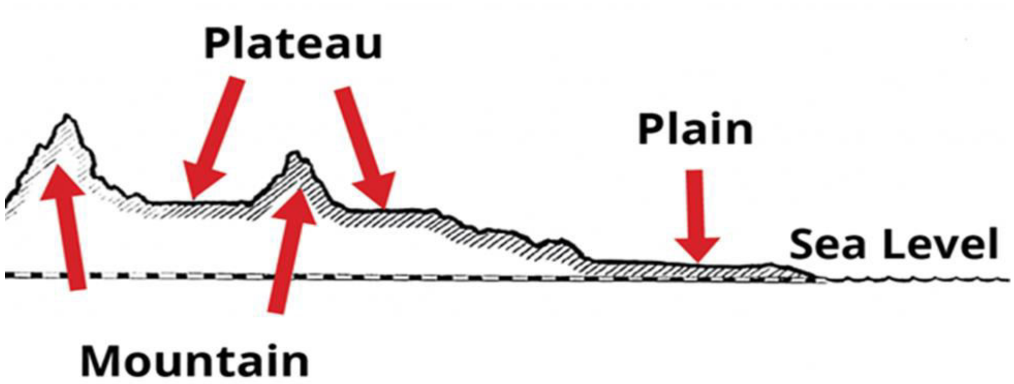
Diastrophic forces include both vertical and horizontal movements, which are caused due to forces deep within the Earth. These diastrophic forces operate very slowly, and their effects become discernible after thousand and millions of years. These forces, also termed constructive forces, after larger areas of the globe and produced meso level reliefs, e.g. mountains, plateaus, plains, lakes, significant faults, etc. These diastrophic forces and movement are further subdivided into two groups viz. (i) epigenetic movements and (ii) orogenetic movements.

Fig.4.7 Diastrophich Movements



(Source: https://qsstudy.com/)

Fig.4.8 Landscape evolved by Diastrophic Movement

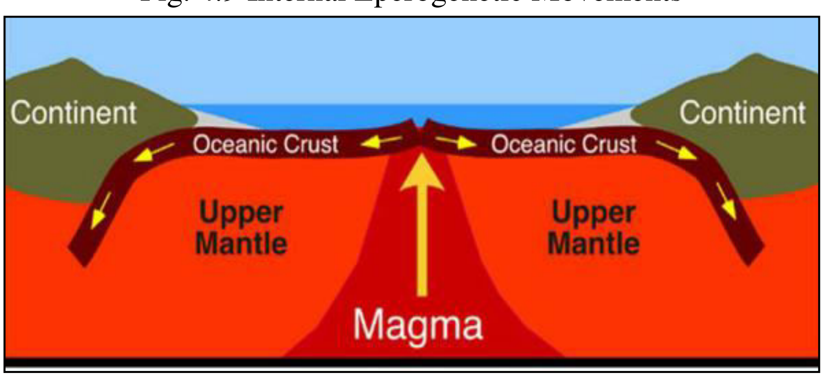


(Source:www.gstatic.com)

(i) **Eperogenetic movements -** Eperogenetic word consists of two words viz. 'epiros' (meaning thereby continent) and 'genesis (meaning thereby origin). Eperogenetic movements cause upliftment and subsidence of continental masses through upward and downward movements, respectively. Both the movements are, in fact, vertical movements. These forces and resultant movements affect more significant parts of the continent. These are further divided into two types viz. (i) upward movement and (ii) downward movement. Upward movement causes upliftment of continental masses in two ways, e.g.(a) the upliftment of the whole continent or part thereof and (b) the upliftment of coastal land of the continents. Such a type of upliftment is called emergence.

Downward movement causes subsidence of continental masses in two ways viz.(i)subsidence of land area. Such a type of downward movement is called subsidence. (ii) Alternatively, the land near the sea coast is moved downward or subsided below sea level and is thus submerged under seawater. Such a type of downward movement is called submergence.

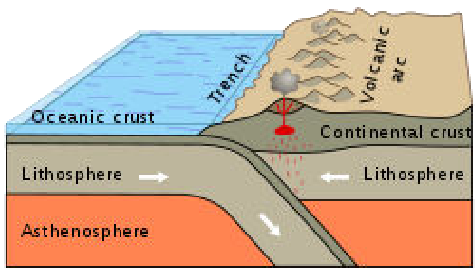
Fig. 4.9 Internal Eperogenetic Movements



(Source: en.wikipedia.org)

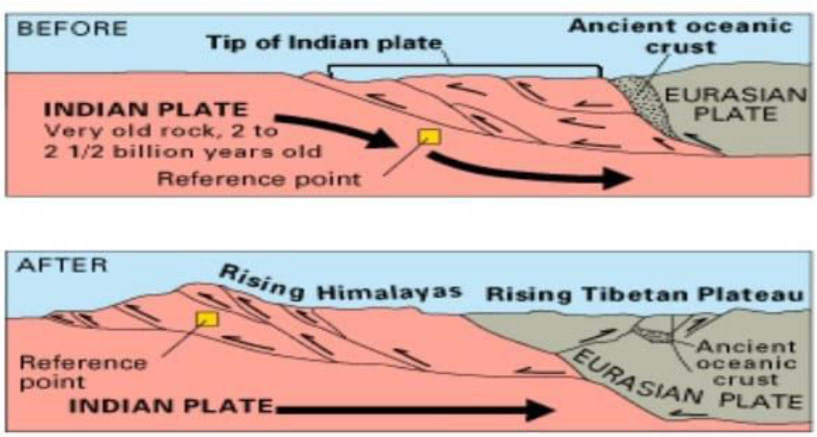
(ii) **Orogenetic movement-** The word orogenetic has been derived from Greek words 'rose (meaning thereby mountain) and 'genesis(meaning thereby origin or foundation). Orogenetic movements are caused due to endogenetic forces working horizontally. Horizontal forces and movements are also called 'tangential forces'.Orogenetic or horizontal forces work in two ways, viz. (i) in opposite directions and (ii) towards each other. This is called 'tensional force' when it operates in opposite directions. Such types of forces and movements are also called 'divergent forces'.Thus tensional forces create rupture, cracks, fracture, and faults in the crustal parts of the compressional force or convergent force. The compressional force causes crustal bending leading to the formation rise or subsidence of crustal features.

Fig. 4.10 Volcanic Mountain evolved By Orogenetic



(Source:www.gstatic.com)

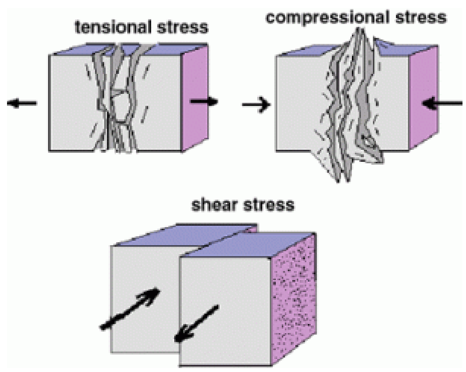
Fig.4.11 Rising of Himalayas Due to Orogenetic Force



(Source: https://hi-static.z-dn.net)

Crustal Bending-When horizontal forces work face to face; the crustal rocks are bent due to resultant compression and tangential force. In other words, when crustal parts move towards each other under the influence of horizontal or convergent forces and movements, the crustal rock undergoes the process of 'crustal bending in two ways, e.g. (i) wrapping (ii) folding. The crustal warping affects more significant areas of the crust wherein the crustal parts are either wrapped upward or downward. The upward rise of the crustal part due to compressive force resulting from convergent horizontal movement is called 'unwrapping. In contrast, the bonding of the crustal part downward in the form of a basin or depression is called down warping. When the processes of up warping or down warping crustal rocks affect more significant areas, the resultant mechanism is of crustal rocks, the resultant broad wrapping. When the horizontal compressive or convergent forces and consequent movements cause buckling and squeezing of crustal rocks, the resulting mechanism is called folding, which causes several folds.

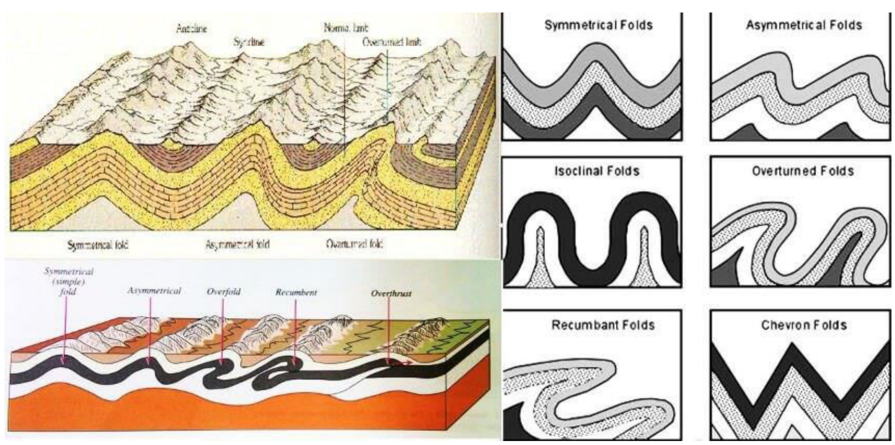
Fig.4.12 Various Types of Stress Which Are Responsible for Crustal bending



(Source: earthquake.usgs.gov)

Folds- Wave-like bends are formed in the crustal rocks due to tangential compressive force resulting from horizontal movement caused by the endogenetic pressure originating deep within the Earth. Such angles are called 'Fold'.

Fig. 4.13 The Diagram Showing Various Kinds Of Folds



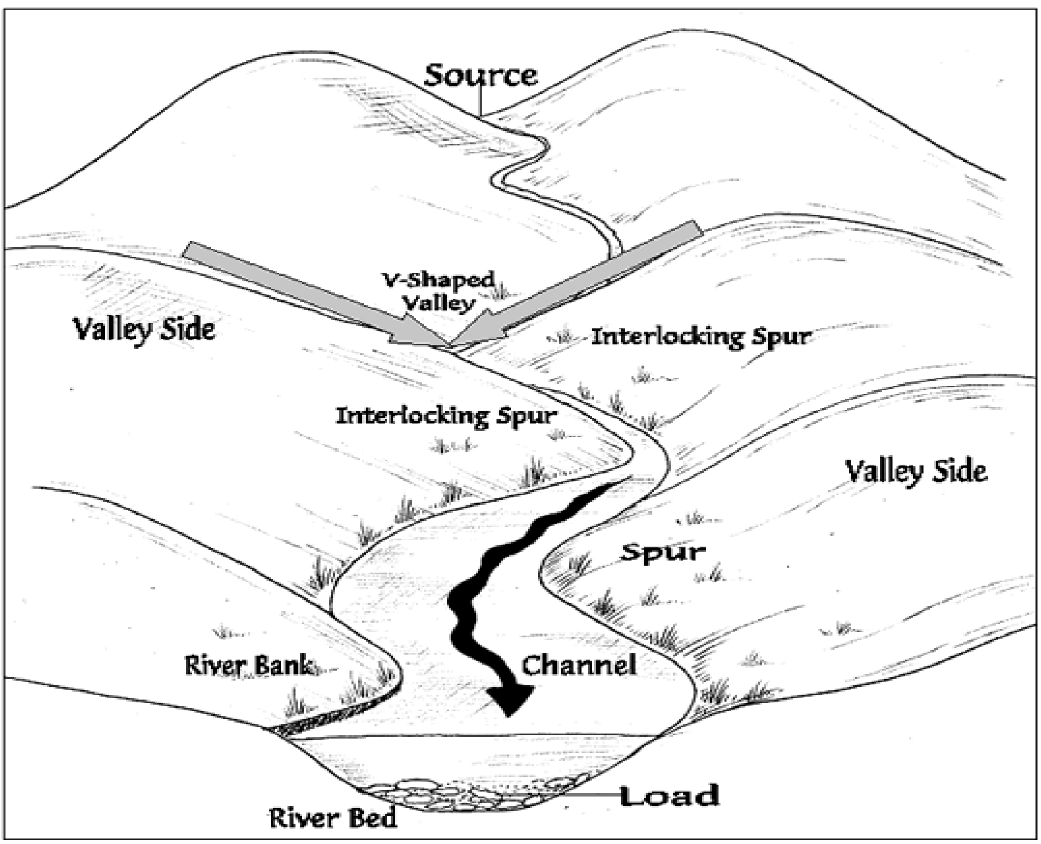
(Source:https://www.pmfias.com)

Exogenetic Forces-TheExogenetic forces or processes, also called denudational processes or destructive forces. Are originated from the atmosphere. These forces continuously destroy the relief features created by the endogenetic forces through their erosional, depositional and weathering activities. Exogenetic forces are, therefore, the plantation process. Denudation includes both weathering and erosion, where weathering is a static process that consists of the disintegration and decomposition of rocks in situ.

In contrast, erosion is a dynamic process that includes removing materials and their transportation to different destinations. Weathering is basically of three types viz. (i) physical or mechanical weathering,(ii) chemical weathering and (iii) biological weathering. The erosional processes include running water or river, groundwater, sea waves, glaciers, periglacial, and wind. These erosional processes erode the rocks, transport the eroded materials (except periglacialprocess) and deposit them in suitable places. Thus, they are from several types of erosional and depositional landforms of different magnitudes and dimensions.

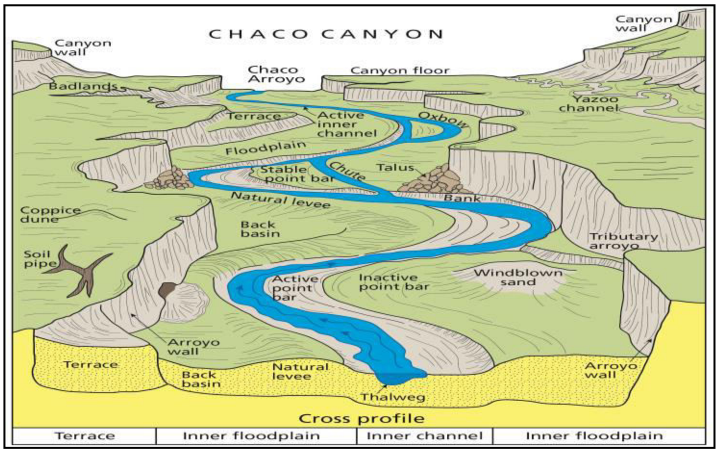
Different types of landforms evolved by Exogenetic Forces or Processes

Fig. 4.14 Erosional landforms by the river



(Source:https://www.internetgeography.net/)

Fig. 4.15 Depositional landforms of the river

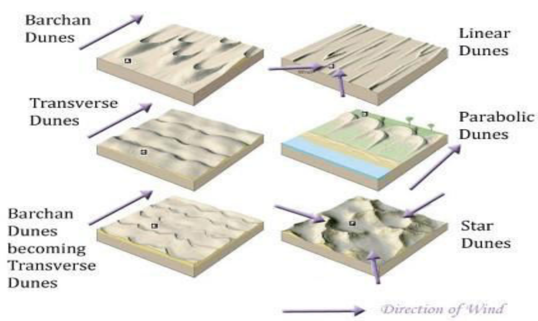


(Source:https://www.nps.gov/subjects/geology/fluvial-landforms.htm)

Fig. 4.16 Erosional landforms of wind

(Source:www.geotoday.com)

Fig. 4.17 Deposinal landforms of wind

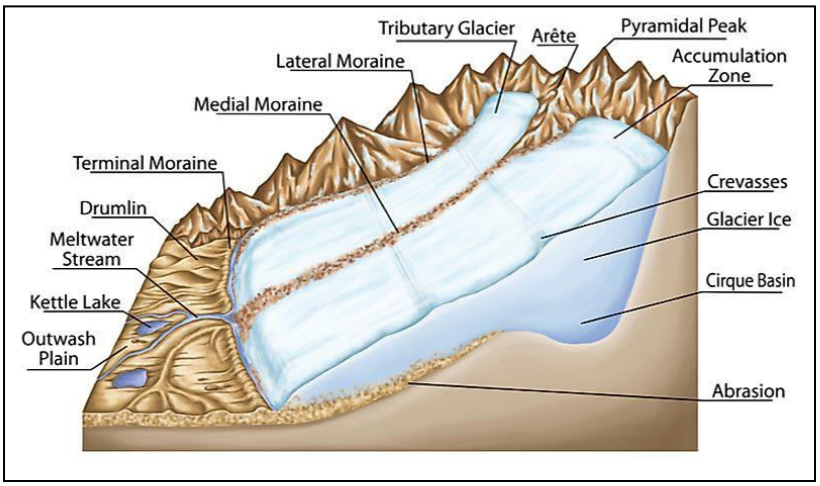


(Source:https://socratic.org/)

Fig. 4.18 Glacial erosional landforms

(Source: http://www.physicalgeography.net/fundamentals/10af.html)

Fig. 4.19 Glacial depositional landforms



(Source: https://www.worldatlas.com/)

Application of geoinformation in Geomorphology

Let's discuss various types of geoinformatics tools to analyze different kinds of geomorphologic processes and landscapes.

Geomorphological research in the twenty-first century is intrinsically tied to geospatial technologies and geographic information systems (G.I.S.). Thanks to rapid technological developments in remote sensing, geodesy, photogrammetry, computer science, and G.I.S., applying digital analysis methodologies on the ground surface revolutionized quantitative geomorphological research. G.I.S. has become more influential in numerous aspects of geomorphology over the last three decades. G.I.S. is designed to aid spatial investigations, such as geostatistical analysis or the mathematical description of surfaces, and are thus inextricably tied to geomorphology methodology and concepts. Many early-stage research topics are supported and enabled by G.I.S. tools. The digital elevation model (D.E.M.) is frequently used as a starting point for G.I.S. investigations and augmented with other picture data forms. On the other hand, G.I.S. tools enable the coupling of remotely sensed data with field data, such as land surface features, process rates, or subsurface information, as captured by geopositioning systems.

We've seen an increase in G.I.S. usage in geomorphological investigations since the late 1990s . Advances in computer science, remote sensing, and photogrammetric techniques, as well as shallow geophysics, have all played a role in this evolution.

Fig. 4.20

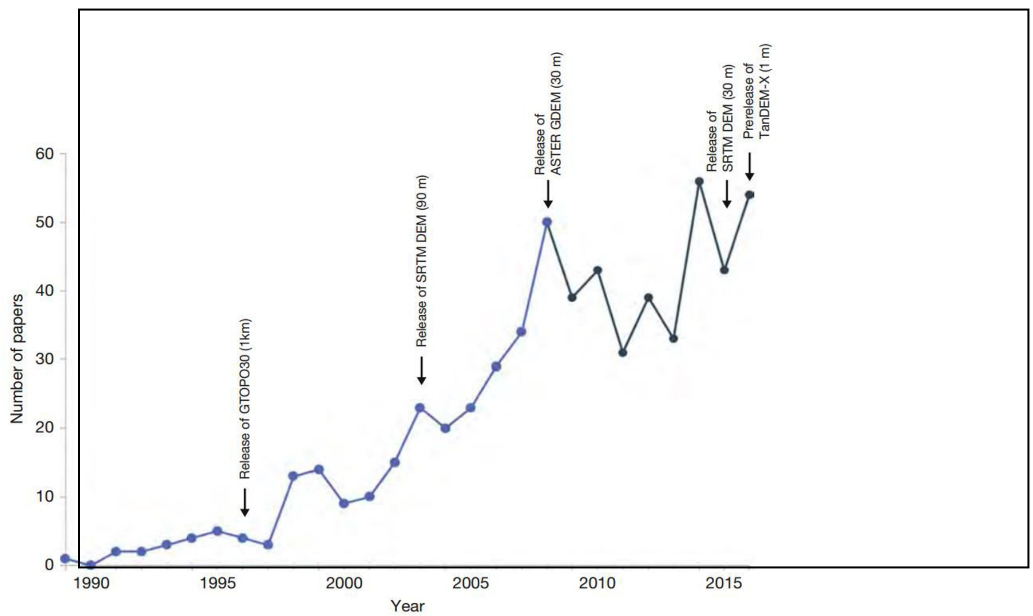


Fig. 4.20 Total annual number of papers explicitly including "G.I.S." in the title, abstract, or keywords, published in four international journals of geomorphology from 1989 to 2016 (data source: Web of knowledge). Release dates of global D.E.M. data sets have been included as benchmarks of data availability. Data from 1989–2009 are taken from Oguchi, T. and Wasklewicz, T. A. (2011). Geographic information systems in geomorphology. In: Gregory, K. J., and Goudie, A. S. (eds.) The SAGE handbook of geomorphology. London: SAGE.

Global digital terrain databases, in particular, have enhanced G.I.S. applications and research for land surface and process study. D.E.M.s (<1m) with resolutions ranging from 1 to 30 meters are now available for the whole terrestrial continent on a worldwide scale. Furthermore, laser scanning (LIDAR: Light Detection and Ranging) and structure from motion(S.F.M.) techniques, both on the ground and in the air, produce high-resolution D.E.M.s on local and regional scales. Furthermore, various commercial and free source G.I.S. software tools provide scientists with virtually limitless possibilities. As a result, The use of geographic information system (G.I.S.) technologies for geomorphological analysis has grown in popularity.

Pure visualization approaches landform classification, land surface and hydrological analysis, process and erosion modelling, topographic change detection, and hazard susceptibility modelling are examples of G.I.S. applications in geomorphology. While many applications focusing on land surface analysis, change detection or hazard modelling use specific G.I.S. software, some approaches use statistical software or special modelling tools for geospatial analysis. Modelling erosional processes and landform evolution, for example, frequently necessitates requirements beyond the capability of G.I.S. software. On the other hand, geomorphological mapping and G.I.S. have become a great fit, and geomorphological symbol sets are widely used and created for specific uses. Geomorphological maps are now commonly used as a starting point for quantitative sediment budget assessments.

In the field of natural hazards, many practical G.I.S. modelling approaches have been developed. Rockfalls, landslides, floods, avalanches, and soil erosion have inherent magnitude and spatial extension hazards. They are heavily influenced by slope angle, aspect, and other elements easily integrated and displayed in G.I.S. systems.

This article provides an overview of various geomorphology G.I.S. applications. We discuss the fundamental principles of parameters and indices used for landform and process analysis and a brief overview of familiar and novel data sources and references mapping geological features. Rather than examining many G.I.S. applications in the literature, we use a case study area in alpine terrain to visualize G.I.S. capabilities for geomorphology using various tools and indices (Obersulzbach Valley, Austria, European Alps). The collection covers a wide range of geomorphology topics. However, it is far from complete. Applications are offered in the following fields:

(i) Hillslope and gravitational processes
(ii) Glacial processes
(iii) Periglacial processes
(iv) Fluvial processes
(v) Sediment flux and erosion in mountain areas

Now, with this background, can you list the applications of geoinformatics in geomorphology. Wherein you can make use of in daily life?

Geomorphological Indices and Land Surface Parameters

Geomorphometry, a highly active research field within geomorphology, defines quantitative analysis of the land surface. It focuses on quantifying land surface parameters (L.S.P.s) and detecting objects in digital elevation data. In turn, geomorphometry as a research discipline provides a theoretical foundation and links G.I.S. and geomorphology. There are two types of geomorphometric analysis: general and specific. The main distinction between the two approaches is whether the object in focus is continuous or discontinuous. Available approaches look at the entire land surface without focusing on specific landforms or boundaries. The goal of particular geomorphometry is to identify and describe discrete landforms and their morphological characteristics. The extraction of these forms from a continuous surface focuses on specific approaches, an issue at the research frontier of geomorphometry.

L.S.P.s are geometrical or statistical characteristics of a land surface that can be extracted directly from a D.E.M. They can be quantified at the local level or through a regional analysis approach. Local parameters are quantified for a single location about its immediate surrounding cells, whereas regional parameters include relationships to further distant cells. Altitude, aspect, slope, and curvature are the most common basic L.S.P.s and are examples of local parameters. Regional parameters include aspects of surface flow, which are used to model hydrological conditions, calculate viewsheds, and calculate solar radiation. Examples of hydrological L.S.P.s are flow direction, flow accumulation, and drainage networks architecture. Relating L.S.P.s to the three fundamental concepts in geomorphology, (i) form, (ii) process, and (iii) material, we could identify curvature and slope as principal descriptors of form, altitude, slope, and contributing drainage area as influential factors of process activity (in case of fluvial and gravitational processes) and surface roughness as an indicator of surface material characteristics.

Numerous topographic or geomorphological indices have been developed to study geomorphological forms and process configurations based on these basic parameters. Geomorphological indices are composites of primary attributes that describe or characterize the spatial variability of specific processes or landforms in the landscape and can be used for landform and process analysis or landscape comparison. These indices are used in various applications, including erosional process modelling, hydrological modelling, and digital soil mapping, to name a few. Many geomorphologic indices were developed before the advent of G.I.S. due to classical geomorphological works from the early days of quantitative geomorphology. On the other hand, G.I.S. tools make it easier to quantify these parameters and, when combined with D.E.M.s, allow for rapid application of these indices over large areas.

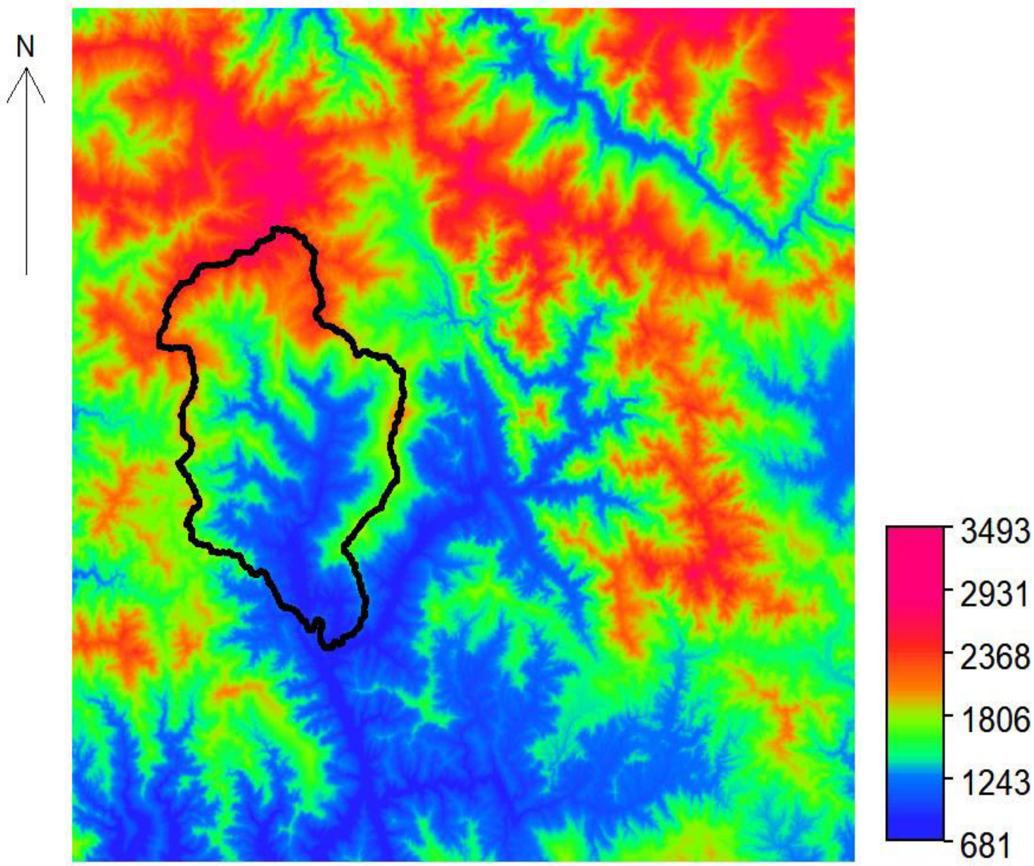
However, it should be noted that some indices are associated with a specific spatial scale, and their application is limited to large scales. They can be used to compare drainage basin characteristics or landform assemblages (e.g., drainage density, hypsometry, elevation relief ratio). Other indices can be applied on several scales, for example, terrain or surface roughness.

Data Sources

Digital Elevation Model

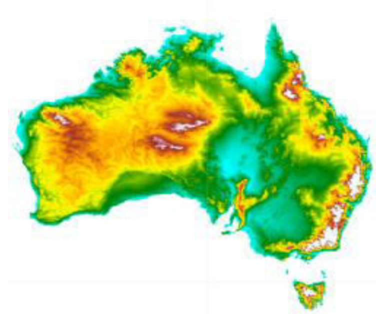
Over the last few decades, a plethora of gridded elevation data has been generated from various sources. The scope and resolution of such datasets have grown in size as computing power, and digital storage capacity has increased. D.E.M.s with solutions ranging from 1 to 90 m are commonly used in modern geomorphological studies. Low-resolution D.E.M.s (cell size 30 m) are widely used for large-scale modelling. The extensive, often global coverage of low-resolution D.E.M.s allows large-scale analyses and comparisons between research areas worldwide. Medium to high-resolution datasets (cell size<30 and 1 m) are typically national grids with a more limited extent and are a good choice for regional modelling of different L.S.P.s. Submeter resolutions are produced mainly by individual campaigns and spatially limited to single catchments or landscape patches. Such data sets are inevitable for detailed weathering processes, soil erosion, and rock wall retreat analyses.

Fig 4.21. Digital elevation model of Bino watershed in Ramganga catchment



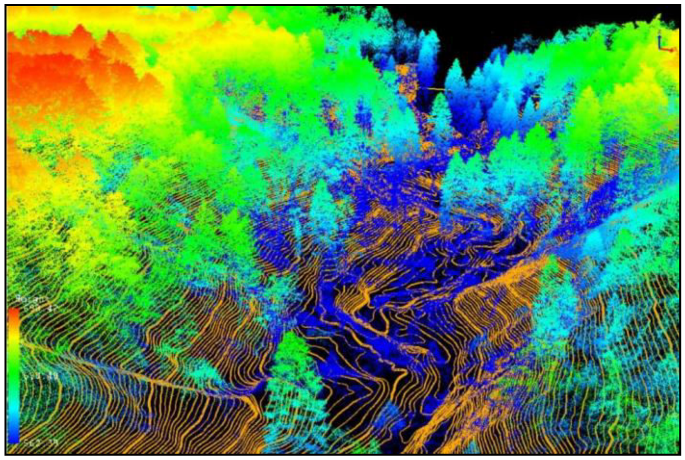
Acquisition techniques vary and comprise active (radar, LiDAR) and passive (optical) remote sensing. While terrestrial and airborne LiDAR dominated the acquisition of high-resolution elevation models over the last two decades, photogrammetry has experienced a renaissance due to affordable drone technology and very high-resolution D.E.M.s from S.F.M. techniques.

Fig.4.22 DEM-H: Australian SRTM Hydrologically Enforced Digital Elevation Model



(Source: https://developers.google.com/earth-engine/datasets/)

Fig. 4.23 UAV LIDAR Survey Over Forest and Mountains Area, Automatic Points Cloud Classification and Terrain Extraction



(Source: https://developers.google.com/earth-engine/datasets/)

Optical Imagery

Satellite imagery

Geomorphologists have been using remotely sensed imagery since it became available during the first half of the 20th century. Carl Troll was one of the first physical geographers who While traditional aerial photography is still widely used for local studies, satellite remote sensing has emerged as an essential tool.

When you're looking at a larger area with the launch of the first Landsat satellite in 1972, space-based earth observation became a reality. It was now possible to continuously survey large areas from space, returning to the exact location in 18 days—systematically used aerial imagery for the emerging field of geomorphology. Since then, the lower earth orbit (160–2000 kilometres on top of the ground) has become filled with satellites from totally different agencies and the enormous fleet of satellites launched by the U.S.A. National physics and area Administration (NASA) since the 1970s, many alternative federal space agencies and personal corporations launched their earth observation missions, for example, the SPOT 1-7 satellites (launched between 1986 and 2014) by CNES (France), the I.R.S. family of satellites (established between 1988 and 1996) operated by ISRO (India), the World-View 1–4 satellites (Digital Globe) (launched between 2007 and 2016), and watcher 1–3 satellites by E.S.A. (launched between 2015 and 2017), to call solely many.

For geomorphological applications, the temporal resolution of satellite images is probably at the least as crucial because of the ever-increasing spatial decision of newly released missions. Each long-term collection of satellite imagery and brief revisit instances of the equal locality are critically essential to detect geomorphological changes. However, the decade's increasing computational electricity political choices have boosted using satellite images off sensing merchandise in geosciences.

The possibility for geomorphological investigations to profit from the vast array of remote sensing products is enormous. The detection of glacial changes from space is one of the most well-known geomorphology applications. Still, multitemporal satellite imagery has also been applied to landslide research, fluvial geomorphology, and coastal erosion. The ability of satellite imagery to (a) pinpoint geomorphological features in remote areas and (b) determine the rates of specific methods from space is beyond the scope of this text; the example below will highlight the ability of satellite imagery to (a) pinpoint geomorphological features in remote areas and (b) determine the rates of specific methods from space.

Sentinel-2A's high Spatio-temporal resolution allows it to detect a geomorphological change in remote places, despite potential distortion from dense cloud cover. In early 2016, a rock avalanche erupted on the Cerro Alto San Juan's northeastern flank, near the Argentina-Chile border (Fig. 3.3). Around 5200 m, the clump separated and fell onto the massif's enormous glacier. The rock avalanche deposit is approximately 1 km2 (length >2000 m 500 m width). Repeated Sentinel-2A imagery narrows the detachment down to the period between 22 January 2016 and 04 February 2016. Comparison with an image obtained on 26 January 2017 shows how the debris is transported 50–100 m on top of the moving glacier.

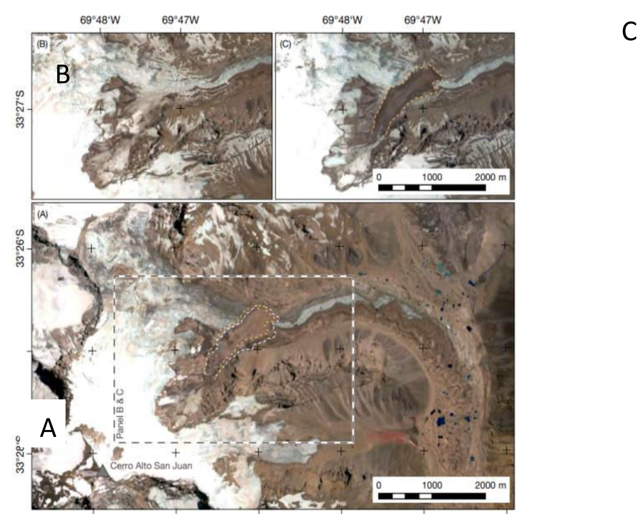


Fig.4.24 Observation of geomorphological processes in remote regions: Multitemporal Sentinel 2A optical imagery (10 m ground resolution) of a rock avalanche at the Cerro Alto San Juan massif on the border of Argentina and Chile. (A) Image acquired on 26 January 2017 showing the rock avalanche in clear conditions. (B) Image obtained on 22 January 2016, shortly before the rock avalanche detached. (C) Image acquired on 04 February 2016 showing the freshly deposited material on the glacier. Image courtesy of E.S.A.

Uncrewed aerial vehicles and structure from motion

Aerial photography still beats satellite pictures in terms of ground resolution. However, the cost-intensive data collecting from small planes or helicopters is a crucial drawback of traditional aerial photography. Aerial photography has seen a resurgence in geosciences due to technological developments over the last decade. Uncrewed aerial vehicles (UAVs), commonly known as drones or multicopters, are low-cost and straightforward to use. For field operations, global positioning systems (G.P.S.s) have become a standard requirement. High-accuracy positioning data is provided by modern G.P.S. receivers paired with correction signals transmitted via mobile communications. Furthermore, every smartphone, which appears to be nearly omnipresent today, has a low-resolution location.

Ground-penetrating radar, seismic, resistivity and E.M., and gravity are the most often utilized geomorphology techniques). Because most geophysical systems have their data format and many methods send data along a survey line, transferring subsurface data often necessitates converting depth data into a point or line data before processing it in G.I.S. software.

Digital Geomorphological Mapping

Map Creation

Manipulation and analysis of numerous types of geomorphological information, such as delineation, measurement, mathematical operations, and others, and the design and production of maps, are all feasible using G.I.S. software. Furthermore, the logical storage structure of geomorphological data allows for the quick creation of derivative maps with a specific theme, such as process domains, surface processes, surface material, or something else entirely. Geomorphological maps can be made with data collected from various sources: field data and digital data sources such as aerial photography, satellite photos, and D.E.M.s. Field mapping is greatly aided by the use of GPS-enabled mobile devices such as tablets or handheld P.C.s. Field mapping software, typically a G.I.S., allows direct observations into a georeferenced database system, then uploaded to a desktop G.I.S. for map generation. Automated or semi automated mapping enables more objective and repeatable data, but it is often less accurate than hand mapping. Feature extraction techniques applied to satellite/aerial images and other D.E.M.s and derivatives are used. The representation of a landform on an image is dependent upon (i) the landform itself, (ii) the data source, and (iii) the visualization method (Otto and Smith, 2013; Smith, 2011). Smith and Wise (2007) identified three main controls on the representation of landforms on images:

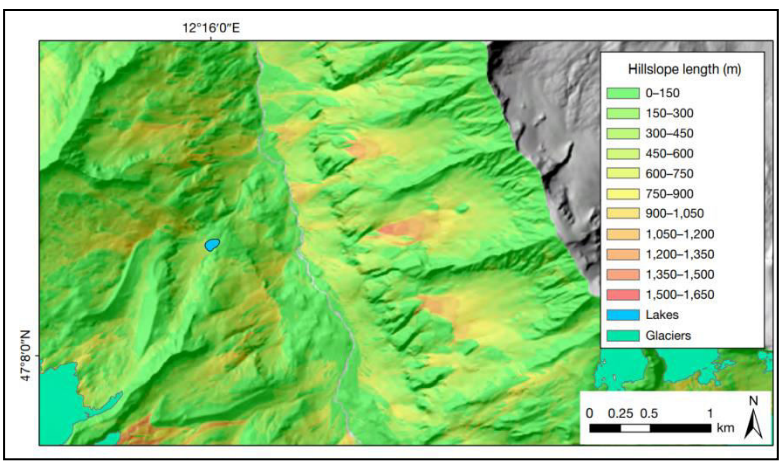
1. Relative size: the size of the landform close to the spatial resolution
2. Azimuth biasing: the orientation of the landform concerning solar azimuth
3. Landform signal strength: the tonal/textural differentiation of the landform procedures

As a result, the detectability of a landform is determined by its relative reflectance regarding surrounding features. D.E.M.s are used to visualize intrinsic information in many ways, such as relief shading, gradient (slope angle), and curvature categorization.
Compound and often artistic symbols are used to depict the complicated content of geomorphological maps. For cartographic design and map generation, G.I.S. software includes creating unique characters expressing geomorphological characteristics and functions. Smith et al. (2013) found that digitally produced maps are easily distributed in various media, ranging from print maps to online web services. They make full use of the data organization structure and georeferencing of the data. In addition, the standard PDF (Portable Document Format) has been enhanced to become a GeoPDF for the display and distribution of referenced map data.

Hillslopes and Gravitational Processes

The length and relief of hillslopes contain information on forcing at various scales and play a vital role in the universal soil loss equation for estimating soil erosion and slope susceptibility for shallow landslides. Glacial landscapes have longer hillslopes and higher relief than fluvial landscapes. We calculated both hillslope length and relief with TauDEM and observed this trend only in different cirques. However, less dissected terrain can generally be expected to have longer hillslopes (Fig. 4.25).

Fig.4.25 Hill Slope Length Index on Western Valley Flank



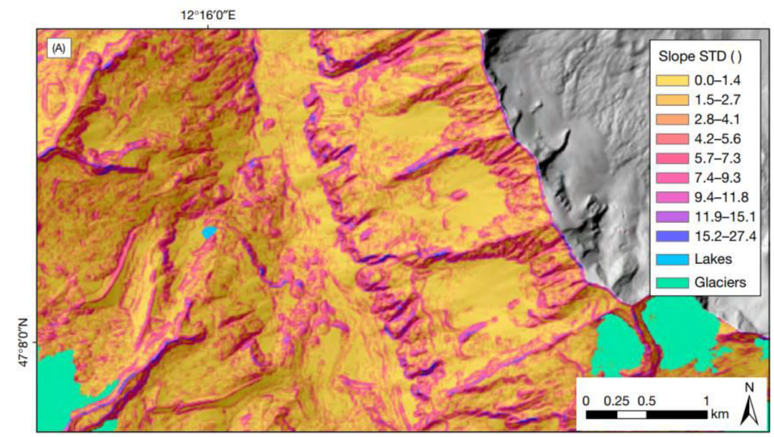
(Source: https://developers.google.com/earth-engine/datasets/)

Glacier Environments

G.I.S. is helpful for understanding and visualizing glaciers and glacially carved landscapes (see the G.I.S. for Glaciers chapter). Glacial geomorphologists use geographic information systems (G.I.S.) to integrate multi-source data, manage multiscale investigations, uncover spatial and temporal linkages and patterns in geomorphological data, and link landform data with numerical models for model calibration and verification.

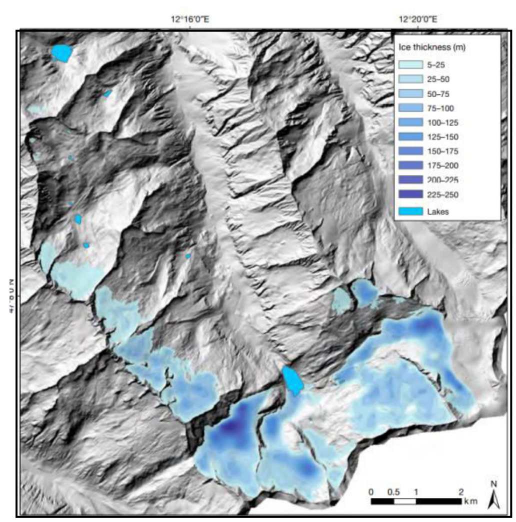
Geospatial information systems (G.I.S.) are appropriate for processing and visualizing relevant data. G.I.S. can be used to view glacier extents that have been manually mapped or to run automatic mapping methods based on D.E.M. and spectral data. The altitude of the equilibrium line (E.L.A.), the imaginary border between accumulation and ablation area crucial for mass balance assessment, can be computed using several approaches such as the accumulation area ratio if the glacier extent is known (A.A.R.).

Fig.4.26 Surface roughness calculated using the standard deviation of local slope



(Source: https://developers.google.com/earth-engine/datasets/)

Fig.4.27 Ice thickness modelling using the model GlabTOP2 applied to the glaciers



(Source: https://developers.google.com/earth-engine/datasets/)

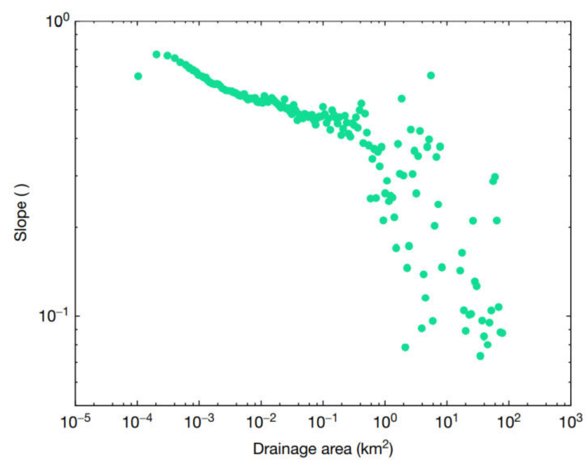
Periglacial Environment

Within periglacial geomorphology, G.I.S. has been used to model and visualize permafrost distribution since the early 1990s. The PERMAKART model is based on empirical geomorphological evidence of permafrost occurrence (e.g., the lower limit of an active rock glacier, the basal temperature of snow) and incorporates classic topo climatic parameters such as altitude and aspect, in addition to perennial snow avalanche deposits (protecting the ground surface from radiation). These L.S.P.s are utilized as proxies for air temperature and solar radiation, two crucial elements in the production of mountain permafrost, respectively.

Fluvial Environment

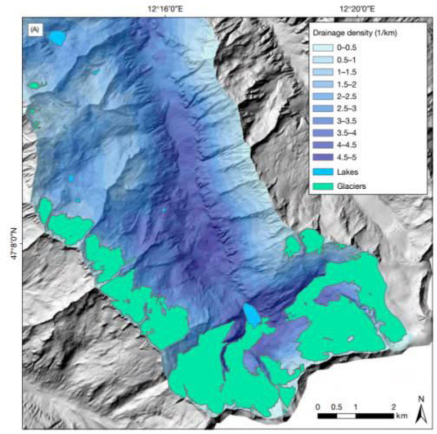
Fluvial environment analysis is a critical task in G.I.S. applications, not only in geomorphology but also in hydrology and ecology. This is since river networks are the backbone of most humid and semi-arid terrain types around the world. pre-glacial fluvial morphology even determines the course of today's glacier valleys. As a result, the fluvial catchment is the basic unit for geomorphological and environmental assessments. The structure of river networks manifested in basins and watersheds is often employed to split the land surface.

Fig.4.28 Slope-area plot of the Obersulzbach Valley. Note the pronounced kink at a drainage area of approximately 0.1 km2.



(Source: Otto et al, 2017)

Fig. 4.29 Drainage density calculated for catchments of Strahler order 2.



(Source: Otto et al, 2017)

Sediment Flux and Erosion in Mountain Areas

The analysis and quantification of sediment flux are also done using G.I.S. techniques. The issue of connectedness is a focus in GIS-based sediment flux studies. The effectiveness of sediment flux depends on the coupling of geomorphological processes and catchment connectivity, which substantially impacts the sensitivity of geomorphological systems to changes. G.I.S. tools may be used to visualize and quantify catchment connectivity in a variety of ways.

4.4 SUMMARY

In the present unit, you have been introduced to the interface of geoinformatics in Geoscience and Geomorphological processes and landforms. Let us now summarise what we have studied in the team:

G.I.S. analysis is intrinsically intertwined with modern quantitative geomorphological research. The availability of high-resolution and global data on the land surface has aided recent fundamental achievements in the area and opened up new study avenues. Pure visualization approaches, landform classification, land surface and hydrological analysis, process and erosion modelling, and topographic change detection are examples of G.I.S. applications in geomorphology. Critical characteristics of G.I.S. used in geomorphology include statistical analysis and spatial interpolation of field data and graphical visualization and map construction.

The capabilities of geomorphological analysis using G.I.S. will be enhanced by increasing the resolution of both D.E.M. and picture data, free access to local and worldwide data sets, and low-cost technologies to generate high-resolution surface information. However, there are issues with scale and the application of tools and parameters built using lower-resolution data.

4.5 GLOSSARY

1. Azimuth - The azimuth is the angle between North, measured clockwise around the observer's horizon.

2. Denudation - It is the name for the processes of erosion, leaching, stripping, and reducing the mainland.

3. Drone - Uncrewed aerial vehicle.

4. Diastrophic - is a condition with many severe skeletal abnormalities.

5. Endogenetic - The internal process of the Earth.

6. Epeirogenetic - Is upheavals or depressions of land exhibiting long wavelengths and little folding apart from broad undulations.

7. Exogenetic - Processes that operate on or close to the surface of the Earth.

8. Fluvial - Process of the river.

9. Geomorphology - A branch of geography deals with physical environments.

10. Geoscience - The study of the Earth.

11. Hypsometry - The science of measuring the stage of the river.

12. Orogenetic - Mechanism of mountain building.

13. Periglacial - The area is located near the glacier.

14. Photogrammetry - the science and technology of making measurements using photographs.

15. Rupture - is the visible offset of the ground surface when an earthquake rupture along a fault affects the Earth's surface.

16. Tangential - One kind of a force.

17. Weathering - The breaking down or dissolving of rocks and minerals on Earths surface.

18. Warping - Warping is (geology) the deformation of the Earth's crust over a large area.

4.6 ANSWER TO CHECK YOUR PROGRESS

1) Write the fields of Geoscience.
2) List two primary geomorphological process
3) List some bioinformatic tools.

4.7 REFERENCES

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4.8 TERMINAL QUESTION

1) What is the Geomorphological process?
2) How is Geosciences related to Geomorphology?
3) What is the exogenetic landform?
4) How can you make an elevation map?

UNIT 5 - GEOMORPHIC APPLICATIONS: PRINCIPLES OF RECOGNITION ELEMENTS FOR TERRAIN EVALUATION, MAPPING OF TERRAIN, AND CLASSIFICATION OF LANDFORMS, INTERPRETATION OF EROSIONAL AND DEPOSITIONAL LANDFORMS, AND INTERPRETATION OF DRAINAGE SYSTEMS

5.1 OBJECTIVES

After studying this unit, you should be able to:

- Quickly identified the types of terrain
- The purpose of the terrain evaluation
- Modifies techniques to evaluate the terrain
- Classified all types of erosional and depositional landforms
- Various kinds of landforms and their interpretation
- Knowledge about the drainage system and pattern
- Multiple approaches to study the drainage basin

5.2 INTRODUCTION

Applied Geomorphology is a sub-branch of geomorphology that deals with the terrain and its appraisal for specific purposes. For land development, a thorough assessment of the landscape is critical. Use planning because it reflects the suitability of the land; for example, Agriculture favours' flat fertile places with minimal aesthetic value. Residential and recreational developments prefer the charm. Hilly or rocky terrain is close by. An area's land use depends on the terrain qualities.

The mechanism of the operation(erosional and depositional work) of exogenetic processes that the mode of operation of each geomorphic process is different from other process and hence the landforms produced by each process may be differentiated if we accept the mono-process concept, e.g. dissected by streams, scoured by wind, glaciated by glaciers etc.

5.3 GEOMORPHIC APPLICATIONS: PRINCIPLES OF RECOGNITION ELEMENTS FOR TERRAIN EVALUATION, MAPPING OF TERRAIN, CLASSIFICATION OF LANDFORMS, INTERPRETATION OF EROSIONAL AND DEPOSITIONAL LANDFORMS, INTERPRETATION OF DRAINAGE SYSTEMS

Terrain evaluation entails two steps: first, analysis, which requires simplifying a complicated phenomenon such as the natural geographic environment, and second, categorization, which involves organizing data. Separating one area from another and describing each; and the third assessment: manipulation, interpretation, and evaluation data analysis for practical purposes. The goal of terrain evaluation is to determine the worth of a specific location.

The method of terrain evolution comes under two groups- (i) The landscape method and (ii) The parametric method. The landscape approach defines a land unit as an area or collection where a recurring pattern of topography, soils, and vegetation can be identified. Aerial pictures and satellite images can be utilized to understand this strategy. On the other hand, the parametric method is defined as the classification and subdivision of land-based on selected attribute values. The first is more subjective, while the second is more objective yet complementary rather than antagonistic.

Many experts from India and beyond have evaluated terrain for various reasons, including land use in general, agricultural land use, urban land use, settlement rationalization, transportation and communication, etc.

Remote Sensing and GIS Technique

Terrain analysis and land-use studies have both used RS and GIS approaches. The Digital Elevation Model (DEM) is a data file that comprises surface elevation data over a particular area and relief detail, drainage features, and three-dimensional views. It is widely used for terrain assessment. Only from stereo pare image we can get DEM. A satellite survey examined before deploying a seismic land party can map survey risks by differentiating surface features in detail. A DEM, for example, is especially effective for recognizing structure at scales of 10 m and more considerable. It can find escarpments and highlight other features with a similar elevation signature, whether flat (as in clay pans, sabkhas, floodplains, swamps, and marshes) or variable (as in clay pans, sabkhas, floodplains, wetlands, and marshes) (such as wadis, dunes and glacial moraine). Radar photography illuminates surface microstructure or texture information at a smaller scale of millimetres to decimeters by separating diffuse and specular reflections. This provides information about rock structure, fractures and ripples. In addition, different mineral types have entirely different responses in the infrared, so those bands are included in studies of lithology or changes in lithology. In most situations, the remote sensing study contains data from one or more satellites, ground observations and maps, including infrastructure and subsurface geology where available. This necessitates meticulous integration utilizing a geographic information system (GIS). All of the data is integrated into a standard 3D workspace as part of the GIS process. An image from a radar satellite, for example, can be overlaid with a combination of visible and infrared bands and the traverse and observations of a ground survey mapped in a shared space. The user can also "fly" across the area using GIS software, which allows them to look at the combined data from any viewpoint. The GIS system can show risk information in an easy-to-understand style by merging sensed data with physical models such as wave propagation and source and receiver coupling to various surface materials and logical criteria such as safe slope angle for vehicles.

Landuse change detection (urbanization, deforestation, flooding, and so on), geomorphic feature recognition (landforms, relief, slope, drainage pattern, and so on), and surface water potential zone identification, among other things. The satellite image has a high level of approval and has already been used. Topographical sheets and a satellite image have been taken for terrain evaluation and land-use mapping.

Table.5.1 A chart showing various types of DEM data and its uses

Surface feature	Type of satellite data	Impact on seismic data quality	Impact on logistics
Loose sand dunes	DEM, VIS–MIR	Elevation statics, strong attenuation, trapped surface-wave modes	Severe limitation of access for vibrators, preparation of track required
Swamps, marshes	DEM, VIS–MIR, Radar	Resonance, mud roll, substantial velocity statics	If wet, no access for vibrators and vehicles, hand carry recording equipment
Dense forest	DEM, VIS	Often strong, low-frequency surface wave noise	Limited vibrator and vehicle access in dense forest
Pine forest on glacial moraines	DEM, VIS–MIR	Low seismic velocity and high attenuation in dry glacial till	Limited vibrator and vehicle access in dense forest
Sabkha	DEM, VIS–MIR, Radar	Resonance, mud roll, velocity statics, high attenuation	Severe risk of access for vibrators and vehicles
Clay pans	DEM, MIR	Resonance	If wet, no access for vibrators
Hard rock outcrop	MIR, SWIR, Radar	Baseplate point loading, poor receiver coupling	Limited risk of access for vibrators
Wadis, drainage patterns	DEM, VIS–MIR, Radar	Ground water table for P-wave statics, poor coupling in wadis	No risk for vibrator or vehicle access
Caliche, mineralization horizons	MIR, SWIR, Radar	Narrow-band resonance, strong absorption	No risk for vibrators and vehicles
Escarpments	DEM	Noise from scattered surface waves	No access for vehicles beyond 25 % slope, severe risk for 15 to 25 % slope
Lateral lithological boundaries	VIS–TIR	Noise from scattered surface waves	No risk for vibrators or vehicles unless escarpment present
Rough surface	DEM, Radar	Baseplate point loading, poor receiver coupling	Severe risk of tire damage for vehicles

(Source: https://researchgate.net)

Photogrammetric analysis procedures can range from obtaining approximate distances, area and elevation using hardcopy photographic products, unsophisticated equipment and simple geometric concepts generating precise DEMs, orthophotos and thematic GIS data.

Various statistical techniques have been utilized to quantify regional disparity, such as the Z-score, composite index, Kendall's coefficient technique, and PCA to construct the Village Development Index (VDI). The multivariate approach frequently employs factor analysis. In 1901, Karl Pearson invented principal component analysis. PCA has typically been used to transform a large set of correlated variables into a smaller group of uncorrelated variables known as Principal Components (PC).

Mapping of Terrain

Overlain on a topographic foundation are polygons, labels describing the qualities of a polygon using codes, and onsite symbols (symbolizing things like landslide paths or cliffs). A terrain map depicts a land area organized into units with similar height, slope, landform, rock exposure, and surficial material type and thickness. Terrain mapping differs from topographic baseline mapping, which is done through Terrain Resource Information Management (TRIM).

There are three types of terrain mapping:

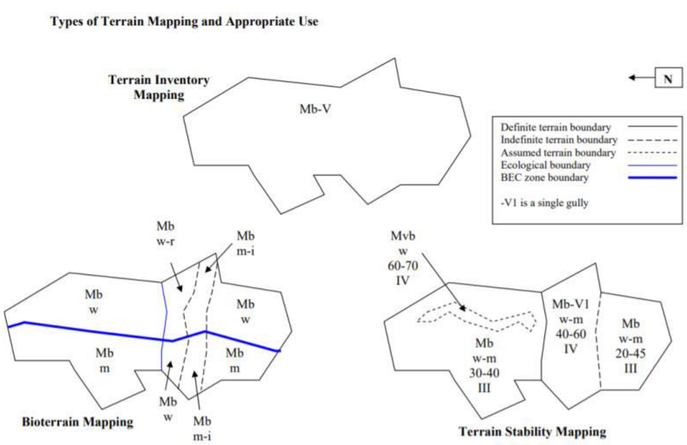
Terrain inventory Mapping: Terrain inventory mapping is a multi-purpose inventory that describes the characteristics and spatial distribution of:

- Surficial materials, the surface materials on top of bedrock
- Landforms, the surface expression or 3D shape of surficial materials
- Geomorphological processes, the mechanisms that continue to deposit and modify surficial materials
- Geomorphological features in the landscape

Terrain stability Mapping: The susceptibility of a terrain polygon to slope failure is known as terrain stability or slope stability. Landforms, surficial material, geomorphological features and processes are all described in Terrain Stability Mapping, which also scores each terrain polygon on a qualitative scale to indicate relative stability.

Bio terrain Mapping: Bio terrain mapping is frequently used as a component of an interdisciplinary terrestrial or projected ecosystem mapping product that uses the same polygon linework but can also be used as a stand-alone product. Surficial materials, landforms, and geomorphic processes are outlined with an ecological lens on bio terrain map units.

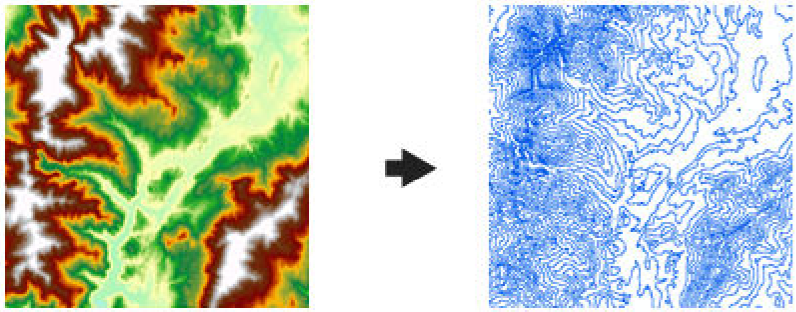
Fig.5.1Types of Terrain mapping



(Source: www.gov.bc.ca/)

Contour lines create a line connecting sites with an identical height above or below a standard level, which aids in the visualisation of surface topology. This is important for locating good project locations, such as evaluating water storage capacity or estimating the volume of excavation work. Existing tools and functions in ArcGIS Pro can build contour lines, depending on the input and output data.

Fig. 5.2 A contour map is generated by using DEM



(Source: desktop.arcgis.com)https://www.google. com/imgres?imgurl=https:// desktop.arcgis. com/de/arcmap/10.3/tools/3d-analyst-toolbox/GUID-3DD18411-6159-457B-AFF8-2A457 C5D 123 B-web.png&imgrefurl=https://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-contouring-works.htm&h=183&w=405&tbnid=oaJxel8lJJ6rYM&tbnh= 151 & tbnw =334 &osm=1&hcb=1&source=lens-native&usg=AI4_-kT7jOVywREg 91IOTGlEQ RSTFIz M5Q&docid= TTQi_sMG8mhepM#imgrc= fTLWZavNlXSU7M&imgdii= oaJxe l8lJJ6qYM

LIDAR Contour Mapping is a quick and cost-effective source of high-accuracy, high-density elevation data for many traditional topographic mapping applications. The technology allows large-area topographic surveys to be done much faster and lower than conventional survey methods. This technology replaces traditional surveying methods, such as stereo imaging and the stereo plotter. Rugged small laser rangefinders (LIDAR), highly accurate inertial reference systems (INS), and the global positioning satellite system are all used in airborne laser contour mapping (GPS). By integrating these subsystems into a single instrument mounted in a small aeroplane or helicopter, it is possible to produce accurate digital topographic maps of the terrain beneath the aircraft's flight path. The elevation data has an absolute precision of 15 cm and a relative accuracy of less than 5 cm. The absolute accuracy of the XY data varies depending on operating parameters such as flight altitude. However, it is often in the tens of centimetres to the range of one meter.

Uses of Terrain Maps

- Manage landslide risk to values such as water quality, high-value habitat, timber resources, utilities and infrastructure
- Plan forest road and cut block locations
- Manage the risk of sedimentation to values such as water quality, fish habitat, wildlife habitat
- Aggregate resources
- Till prospecting
- Terrain hazard and constraint identification

- Parent materials for soil classification
- Watershed assessment
- Environmental impact studies
- Geological hazard mapping and geological risk assessment

Classification of landforms

The main task of a geomorphologist is to study the evolution and characteristics of erosional and depositional landforms and geomorphological processes operating therein; the entire practice e and exercise of landforms studies may be grouped into three closely linked steps, e.g. (A) main tasks, (B) approaches, and (D) methods.

(A) Main Tasks

The first, foremost task of a student of the science of landforms is (i) to describe the landforms characteristics either subjectively or objectively based on detailed information more available to them (ii) to classify the landforms either genetically or quantitatively, and finally (iii) to explain the evolutionary processes of the concerned landforms.

(i) Description of landforms

Landforms characteristics may be described in various ways depending on the audience in multiple ways depending on the audience to which the description is addressed and the nature of problems needing description and explanation. Generally, landforms description involves (a) subjective description, (b) genetic description and (c) objective scientific description.

(ii) Classification of Landforms

After observing physical landforms and processes and their distribution patterns in the field, an investigator attempts to classify them into identifiable categories. The landforms may be classified on two bases, i.e. (a) quantitative basis (b) genetic basis.

(a) Quantitative classification

It involves numerical data obtained through morphological mapping, field instrumentation, air photographs and satellite imageries interpretation. It is descriptive as it does not consider the mode of origin and nature of the development of landforms, which, no doubt, is an essential aspect of geomorphology. A hillslope profile may be classified based on slope angle and slope plan into summital convex, free-face, rectilinear and basal concave slope.The measurement of slope angles of hillslope profiles in the field facilitates the geomorphologists to classify slopes into (i) level slope (0o-0.5o) (ii) almost level slope (0.5o-1o) (iii) very gentle slope(1o-2o) (iv) gentle slope (2o-5o) (v) moderate slope(5o-10o) (vi) moderately steep slope (10o-15o) (vii)steep slope (15o-18o) (viii)very steep slope (18o -30o) (ix) precipitous to vertical slope(30o-45o).

(b) Genetic classification

It involves dividing landforms assemblage of a given geomorphic region into specific categories based on their mode of origin. For example, a slope can be genetically divided into tectonic slopes, erosional slopes, the slope of accumulation etc.

(iii) Explanation of landforms

The origin and development landforms are explained based on available information derived through their description and classification. The explanation of landscape may be approached through (a) establishing relationships between landforms and climate or between landforms and structure or rock types, (b) through seeking landform origin and development from a historical perspective and (c) through establishing relationships between landforms and processes.

(B) Approaches to Geomorphological analysis

The explanation of morphological characteristics of a given region may be approached in several ways depending on the geomorphologists' spatial and temporal scales and goals. Based on conceptual bases, the geomorphic studies may be approached in two ways, e.g. (i) historical approach and(ii) functional approach.

(C) Research Methods

Explanation of processes and landforms and building of models require data acquisition from various sources. R.J Chorley (1966) has outlined three steps and data acquisition methods, ultimately leading to theoretical work. The integrated approaches to research methods in geomorphology include, according to R.J Chorley, field observations, laboratory observation, office observation and academic work.

(D) There are three alternative routes for a satisfactory scientific explanation of geomorphological problems, e.g. (i) inductive method (ii) deductive method (iii) analytical method, all of which are based on data acquisition, their classification and analysis to come to certain conclusions concerning the nature and genesis of the particular feature, investigated, whether it be a whole continent or one slight slope on a spit.'

Interpretation of erosional and depositional landforms

The erosional work by different processes(e.g. river, wind, groundwater, waves, glacier) is performed through the mechanism of chemical erosion, corrosion or abrasion, attrition, hydraulic action, deflation, plucking polishing, cryoturbation etc.

Erosional landforms of river

1. River valleys: The valleys carved out by the rivers are significant erosional landforms. The shape and dimension of fluvially originated valleys change with the advancement of the fluvial cycle of erosion stages. The V-shaped valleys are divided into two types, viz. (1) gorges and (2) canyons.

2)Waterfalls: Waterfalls or falls are caused by sudden descents or short breaks in the longitudinal course of the river due to a host of factors, e.g. difference in topographic relief, fall in the sea level, and related rejuvenation, earth movements etc.

3)Pot Holes: The kettle like small depressions in the rocky beds of the river are called potholes which are usually cylindrical shapes. Potholes are generally formed in coarse-grained rocks such as sandstones and granites.

Except all these, there are many erosional landforms of river viz. structural benches, river terrace, river meanders, oxbow lake etc.

Depositional landforms of river

1. Alluvial fans and cones: Alluvial fans and cones due to the accumulation of materials are continuously formed at the base of foothills where there is an abrupt drop in the channel gradient.

2. Natural levees: The narrow belt of ridges of low height built by the deposition of sediments by the spilt water of stream on its either bank called natural levees.
3. Delta: The depositional feature of almost triangular shape at the mouth of the river debouching either in a lake or sea is called delta.

Erosional landforms of groundwater

They are mainly developed in the karst region.

1)Ladies: The highly corrugated and rough surface of limestone lithology characterizes by low ridges and pinnacles, narrow clefts and numerous solution holes are called lapis.

2) Karst window: It is formed due to the collapse of an upper surface of sinkholes or dolines.

3)Ponores: The vertical pipe-like or passages that connect the caves and swallow are ponores.

Except all these, there are lots of erosional landforms of groundwater in the karst region viz. natural bridge, blind valley, sinking creek, karst valley, caverns,poljies etc.

Depositional landforms of groundwater

All types of deposits in the caves are collectively called speleothems, of which calcite is the common constituent.

Erosional landforms of winds are also prominent features. They are deflation basin, mushroom rock, inselberg, demoiselles, yardang, dreikanter etc.

There are so many depositional landforms of winds, viz—dunes, ripple marks, loess etc.

There are so many erosional landforms in the coastal area, viz. cliff, wave-cut platform, etc., and depositional landforms viz. bars, barriers, spits, etc.

In the higher latitudinal area, there are so many glacial erosional and depositional landforms. The erosional landforms are U shaped valley, hanging valley, cirques, tarn, coles, aretes, horns etc. The depositional landforms are formed due to the setting down of glacial drifts. They are moraines, drumlins etc.

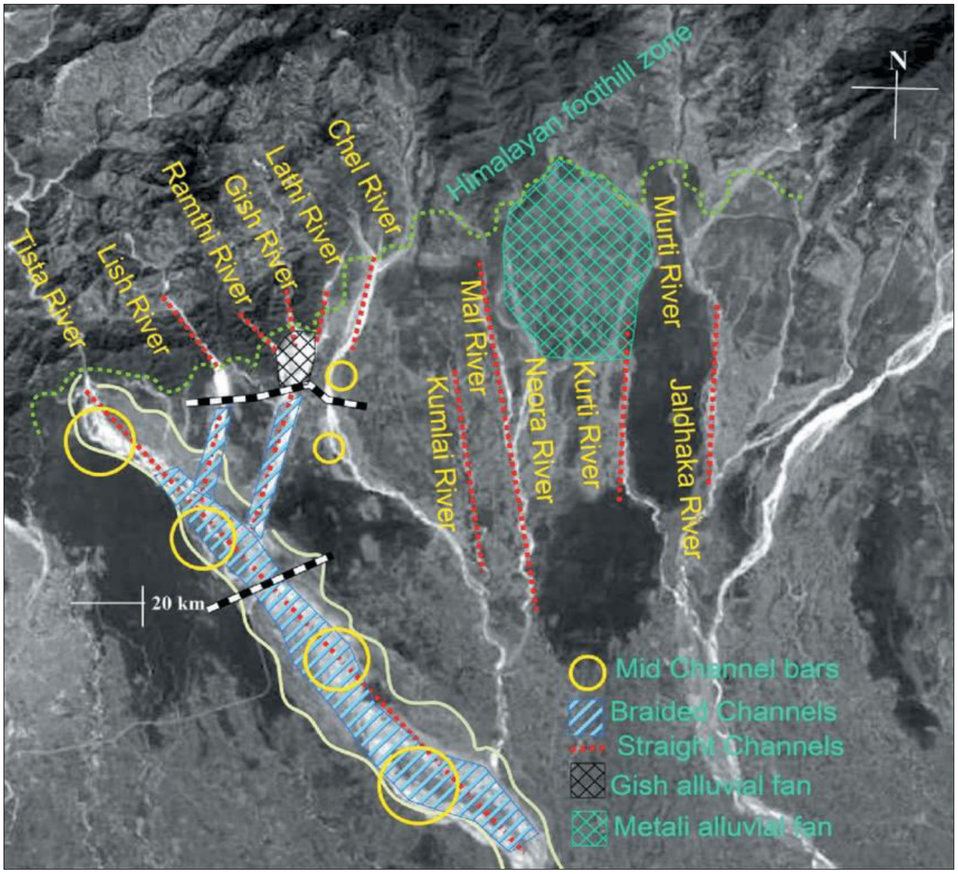
GIS Application in Fluvial Geomorphology and Landscape Change

GIS can be used to describe fluvial geomorphology and river dynamics, linear erosion processes, erosion rates, ancient landscapes changed by fluvial action, flooding zones, and historical anthropogenic alterations to the river landscape and land usage. The usage of geographic information systems (GIS) has been very beneficial for many years; it has been widely used in various disciplinary sectors, providing vital support to research activity and the decisional and programming phases in the planning field. Many geomorphic and Quaternary geology research topics can be solved using this method.

Some morphological and environmental contexts, such as the fluvial one, are particularly suitable for reconstructing historical fluvial landscape and dynamics, experimenting with new tools, useful for constructing detailed geomorphological maps, including semi-automatic extraction of the prominent landforms, or applying morpho-evolutionary models of the river.

The map graphically represents the field-checked results of a detailed geomorphological study using GIS analysis of historical and topographic maps and orthophotos. The fluvial landforms research is backed by field surveys and is based on a quantitative multitemporal analysis of aerial pictures and satellite images performed in a GIS environment.

Fig.5.3Heterogeneous fluvial forms of Eastern Himalayan piedmont zone, India. The fluvial landforms observed like Channel bars, straight channel form, channel avulsion, alluvial fans braided channels are evidence of recent tectonics.

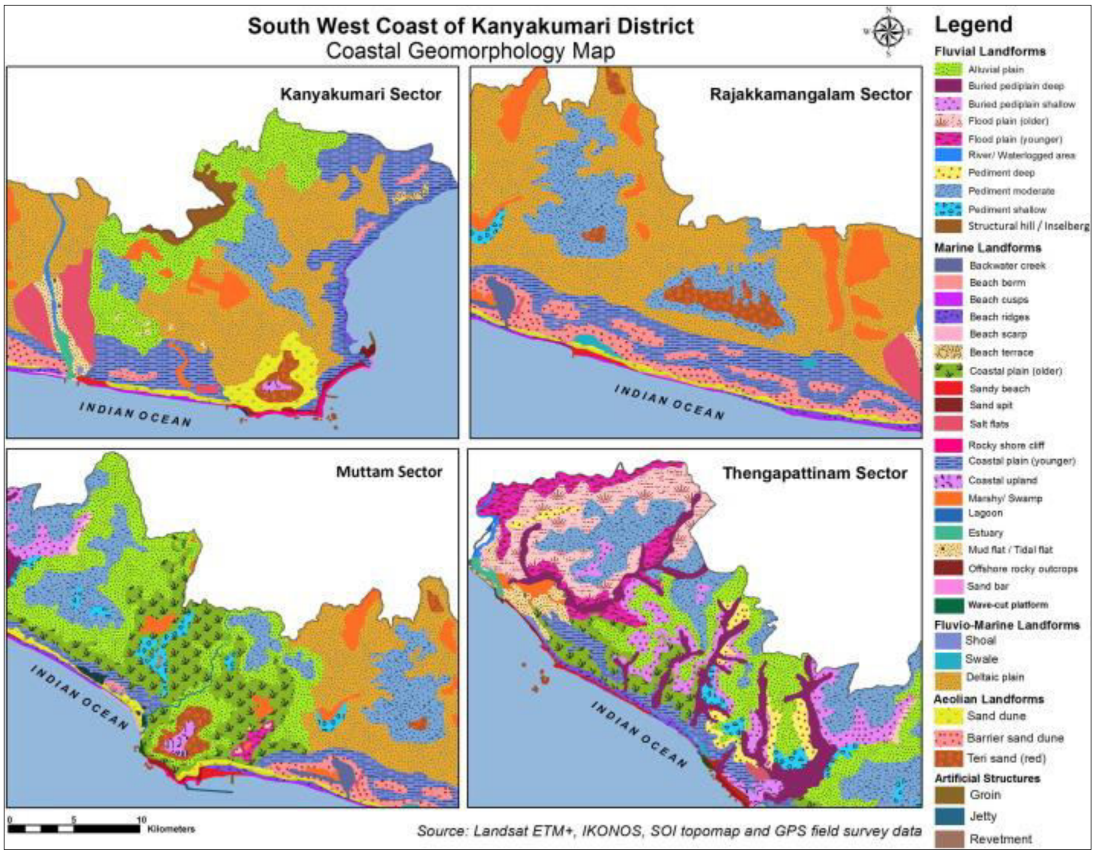


(Source: Suman and Kutubuddin 2019)

GIS Application in Coastal Geomorphology

High-resolution data on the exposure of buildings and infrastructure to coastal erosion were generated using a geographic information system (GIS) for seven-time horizons from now until 2100. The results are based on a rigorous analysis of coastal dynamics that takes into consideration historical coastal migration. Using aerial photographs, sea-side infrastructure was digitally traced in a GIS. For extracting coastal landforms, spatial data sources include the Survey of India's topographical map, Landsat ETM+ (30 m) picture, IKONOS image (0.82 m), SRTM, and ASTER DEM datasets have been thoroughly investigated. For assessing volumetric changes of coastal landforms for the period, change detection approaches such as I topographical change detection, (ii) cross-shore profile analysis, and (iii) Geomorphic Change Detection (GCD) employing DEM of Difference (DoD) were used. Data from a GPS-based field survey was used to validate volumetric changes in coastal landforms. Beach landforms such as sandy beach, cusp, berm, scarp, beach terrace, upland, rocky shore, cliffs, wave-cut notches and wave-cut platforms; were mapped based on their evolution.

Fig.5.4Mapping of coastal landforms and volumetric change analysis in the south-west coast of Kanyakumari, South India using remote sensing and GIS techniques



(Source:Kaliraj*et al.* 2017,LandsatETM+,IKONIOS,SOI topomap and GPS field survey data)

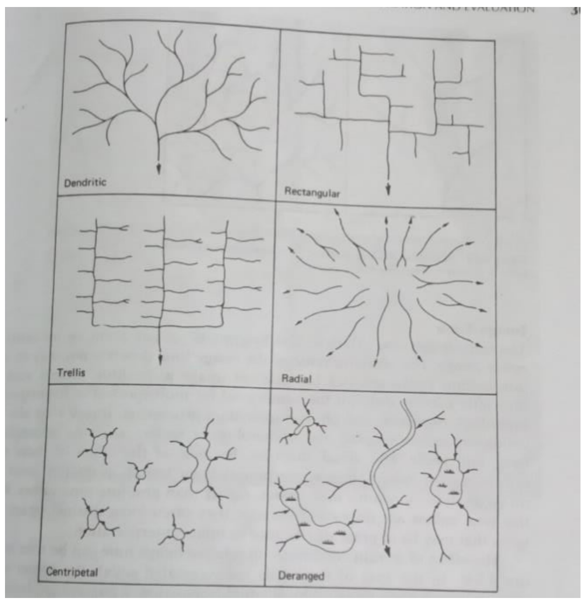
Interpretation of drainage system

The origin and subsequent evolution of any drainage system in a region are determined and controlled by two main factors, viz. (i) nature of initial surface and slope and (ii) geological structure. Streams or drainage systems are divided into two broad categories based on the adjustment of the streams to the initial surface and geological structure, e.g. (i) sequent stream (2) in the subsequent stream.

This drainage pattern and texture seen on aerial and space images indicate landform and bedrock type and suggest soil characteristics and site drainage conditions.

Six of the most common drainage patterns are illustrated in Fig. 5.5. The dendritic drainage pattern is a well-integrated pattern formed by the mainstream. Its tributaries branching and rebranching freely in all directions and occur on relatively homogenous materials such as horizontally bedded sedimentary rock and granite. The rectangular drainage pattern is a dendritic pattern modified by structural bedrock control. The tributaries meet at right angles and are typical of a flat-lying massive sandstone formation with a well-developed joint system. The trellis drainage pattern consists of streams having one dominant direction, with a subsidiary focus of drainage at right angles, and occurs in areas of folded sedimentary rocks. The radial drainage pattern is formed by streams that radiate outward from a central location as typical of volcanoes and domes pattern (drainage is directed toward the mainpoint) and occurs in limestone sinkholes and glacial areas kettle holes, volcanic craters, and other depressions. The deranged drainage pattern is a disordered pattern of aimlessly directed short streams, ponds, and wetland areas typical of ablation glacial till area.

Fig.5.5Six types of Drainage system

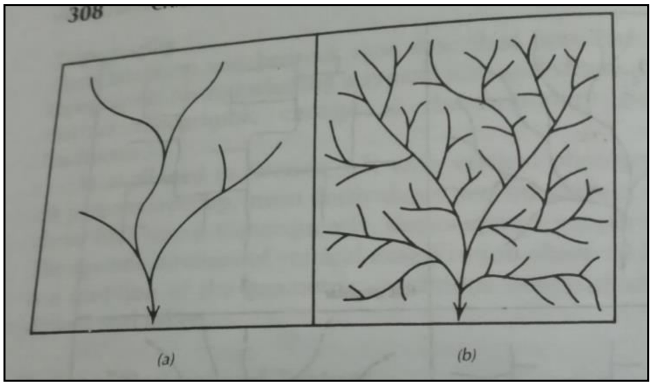


(Source: Thomas M. Lilesand Ralph W. Kiefer, Jonathan W. Chipman, Remote sensing and image interpretation)

The previously described drainage patterns are all erosional drainage patterns resulting from the erosion of the land surface; they should not be confused with depositional drainage features that are remnants of the mode of origin of landforms such as alluvial fans glacial outwash plains.

Coupled with the drainage pattern is the drainage texture. Fig. 5.6 shows coarse-textured and fine-textured drainage patterns. Coarse textured drainage patterns develop where the soils and rocks have good internal drainage with little surface runoff. Fine-textured drainage patterns develop where the dirt and rocks have poor internal drainage and high surface runoff. Also, fine-textured drainage patterns create soft, easily eroded rocks, such as shale, whereas coarse-textured patterns develop on hard, massive rocks, such as granite.

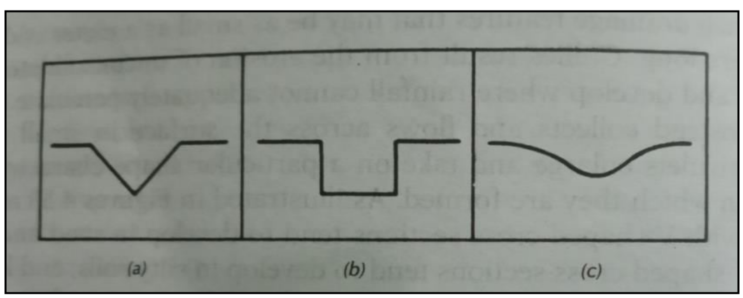
Fig. 5.6 Illustrative drainage pattern : (a) coarse-textured dendritic pattern;(b) fine textured dendritic pattern



(Source: Thomas M. Lilesand, Ralph W. Kiefer, Jonathan W. Chipman, Remote sensing and image interpretation)

Gullies are small drainage features that may be as small as ammeter wide and a hundred metreslong. Gullies result from erosion of unconsolidated material by runoff and develop where rainfall cannot adequately percolate into the ground but instead collects and flows across the surface in small rivulets. These initial rivulets anlarge and take on a particular shape characteristic of the materials in which they are formed. As illustrated in Fig.5.7, short gullies with V-shaped cross sections tend to develop in silty soils; and long gullies with gently rounded cross sections to develop in silty clay and clay soils.

Fig 5.7 Illustrative gully cross sections: (a) sand and gavel;(b) silt; (c) silty clay or clay



(Source: Thomas M. Lilesand, Ralph W. Kiefer, Jonathan W. Chipman, Remote sensing and image interpretation)

5.4 SUMMARY

In the present unit, you have been introduced to the concept of terrain evaluation and terrain mapping, classification of landforms, various types of erosional and depositional landforms and interpretation of drainage systems. Let us now summarise what we have studied in the unit:

- The term *terrain evaluation* is used to denote the assessment of terrain properties as a whole, whether over large or small areas, that apply to any given purpose.

- DEM, typographical sheets and a satellite image are usually used to analyse the nature of the terrain, and GIS applications help create a model such as a contour map. Slope map etc.
- The terrain evaluation is helpful for planning, interpret the land use and land cover.
- There are two types of landforms (i) erosional landforms and (ii) depositional landforms.
- The agent of the exogenetic forces like river, wind, glacier, groundwater has their own erosional and depositional landforms.
- GIS and remote sensing can be used to analyse all types of landforms with a different methods.
- Geomorphological map, morpho-evolutionary model, orthophoto, LANDSAT ETM+ picture, SRTM are used to interpret fluvial morphology and coastal morphology.
- The drainage system of any region depends on the geological structure of this region.
- There are mainly six types of the drainage system.
- Drainage patterns are dependent on the geological structure of the region.
- Mapping of drainage patterns is essential for road construction, risk zonation map, soil seepage etc.

5.5 GLOSSARY

Anthrpogeneic - Human activity.

Bifurcation - The division of something into two branches or parts.

Evaluation - The making of a judgement about the amount, number, or value of something; assessment.

Global Positioning System - The Global Positioning System, originally Navstar GPS, is a satellite-based radionavigation system.

Orthophoto - It is an aerial photograph that has been geometrically corrected.

Surface Runoff - Surface runoff is water from rain, snowmelt, or other sources that flows over the land surface.

Sinuosity - A bends, especially in a stream.

Terrain - The vertical and horizontal dimensions of a land surface.

1.6 *ANSWER TO CHECK YOUR PROGRESS*

1) List the three types of terrain mapping.
2) List the depositional landforms of the river.
3) List the six types of the drainage system.

5.7 REFERENCE

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- International Journal of Current Research Vol. 3, Issue, 7, pp.296-301, July 2011.
- Langat, P.K.; Kumar, L.; Koech, R. Monitoring river channel dynamics using remote sensing and GIS techniques. Geomorphology 2019, 325, 92–102.
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- The Egyptian Journal of Remote Sensing and Space Science Vol.20, Issue 2, December 2017, Pages 265-282.

5.8 TERMINAL QUESTION

1) Write the uses of terrain maps.

2) What are the methods to assess coastal geomorphology?

3) How to manage gully erosion?

4) Write the geological characteristics of the Radial Drainage pattern.

UNIT 6 - HYDROGEOMORPHOLOGICAL APPLICATIONS-HYDROLOGIC FEATURES AND THEIR ELEMENTS, SURFACE WATER AND GROUND STUDIES, INTERPRETATION TECHNIQUES FOR TARGETING GROUNDWATER POTENTIAL ZONES, DELINEATION OF WATERSHED, WATERSHED PRIORITIZATION AND MANAGEMENT

6.1 OBJECTIVES

After studying this course you should be able to

- Landform characteristics (nature of landform occurrence, lithology, structure, interconnection with other units, etc.) and sub-surface geology are used to assess the relationship of geomorphic units with their groundwater potential.
- Hydro geomorphology describes and assesses the environment where water circulates, providing the information needed to comprehend the situation and make the best decisions possible.
- The hydrogeomorphic approach is based on a quantitative examination of drainage basins, suggesting that certain unchanging drainage basin characteristics can be associated with a basin's hydrologic response.
- Development and application phases of the HGM Approach.
- The application of hydrogeomorphology can be seen in the planning and management of various activities on the earth surface.
- Water budgets at the regional, subregional, and municipal levels.
- Trends in recharge, groundwater storage, and outflow to streams or other surface-water bodies as influenced by human and environmental factors are documented.
- We are developing methods for assessing groundwater availability through modelling.
- To assess impacts of groundwater/surface water interactions on the quantity and quality of water.
- To reduce harmful runoff and deterioration, resulting in soil and water conservation.
- We are managing and utilising runoff water for beneficial purposes.

6.2 INTRODUCTION

Human beings require resources to live indefinitely. Water and land are two of the most valuable resources out of all of them. Both of these resources are addressed in hydrogeomorphology. Hydro geomorphology is a new geosciences topic that studies the interactions between water and landforms. It's the result of combining three terms:
Water (surface and subsurface) is referred to as hydro.
The earth and landforms are referred to as Geo.
The surface properties of landforms are described by morphology.
The effects of moving water on geomorphic processes and patterns on hill slopes, rivers, and landscapes are studied in hydrogeomorphology—the effects of geomorphic structure on shallow groundwater spatial and temporal distribution.
As a result, hydrogeomorphology is an interdisciplinary study investigating the relationship between two significant branches of geosciences: hydrology and geomorphology. Hydro geomorphology principles are generally derived from several fields of geosciences such as

geology, remote sensing, climatology, and natural hazards, in addition to hydrology and geomorphology.

In a scientific article published in the Journal of Hydrology in 1973, Scheidegger used "hydrogeomorphology" for the first time. Hydro geomorphology, he stated, is the study of forms induced by water activity. Water, he believed, was the most significant shaping force for landforms. After a 15-year hiatus, Richards reintroduced the term in 1988 to emphasise the importance of hydrogeomorphological studies in comprehending forecast scenarios for river evolution at the hydrographic basin scale. In 1994, Okunishi researched the term "hydrogeomorphology," bolstering hydrogeomorphology's position as an important discipline of geosciences. Hydro geomorphology is a branch of geology that deals with the study of water.

In recent years, hydrogeomorphology scholars have placed a greater emphasis on describing landforms, including their roles and the process by which landforms have evolved in response to hydrological circumstances. In France, hydrogeomorphology is used to restrict flooded areas using topographic data.

The HGM approach is a set of concepts and methods for creating functional indices and then utilising them to assess a wetland's ability to perform functions compared to other wetlands in the region. The HGM approach comprises four key elements: the HGM Classification, reference wetlands, assessment models/functional indices, and assessment processes. These four components are combined throughout the HGM Approach's Development Phase to analyse the functions of a regional wetland subclass.

With this brief introductory note on hydrgeomorphology and its diverse applications, we further appraise you of the varied components and products of hydrgeomorphology.

6.3 HYDROGEOMORPHOLOGICAL APPLICATIONS-HYDROLOGIC FEATURES AND ITS ELEMENTS, SURFACE WATER AND GROUND STUDIES, INTERPRETAION TECHNIQUES FOR TARGETING GROUND WATER POTENTIAL ZONES, DELINEATION OF WATERSHED, WATERSHED PIRORITIZATION AND MANAGEMENT

Hydrogeomorphological applications-hydrologic features and its elements

Mechanism and Process

The process is the simultaneous action of a set of distinct mechanisms over a certain length of time, whereas the mechanism provides the explanation by explaining the physical and chemical effects. Landforms are explored in hydrogeomorphological investigations in relation to the area's groundwater conditions. As a result, morphological, climatic, and hydrological factors are taken into account when researching the mechanism and process of Hydrogeomorphology. The study of the mechanisms and processes involved aids in the explanation of landform shape and distribution.

The process is the simultaneous action of a set of distinct mechanisms over a certain length of time. In contrast, the agency explains by

Basic tools required

To conduct a hydrogeomorphology study, it is critical to first create a geographic database that includes both spatial and non-spatial data requirements and their sources. Maps are the most significant necessity for hydrogeomorphology research. Topographical maps, geological maps, soil maps, rainfall and climate distribution maps, geomorphological maps, population density maps, and groundwater fluctuation maps are all included. Various government institutions and publications in India serve as sources for these maps, including:

· Survey of India for Toposheet Maps
· National Bureau of Census for Population Density Map
· Geological Survey of India for Geological Maps
· Indian Meteorological Division for Climate and Rainfall Distribution data Maps
· National Bureau of Soil Survey and Landuse Planning, for Soil Maps
· All India Soil and Land Use Bureau for Landuse and Land Cover Maps

The maps and data from several national and international remote sensing institutes, such as the Indian Institute of Remote Sensing (IIRS) in Dehradoon and the National Remote Sensing Agency (NRSA) in Hyderabad, must be updated.

Hydrological Cycle and Water Budget

Hydrogeomorphologists must investigate the hydrological cycle, water balance, and water budget for their research investigations because hydrology is an essential aspect of hydrogeomorphology. The hydrological cycle is the movement of water in various forms between different spheres of the earth's surface. Earth's water is recycled through the hydrological cycle. Water flows in, out, and is stored at various levels during the hydrological cycle. Water is added to the system by inflows, while outflows remove it. Water retention in the system is aided by storing it.

The availability of water is studied using a water budget. It comprises the water flow balance between inflows and outflows. Precipitation, surface water inflow, and groundwater inflow are the inputs in the water or hydrologic budget. Evaporation, combined surface and groundwater outflow, and transpiration are all output factors.

Application of Remote Sensing and Geographic Information Systems in Hydro geomorphology

It is critical to collect geological, structural, and hydrological data from the region to properly understand hydrogeomorphology. Hydrological data collection, or reviewing surface and subsurface water resources, takes a lot of time and effort. GIS and remote sensing are the platforms that allow all of the essential data to be acquired more accurately and in a shorter amount of time. Hydrogeomorphological investigations rely heavily on remote sensing and geographic information systems (GIS).

Satellite images and aerial photographs result from a remote sensing procedure that has gone through all of the stages listed above. The distinct parts of visual interpretations are used to understand satellite photos and aerial photographs obtained by remote sensing. Tone, texture, size, shape, shadow, pattern, and connection are all key factors. The same aspects of visual interpretation are employed in hydrogeomorphology to obtain information through the understanding of images generated by remote sensing of landforms and regions encompassing water resources.

A Geographic Information System (GIS) is a computer-based tool for digitally gathering, managing, analysing, and displaying geographic data. The critical components of GIS are maps, computer hardware and software, information, procedures, and people. Because it analyses and responds to real-world situations, GIS is a crucial tool for geographic studies. It generates dynamic maps and provides detailed information about the map's features. It not only shows but also investigates and establishes relationships between the various components. GIS is used to analyse the relationships, patterns, and trends of numerous spatial and non-spatial features of the earth's surface.

Surface water availability has been limited over time due to rapid population growth, rapid urbanisation and industrialisation, and monsoon failure. The increased availability of surface water has put a strain on groundwater resources. This has resulted in increased groundwater withdrawal rates, leading to groundwater depletion. The study of groundwater resources is critical for management and conservation. Geomorphology and other associated aspects can now be used to examine the geographical distribution of groundwater prospects using satellite remote sensing. Groundwater exploration and delineation of hydrogeomorphological units can both benefit from satellite remote sensing. Drainage, geomorphology, and slope of the terrain, vegetation, soil, and weathering depth all have a role in groundwater accumulation, infiltration, and movement. At various levels, remote sensing can be used to investigate all of these elements. Because of its synoptic, multispectral, and multi-temporal capabilities, remote sensing is a valuable tool for geological, structural, and geomorphologic investigation and mapping in addition to hydrological issues. To acquire data on various lithological units, geologists rely heavily on satellite imageries.

The following are some of the most significant advantages of remote sensing in hydrogeomorphological studies: remote sensing has access to vast and inaccessible areas.

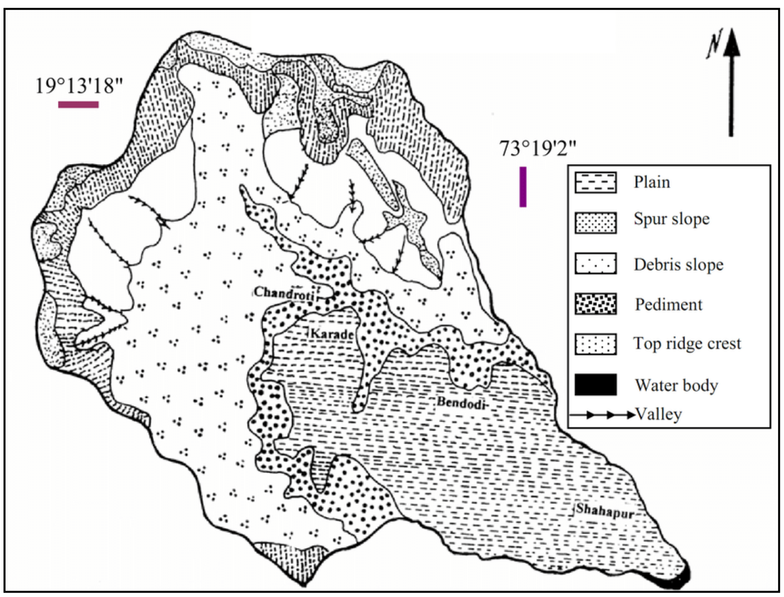
1)Aerial pictures and satellite images provide accurate information about the earth's uppermost layer, critical for hydrogeomorphological research.

2)The degree of information usable in studying hydrogeomorphology is improved through the digital augmentation of satellite images.

3) Compared to hydrogeological surveys, data generated by remote sensing provides more accurate and geographical information.

4) Hydrogeomorphological mapping of terrain and analysis of their processes can be done via remote sensing.
5)The application of geomorphologic mapping using remote sensing can also be seen in land use planning and water resource management.
WiFS, LISS-III, and PAN sensors' IRS-1C and 1D data are precious for geological mapping. The wifi camera provides large-area synoptic coverage, making it valuable for regional mapping and comprehension. Finer geological details, such as indications of Panchromatic data, makes it simple to identify the bedding and minor joints. The Panchromatic data allows for detailed mapping, whilst the multispectral LISS-III allows for semi-detailed mapping.
The main advantages of GIS in hydrogeomorphological studies are as follows:
1) Large volume of data can be analysed and integrated using GIS.
2)Manipulates and analysis the individual layer of spatial data.
3)Rapid, accurate and cost-effective tool.
4)GIS is a powerful tool for the generation of hydrogeomorphological mapping.

Fig. 6.1Hydrgeomorphological Map



(Source: Pradhan, 2009)

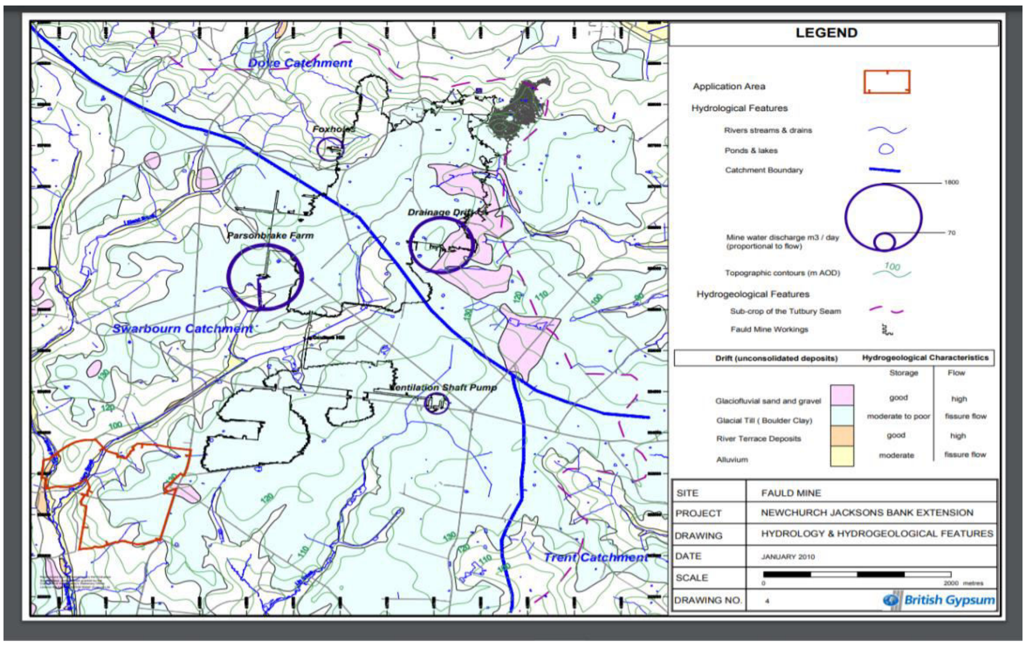
Application of Hydrogeomorphology

Hydro geomorphology is used in the planning and administration of numerous operations on the surface of the earth. The following are some of the essential uses of hydrogeomorphology:

- The accurate, detailed, timely and reliable data on the extent, location and quality of land, water resources, and climatic characteristics help resource planners in agricultural land use.

- Hydrogeomorphological studies help to improve land quality by providing information on land potential and conservation requirements.
- Environmentalists find hydrogeomorphological research useful in identifying dangers and studying climate change.
- It's been valuable for geologists studying the effects of surface and subsurface flow regimes and flow pathways on fluvial erosion and mass wasting.
- Ecologists found it beneficial to characterise the interconnected water and geomorphic characteristics that determine habitats in wetlands, rivers, and other environments.

Fig. 6.2 Hydrogeomorphological characteristics of a stream



The hydro geomorphological characteristics of a strams determined by

1) Flow geometry with the help of Chezy Equation, Manning eaquation and Darchy-Weibach Equation,
2) Channel geometry with the help of cross sectional form, bed configuration, planimetric geometry of a channel pattern and channel bed slope.

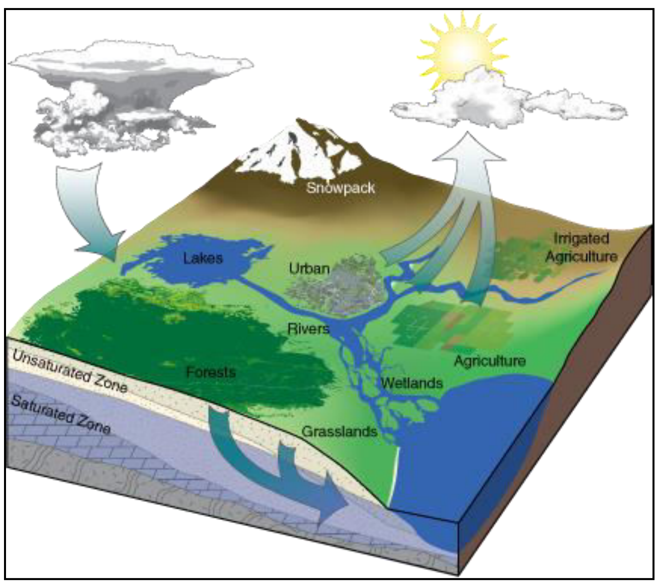
Surface water and ground studies

Any water above Earth is considered surface water, including streams, rivers, lakes, wetlands, reservoirs, and creeks. Despite being saltwater, the ocean is classified as surface water. The hydrologic cycle, often known as the water cycle, involves water transfer from and to the Earth's surface. Surface water bodies are fed by precipitation and runoff. Water bodies, on the other hand, lose water due to evaporation and seepage into the ground. Groundwater is water that seeps down into the ground.

Surface water is divided into three categories: perennial, ephemeral, and manufactured. Surface water that is perennial or permanent lasts all year and is supplemented with groundwater when there is little precipitation. Surface water that is temporary or semi-permanent is only present for a portion of the year. Small creeks, lagoons, and water holes are examples of quick surface water. Artificial structures, such as dams and built wetlands, contain synthetic surface water.

Surface data and satellite photography can be used to track the planet's surface water. The discharge—the amount of water moving down the stream per unit of time—at numerous points along the creek is used to calculate the flow rate of the stream. Monitoring stream flow rates is critical because it aids in determining the influence of human activities and climate change on surface water supply. It's also crucial to keep track of the flora that grows near bodies of water. Surface water can be harmed by the removal of vegetation, either naturally through fires or deforestation. Increased surface runoff can occur when vegetation is lost. Loss of vegetation can lead to increased surface runoff and erosion, increasing the risk of flooding.

Fig. 6.3 Surface water



(Source: britannica.com)

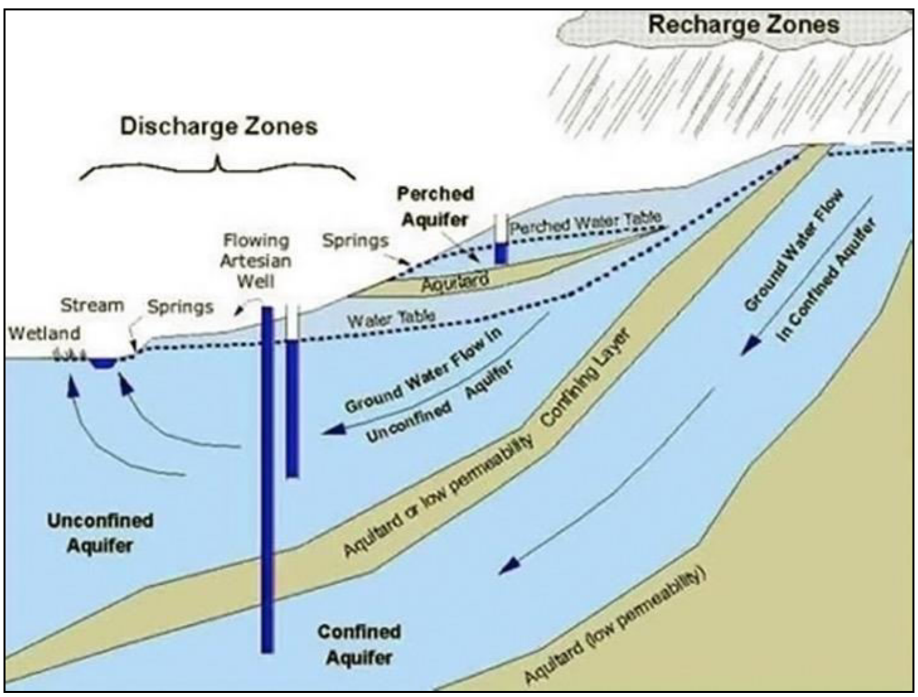
Groundwater is water that has travelled down from the soil surface and accumulated in the crevices between sediments and fissures in the rock. In the saturated zone, groundwater fills in all the empty spaces underneath until it reaches an impenetrable layer of rock. Aquifers are rock and sediment-filled bodies that retain and transport groundwater. The length of time that groundwater remains in aquifers is referred to as residence time, and it can range from a few days or weeks to tens of thousands of years or more.

The water table is located at the top of the saturated zone, while the unsaturated zone is above it, where the spaces between rocks and sediments are filled with both water and air. Soil moisture, as opposed to groundwater, is the water found in this zone. Springs, lakes, rivers, streams and constructed wells can all be used to release existing groundwater. Precipitation, melting, and water seepage from other sources, such as irrigation and leakage from water supply lines, recharge it.

A well must be bored into an aquifer to discharge groundwater artificially, and a well often requires a pump to transfer water upward out of the aquifer. Artesian wells are dug into aquifers both above and below bounded by an impermeable rock layer, and groundwater is driven upward via the artesian well by water pressure from a recharging source above the good outlet point, eliminating the need for a pump.

Groundwater is found beneath the soil surface and can be found in many locations if it is replenished. Even in dry weather, it keeps rivers and streams flowing by refilling them, acting as a helpful substitute for precipitation.

Fig. 6.4 Groundwater



(Source: Oldmanwatershed.ca)

For creating long-term water resource predictions, numerical or computer models have become the tool of choice. Field studies aid in the documentation of groundwater recharge rates and flow patterns in the recharge zone. To better understand all aspects of an aquifer, including geologic distribution of hydraulic properties (hydraulic conductivity and storativity), recharge and discharge, exchange or interaction of groundwater and surface water, and groundwater movement across aquifer boundaries, data must be collected and analysed.

INTERPRETAION TECHNIQUES FOR TARGETING GROUND WATER POTENTIAL ZONES

Geophysical methods to interpret ground water potential zones

Geophysics divided into several methods:

Active	Passive
1- Seismic method	1- Gravity method
2- Electrical method	2- Magnetic method
3- GPR method	3- Seismology method

Active methods : Depend on artificial source

Passive methods : Depend on natural source

Resistivity method-Elementory theory

The problem with using resistance as a measurement is that it depends not only on the material from which the wire is made, but also the geometry of the wire.

We want to define a property that describes a material's ability to transmit electrical current that is independent of the geometrical factors.

Fig.6. 5 Resistivity method

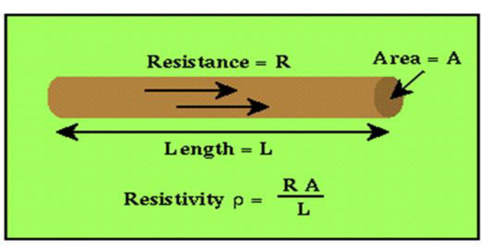
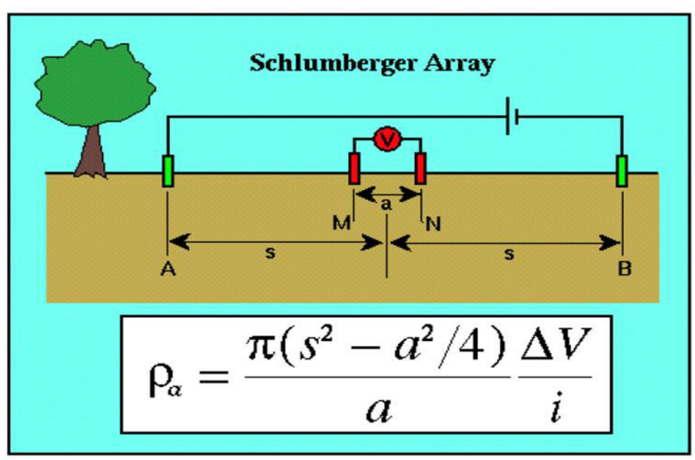


Fig. 6.6 Schlumberger Array



(Source: archive.epa.gov)

Equipment for resistivity field work

- DDR 3 Resistivity Meter used in Resistivity surveys up to about 300m depth
- housed in sturdy aluminium box fixed in a briefcase
- utilizes rechargeable batteries as power source
- consists of two separate compartments

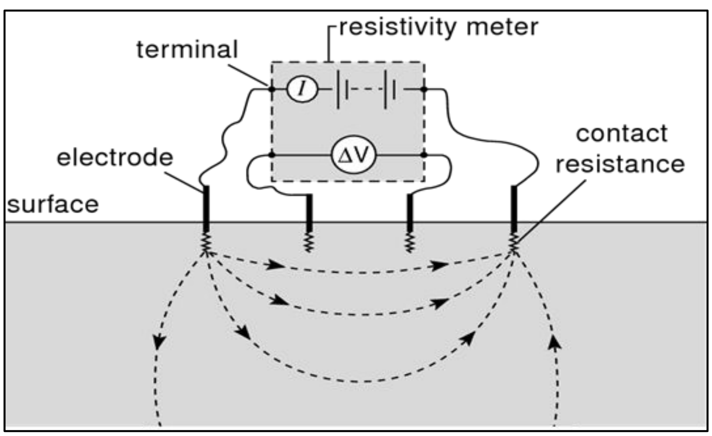
-one for reading the current(I)

-other for reading potential difference(V)

Fig. 6.7 DDR 3 Resistivity Meter

(**source**https://www.jlabexport.com/resistivity-meters)

Fig.6.8 Components of Resistivity Meter



Electrode Layouts of Schlumberger Array – Generally used for VES.

Fig. 6.9 Ground resistance, resulting from several layers with different resistivities

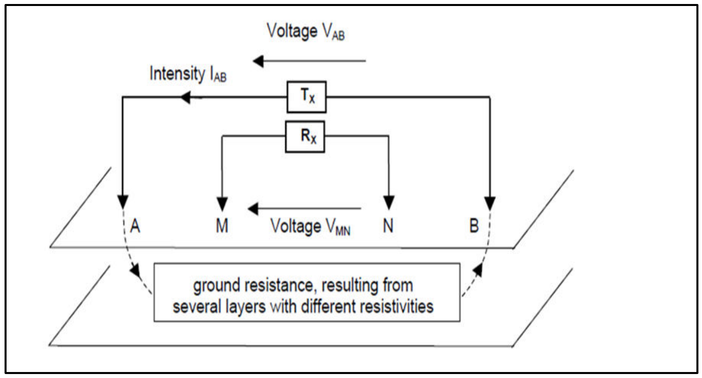
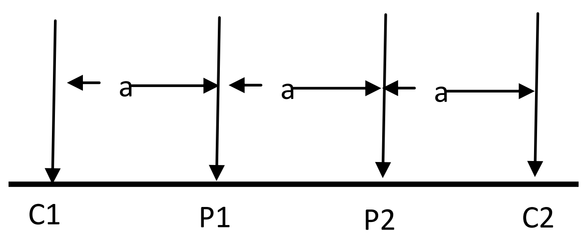


Fig.6.10 Wenner Array



Field Procedure and Data Collection

- Current is sent into the ground through two outer current electrodes
- Resulting potential difference is measured between two inner electrodes comprising carbon pots
- Voltage(V)/ Current (I) is recorded from the voltmeter and ammeter for different sets of electrode spacing
- Separation between the current electrodes are increased and the same measurement is repeated
- As the separation between the electrodes are increased, current penetrates deeper and the measurement pertains to resistivity of the deeper bodies

Method of Interpretation

- Collected data are plotted on a log-log scale
- Curves are interpreted by Curve-matching technique using a set of master curves (developed by Orellena and Mooney)

- Manual Interpretation
- Software Interpretation – IPI2WIN
- Interpreted results – Resistivity and Thickness of each subsurface layers

Fig. 6.11Plotted the collected data on log-log graph

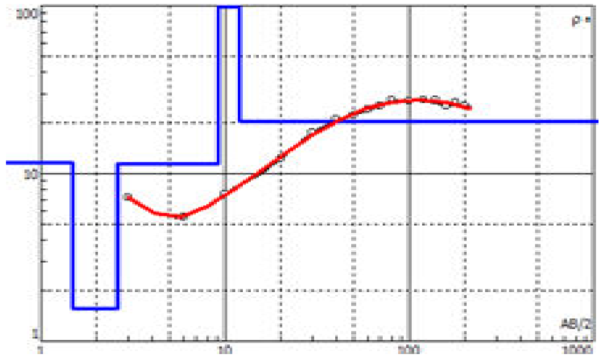
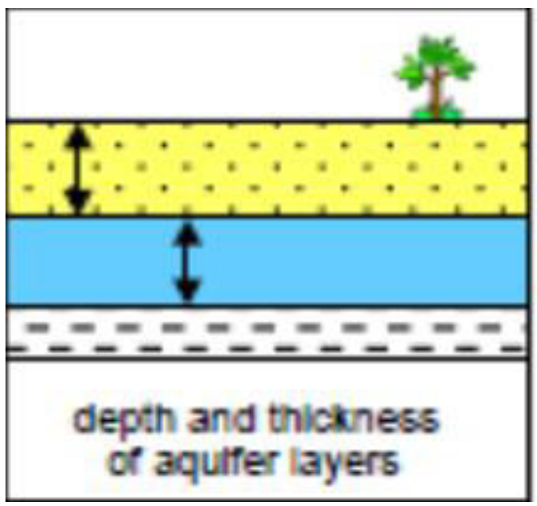


Fig. 6.12 Depth and thickness of aquifer layers



Monitor an aquifer's long-term viability as a safe and reliable source of water and adapt policies accordingly. Identify subsurface contaminants, estimate contamination flow speed and direction, and narrow down contamination sources.

Groundwater levels must be managed to avoid harm from saltwater intrusion, drought, or flooding. The data from the groundwater monitoring network can be used to build measures and determine when your water management system's parameters should be changed. Water boards and municipalities will issue drought or flood alerts and take appropriate mitigation actions thanks to the groundwater monitoring network.

Overall, continuous groundwater monitoring is critical for maintaining or improving water quality and ensuring a consistent water supply.

Delineation of watershed, watershed prioritization and management

A watershed is the area of land where all of the water that falls in it and drains off of it goes into the same place or common outlet. Broadly a watershed have five components: watershed boundary, Sub basin, Drainage divides, Stream network, Outlets (pour points).

Fig.6.13Steps Involved in Delineation of Watershed

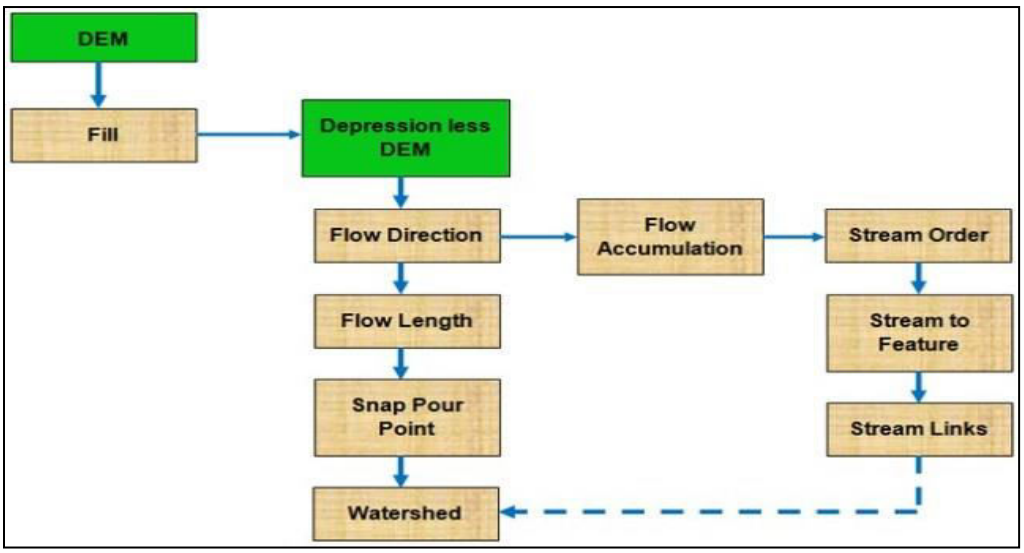


Fig.6.14 Components of watershed

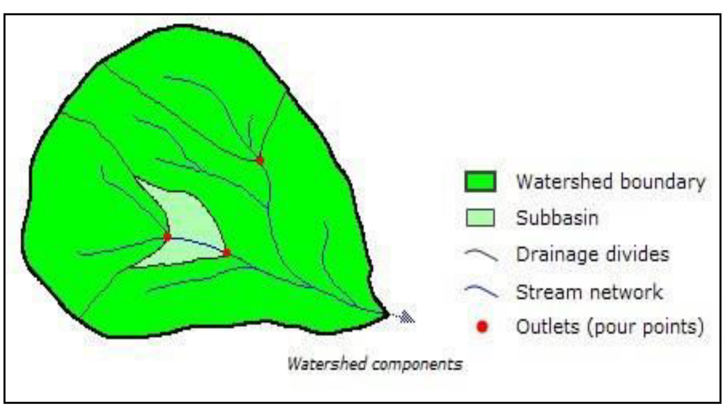


Fig. 6.15 components of drainage system

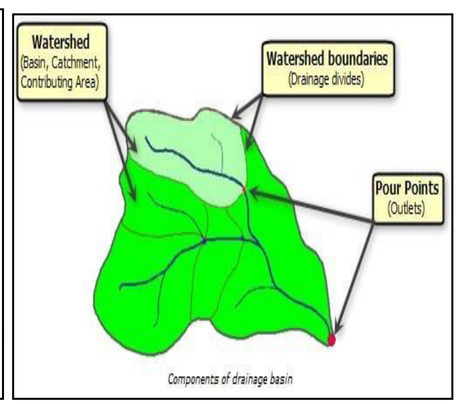
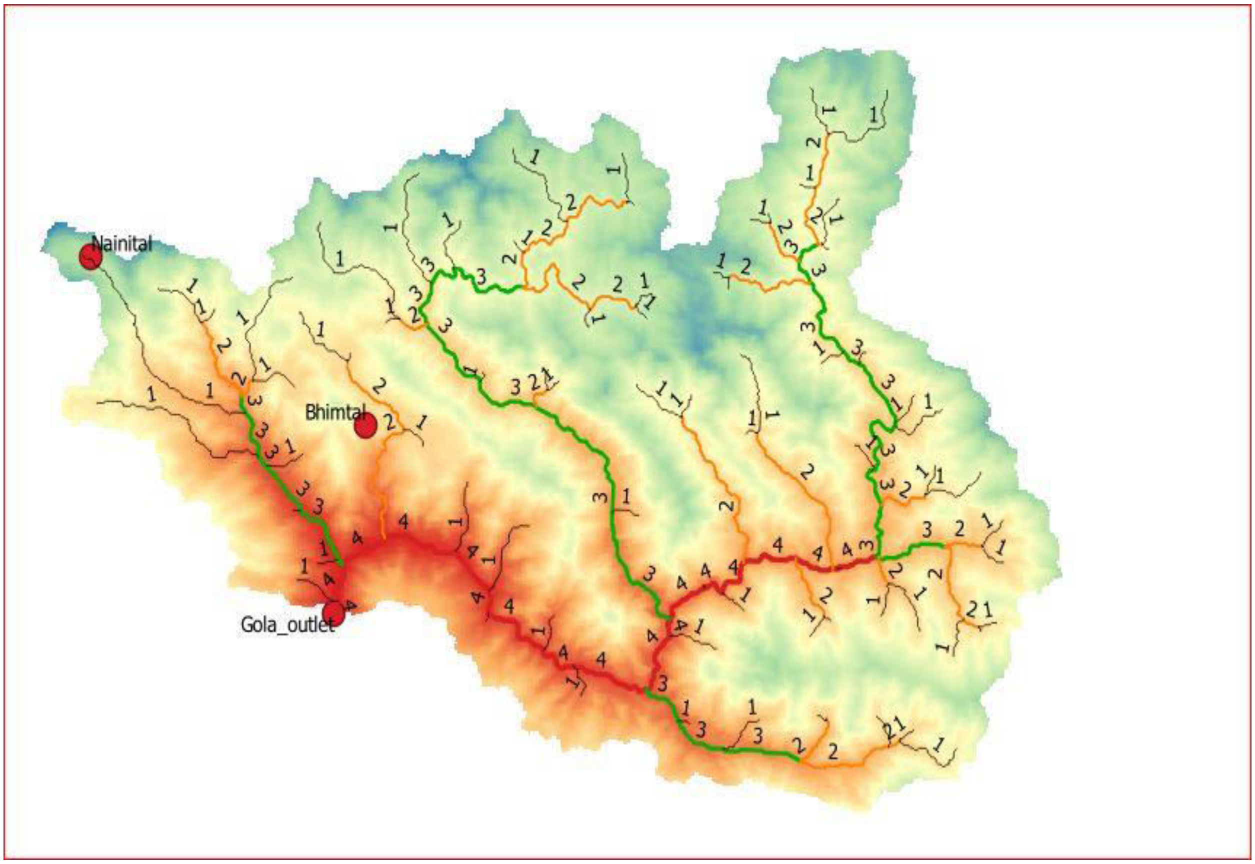


Fig.6.16 Stream order of Gola watershed with outlet at Kathgodam, Nainital



Watershed analysis is carried out for quantitative evaluation of drainage basin and for planning and management of water resources.

Three major aspects: Linear, Areal and Relief have been described for analysis.

A. Linear Aspect

- Stream Order
- Stream Length
- Stream Length Ratio
- Bifurcation Ratio
- Sinuosity Ratio
- Rho coefficient

B. Areal Aspects

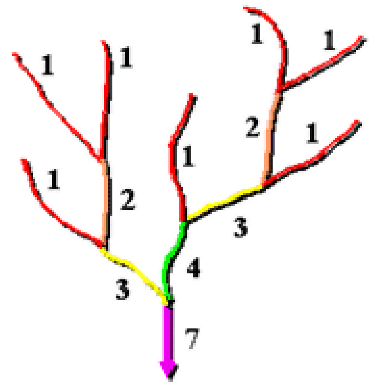
- Drainage density
- Drainage frequency
- Form factor

- Circularity index
- Elongation ratio
- Length of overland flow
- Drainage Texture (Density x frequency)
- Area and Perimeter of Basin

C. Relief Aspects

- Stream slope
- Basin relief
- Ruggedness number
- Asymmetry Ratio
- Hypsometric Integral
- Valley width to height ratio
- Knick Points
- A **watershed** is an upslope area that contributes flow—generally water—to a standard **outlet** as concentrated drainage.
- The **flow** length is the distance from any point in the **watershed** to the **watershed** outlet. This distance is measured along the **direction** of **flow**, not "as the crow flies".
- The **outlet**, or pour point, is the surface at which water flows out of an area. (lowest point). A watershed must have an outlet or pour point.
- Depressions (or pits) are low areas within a digital elevation model surrounded by higher terrain, with no outlet to lower regions. Filling them so they are level, as fluid would serve them if the landscape were impermeable, is often necessary for preprocessing DEMs.
- Length ratio is the ratio of the mean (Lu) of segments of order (So) to the mean length of elements of the next lower order (Lu-1). Variation in stream length ratio indicates the late youth stage of geomorphic development.
- Stream order is a measure of the relative size of streams. The most minor tributaries are first-order streams, while the largest river in the world, the Amazon, is a twelfth-order waterway.
- Stream order is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their numbers of tributaries.

Fig.6.17 concept of stream ordering



(Source:pro.arcgis.com)

Constant channel maintenance is the area necessary to maintain 1 m of the drainage channel. The continuous channel maintenance represents the drainage area required to maintain one unit of channel length; hence, it is a measure of watershed erodibility. Lower values reflect the low infiltration and permeability, poor vegetal cover and weak rock types. A small area can maintain a 1m flow path, i.e. not getting inside the earth but creating the channel.

High values reflect the higher infiltration and permeability of the materials, fairly good vegetal cover and relatively resistant rock type.

The length of overland flow is a measure of stream spacing. It refers to the size of the rainwater runoff on the ground surface before it gets localized into definite channels.

The length of overland flow values in the two watersheds is 0.08 and 0.37. These estimations mean that the rainwater has to run over 0.08 km and 0.37 km for respective watersheds before it gets concentrated in stream channels.

Smaller values mean more significant runoff. In other words, with less value, it requires less rainfall to contribute a substantial volume of surface runoff.

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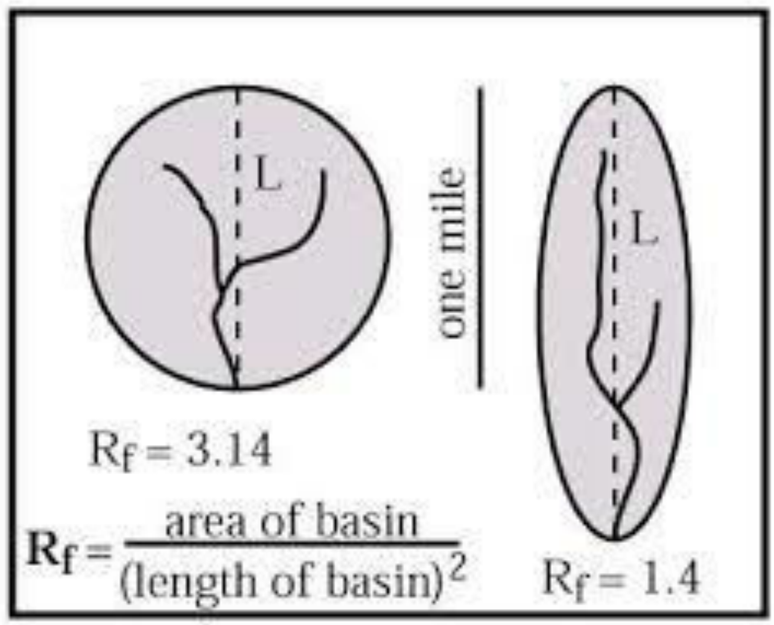
Defines the shape of the watershed as form ratio and describes it as a dimensional ratio of the area to the watershed length (squared).

For circular watershed, the form ratio value is one, and for the elongated watershed, the value is 0 (scaled values).

Fig.6.18 Circular and elongated watershed



(Source: Slidetodoc.com)

The watersheds with high form factor values have high peak flows for a shorter duration, whereas elongated watersheds with low form factor values will have a flatter flow peak for a more extensive course.

Flood flows of elongated watersheds are easier to manage than that of circular watersheds.

The maximum discharge rate during the period of runoff caused by a storm is called a "peak flow".

The ratio of the length of a river's channel length to the size of the valley proper. A measure of a river's meandering. Rivers with a sinuosity less than 1.5 are usually considered straight. More sinuosity means less sediment load.

Rho coefficient is the ratio of Stream length ratio / Bifurcation ratio. In the bifurcation ratio, you divide the number of first-order streams by the number of second-order streams. The Rho coefficient represents the storage capacity of the drainage network during a rainfall event.

The circularity ratio is the ratio between the areas of a watershed to the size of the circle having the same circumference as the perimeter of the watershed. The flood flows of elongated basins can be easily managed than that of circular ones. High CI is difficult to manage.

Ruggedness index is the maximum basin relief (difference between highest & lowest) and drainage density. Its higher values occur when the slope of the basin is not only steep but also long as well. A low value indicates less soil erosion.

Rainwater or snowmelt runoff can pollute a lake or river in substantial volumes. Watershed management identifies the many types of pollution present in the watershed, how those pollutants are carried, and recommends strategies to minimise or remove those pollution sources, which helps regulate pollution of the water and other natural resources in the watershed.

All activities within a watershed have an impact on the natural resources and water quality of that watershed. New land development, runoff from developed regions, agricultural activities, and home activities like gardening/lawn care, septic system use/maintenance, water diversion, and car maintenance can all impact the quality of the resources within a watershed. Watershed management planning evaluates all activities that affect the watershed health and gives recommendations for effectively treating them so that pollution's adverse effects are minimised.

Watershed management is also significant since the planning process leads to collaboration among all watershed stakeholders. Because all parties have a stake in the watershed's health, this collaboration is critical to successfully managing the watershed's land and water resources. It's also a practical technique to prioritise the implementation of watershed management plans when resources are scarce.

Because watershed limits do not coincide with political boundaries, activities taken by nearby municipalities upstream can have just as big of an influence on the land and water resources of the downstream city as those born locally. Impacts from upstream sources can occasionally sabotage downstream communities pollution control efforts. To safeguard the health of the watershed's resources, comprehensive planning for help throughout the entire watershed, with participation and commitment from all municipalities in the watershed, is essential.

Fig.6.19 Morphometric analysis of a drainage basin

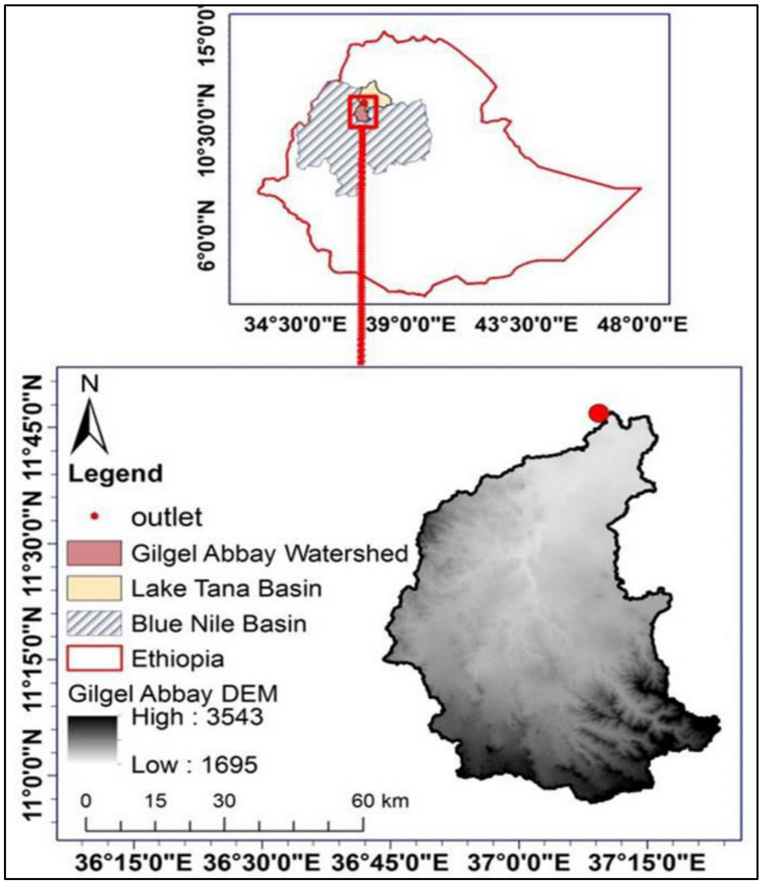
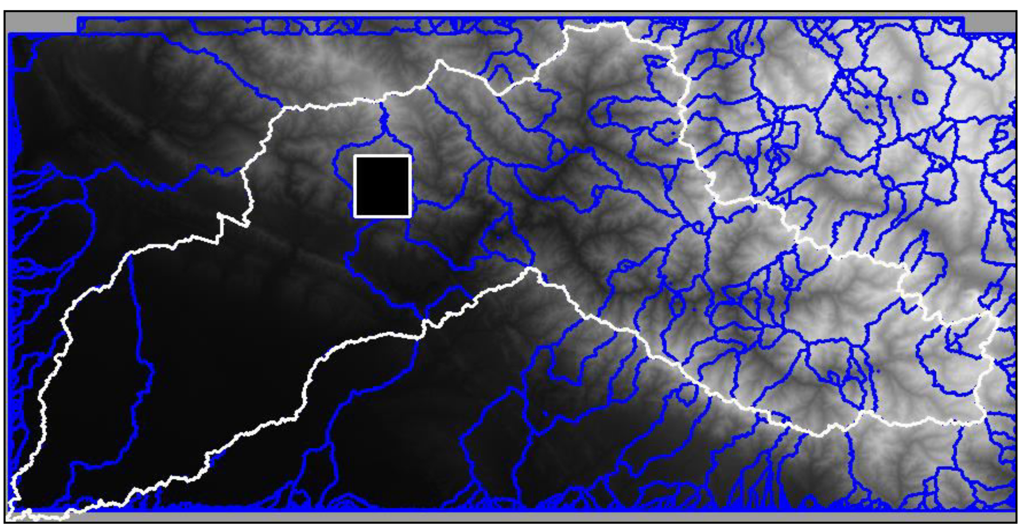


Fig. 6.20 By D-8 method with Fill Depressions (Many small watersheds)



(Source: TNT.mip)

A watershed analysis is used for the management and planning of natural resources.

- To provide necessary inputs for hydrological modelling.
- Flood prediction modelling and snowmelt runoff models etc.
- Watershed analysis provides catchment boundaries but also hydrological parameters useful for management programs
- Erosion and sedimentation control
- Agricultural runoff control
- Rainwater harvesting and groundwater recharging
- Watershed management depends on collecting and managing information on the physical relationship between vegetation, soil, and water resources, which hydrogeomorphological studies can easily do.

6.4 SUMMARY

The interaction between the physical and human environment has changed and evolved. The emergence of numerous issues due to the expanding human population and its effects on environmental and water resource systems prompted the creation of the new subfield of hydro geomorphology. This shift in the man-environment relationship has resulted in changes in the hydrological cycle, water consumption, land use, and climate. Hydro geomorphological investigations are a fantastic way to manage and control environmental issues in today's world.

The relevance of hydro geomorphology as geoscience has grown to the point where international organisations such as the UNDP and the World Bank have included a clause requiring an awareness of the hydro geomorphology of the area before beginning any development project there. These organisations have emphasised in-depth knowledge of landforms, hydrogeology materials, and earth surface processes used in remedial work, planning frameworks, and land zoning plans. As a result, hydro geomorphological information is currently being used in the plan and develop the entire planet. This shows the growth in status and responsibility of hydro geomorphology in recent years as an essential field of geosciences.

Water managers and scientists must be able to understand how groundwater and surface water interact. Each management is a part of the hydrologic system; most of the time, a stream or an aquifer is partially filled. Since each component of the hydrologic system is in a constant state of interaction with other elements.

Watershed management planning is a method of generating a plan or blueprint for protecting and improving the water quality and other natural resources in a watershed. Watershed limits frequently extend beyond political boundaries into neighbouring municipalities or states. That is why, to manage a watershed effectively, a comprehensive planning process involving all affected cities in the watershed is required.

6.5 GLOSSARY

- Aquifer- An aquifer is a body of rock and/or sediment that holds groundwater.
- Hazard- A hazard is a potential source of harm.
- Hydro geomorphology- An interdisciplinary science focuses on the interaction and linkage of hydrologic processes with landforms or earth materials and the exchange of geomorphic processes with surface and subsurface water in temporal and spatial dimensions.
- Morphometric- refers to the quantitative analysis of form.
- Panchromatic- It is a type of black-and-white photographic emulsion.
- Ruggedness- (Highest relief –lowest relief)/Drainage density.
- Evaporation- The process of turning from a liquid into vapour.
- Transpiration- The exhalation of water vapour through the stomata.

6.6 CHECK YOUR PROGRESS

1) What is the meaning of the word Hydro geomorphology?
2) What is the difference between surface and groundwater?
3) What is the critical components of watershed management?

6.7 REFERENCES

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6.8 TERMINAL QUESTIONS

1) What is watershed management?

2) How to measure the ground water potential zone?

3) Write the application of hydrogeomorphology.

4) What are the sources of surface water?

BLOCK 3 : GPS BASED RS SURVEYS ADVANCE APPLICATION POTENTIAL OF GPS

UNIT 7 - ENVIRONMENT

7.1 OBJECTIVES

By the end of this unit you will be able to understand the following:

- Concept of environment.
- GPS role in environmental studies.
- GPS role in environmental mapping.
- GPS in collection of environmental data.

7.2 INTRODUCTION

The invention of GPS was solely done by the Air force of United States to cater the need of defense services. Later U.S. decided to open it for civil usage which brought revolution in the navigation services. Not only navigation, the use of GPS started in almost every aspect and discipline. The use of GPS in defense, research, education, navigation, and environment of late has increased manifold. Any research or invention is done in order to provide welfare to the society and environment we are living in. the use of space technology is now rightly used for saving and maintaining the environment and natural resources.

"**The natural environment, commonly referred to simply as the environment, is a term that encompasses all living and non-living things occurring naturally on Earth or some region thereof. The natural environment is contrasted with the built environment, which comprises the areas and components that are strongly influenced by humans**" (Ecology, 2003).

Global environment is facing is a tough time because of the severe impact of climate change. Also from the point of view of sustainable development, the balance that is required between human needs and environmental produce can be assessed. Every important organization of the world like United Nations (UN), Food and Agricultural Organization (FAO), World Bank etc. and also the countries themselves are looking after the better technologies that can monitor environmental degradation or change. The advancement in space science especially by the countries like United States, Russia, China and India has put forward the accuracy and collection of real and near time data. In the earlier time gathering timely and accurate data was one of the biggest challenge faced in order to plan or make decision related to environment. Environmental scientists are beginning to use the Global Positioning System (GPS) for in situ determination of the location of point and line features. The accuracy of data collected by inexpensive GPS units can be quite variable (Peter August, 1994).

Geo-spatial technologies have proved to be an accelerator in the research related field. In the field of environment it has proved to be very important as environment involves all the aspects surrounding us living and non- living, which at times are in accessible. With the help of space technology: areal and satellite imageries, it has become easier to touch almost all the aspects of our surroundings. This has also led to define the areas that need quick action for their current degrading situation. The advancement in technology also gives birth to millions of questions. Geographic Information system (GIS) together with GPS has led to better measure patterns of access to and engagement with the environment. This combination gives best accuracy and mapping out comes with storing huge database in it (Jankowska, 2018).

7.3 ENVIRONMENT

GPS is becoming one of the major tools for collecting environmental data. One of the exclusive feature of GPS is that, GPS can provide reliable, accurate and elevation information. The space technology provides best satellite imageries with wide coverage to very high resolution images for better research activity. To study of environment is highly interdisciplinary in nature with its roots with almost all the scientific disciplines. The main advantage of space technology and computer aided software over any technology is that this technique has, multispectral approach, synoptic overview and repetitive coverage. With the repetitive and frequent coverage it is easy to detect any change in the environment whether positive or negative. GPS has proved to be a very cost effective and beneficial tool for surveying in terms of environmental investigations. One of the key feature of this techniques is also that this can be used all weather with no limitations. The level of GPS accuracy can be varied as per the requirement. The 1- or 2-meter accuracy of hand-held units is usable and satisfies much of the requirement at low cost. Millimeter accuracy can be provided for traditional survey applications. GPS positions and site characteristics can be converted into most common geographic information system (GIS) formats, eliminating time-consuming intermediate conversion steps (Stankoff, 2000).

GPS provides widest application in mapping. The coordinated recorded by GPS are inserted in Geographic Information System (GIS) to create map. The satellite and areal images used in Remote Sensing and GIS are first geo referenced and then put to use. The data collection through GPS can be received from static and also from a moving object. Just by connecting GPS with other type of data, it is easier to analyze and manage many environmental problems.

The various applications of GPS in environment can be listed below:

1. **Mapping of Environmental Resources** like wetland, wildlife habitats, extents of forest cover, their density and changes, land-use changes, watersheds and water quality. These environmental resources have been facing a decline in their quantity because of the over exploitation by humans. This has also resulted in changing patterns of climatic conditions and hence it is important to map these resources to come up with some effective measures. GPS gives higher accuracy which helps in creating real time and true to ground information on GIS and later displayed on maps.

Figure 7.1 Before and After Imagery of deforestation in Amazon.

Source: (GPS.GOV, 2006)

2. **Oil spill tracking** is also done using GPS. This application was brought to use by the National Oceanic and Atmospheric Administration (NOAA). They build a GPS based oil spill tracking system. An airborne tracking system consisting of a stand-alone GPS receiver and a custom data logger was used to track oil slicks from the air. The data logger was configured with custom keys to annotate the data record with flags on slick quality, appearance, and other characteristics. This data collection through the data logger is later processed to validate (Zueck, 1999).

Figure 7.2 Massive oil spill at Gulf of Mexico

Source: (GPS.GOV, 2006)

3. **Landfill Gas monitoring** is also done through GPS. A solid waste landfill is a engineered pit that is basically layers that are filled with solid waste, these are compacted

and covered for final disposal. These landfills also emit gases like carbon monoxide and methane. Landfill gas emissions are being controlled by gas extraction systems consisting of well, piping, and flares, engines, and gas turbines. Usually the conventional method of surveying and expensive field visit is used in order to collect data from a portable flame ionization methane detector. This method is very tedious and harmful because of the emission of harmful gases and also brings ambiguity in the location of the survey points. The new technique includes an all terrain vehicle equipped with differential Global positional system and data logger, this system has proved to be more convenient, economic and better in accuracy (Zueck, 1999).

4. **Strain built in active plate boundaries** is also detected through GPS. The active plate boundaries like the Pacific rings of fire is installed with many GPS station and devices which continuously monitor the movement and precise positional data of these plates and also helps the scientists to anticipate the earthquakes and volcanic eruptions. The stain that builds up with the movement of plates can be studies through this technology.

5. **GPS technology helps in understanding of forecast** as the integration of it with operation methods used by the weather scientists helps in monitoring the atmospheric water content. This helps in determining and forecasting the weather conditions with great accuracy. The forecast of weather helps the authorities to warn or inform the mass about the probability of any event that they might encounter.

6. **Availability of Digital data** through GPS has always been an advantage to the users and scientists. Since the data is digital in its form it can be used worldwide, captured and analyzed in a quick time. This helps to analyze the work in hours rather than working on the data for weeks and months. This ensures the quick outcome of the data analyzed and timely actions and planning to be done in case of requirement.

7. Another very important aspect of environment is **wildlife**. GPS has greatly helped in tracking the movement of migratory birds and animals. Endangered species, such as the mountain gorillas of Rwanda, are tracked and mapped using GPS, helping to preserve and enhance declining populations. Not just the endangered species, it has also become easier to monitor the movement of wildlife in reserved national parks and wildlife sanctuaries for example movement of Tigers, Lions, Hyenas and wilder beasts. Until the advent of GPS tracking, it was practically impossible to record elephant movements with sufficient temporal resolution to give a full picture of movement patterns. The presence of elephants in Kenya is a key indicator of the health of the environment (GPS.GOV, 2006).

GPS wildlife tracking is a great way to remotely observe the finest movement of migratory wildlife which is free ranging. This is done using the GPS and environmental sensors or automated data retrieval technologies such as GPRS (GailSchofield, 2007).

Figure 7.3 Elk wearing a radio collar that will be used to gather movement data

Source: (Spreiser, 2018)

7.4 SUMMARY

GPS has proved to a very important tool for navigation and tracking, of late the use of GPS has been initiated in almost all the disciplines. The popularity of GPS has not been untouched by any domain now. The use of GPS along with GIS enhances its usage and makes it more versatile. GPS has now giver new scope of research to the environmental scientists as the conventional methods had the limitations. The use of GPS in environmental data collection has widened the scope of environmental studies. GPS can also be used to improve the quality of environmental data collected by improving accuracy and providing better and accurate spatial coordinates. This data can be correlated with GIS to produce environmental models and maps. GPS is also relatively inexpensive than those conventional data collection methods and surveying with chain and tapes. The dynamic nature of our environment can be easily monitored now within no time and thus can be analyzed too for betterment. The current status of our environment calls for a quick and effective action in order to save it from getting worse. The climate strikes that are going on throughout the world on massive scale now calls for a quick and timely action to revive what we have lost from the environment.

7.5 GLOSSARY

1. Sustainable Development - Economic development that is conducted without depletion of natural resources.

2. **Sensors -** A device which detects or measures a physical property and records, indicates, or otherwise responds to it.

3. **Temporal Resolution -** It is defined as the amount of time needed to revisit and acquire data for the exact same location.

4. **Interdisciplinary -** Relating to more than one branch of knowledge.

7.6 ANSWER TO CHECK YOUR PROGRESS

1. Define environment.
2. What are the major components of environment?

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7.8 TERMINAL QUESTIONS

1. Discuss the concept of mapping environmental resources.
2. Briefly discuss the uses of GPS in wildlife monitoring.

UNIT 8 - AGRICULTURE

8.1 OBJECTIVES

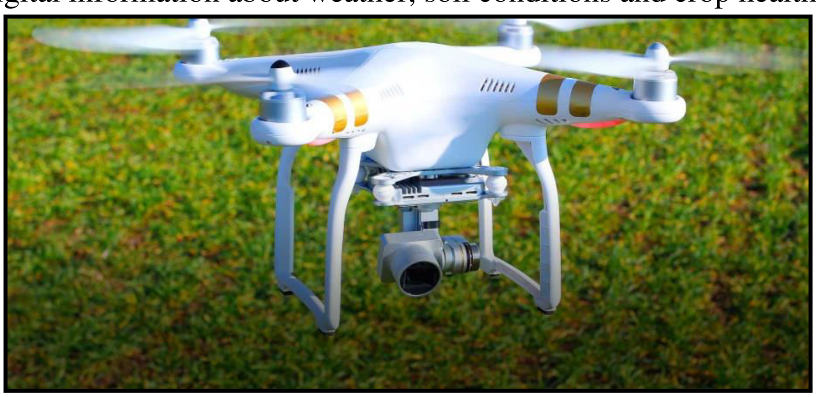
By the end of this unit you will be able to understand the following:

- Introduction to Agriculture
- Concept of precision Agriculture
- GPS application in Agriculture
- Mapping in Agriculture

8.2 INTRODUCTION

Agriculture is a science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool, and other products. Agriculture is the backbone to Indian economy. India is agricultural dominant country; most of its population is directly or indirectly engages in primary economic activity. Food grain production has increased from 51 million tons in 1951 to 230.67 million tons in 2007-2008. The aim of any agrarian economy is to attain self sufficiency. The country have come a long way post division from importing food grain to exporting the food grains and other agricultural produce. But the rapid increase in population still demands for 250 million tons of food grains and calling for efficient agricultural management. Agriculture contributes 35 percent to the gross national product. Agricultural exports constitute a fifth of the total exports of the country. In perspective of the overwhelming position of the Agricultural Sector, gathering and support of Agricultural Statistics expect incredible significance. Conventional techniques to provide the information regarding agriculture are tedious, time consuming, and more often subjective. Agriculture sector has seen tremendous advancement through ages. Also the shift from subsistence and shifting agriculture to plantation and commercial agriculture has modernized the agricultural trend in India. The modernization and advancement of Indian remote sensing satellites and Indian space programme has also helped in forecasting the Indian monsoon, as the agriculture practices in India are still highly dependent on the Indian monsoon system. Satellite remote sensing has the requisite potential to provide this information on a regular, synoptic, temporal, timely and in a more objective manner.

Figure 8.1 Digital information about weather, soil conditions and crop health using Drone



Source: **https://www.research.bayer.com/en/digital-farming.aspx**

8.3 AGRICULTURE

The remarkable development in the space borne remote sensing (RS) technology and its applications during the last three decades have firmly established its immense potential for mapping and monitoring of various natural resources . With the help of remote sensing, it has become far easier to acquire information of places without being in physical contact with each other. Remote sensing can be defined as a science and art of acquiring information about objects from measurements made from distance, without coming in direct contact of the object. Remote sensing is a process and GPS forms one of its system using remotely sensed data to convert it into information for users. Remote sensing technology through the help of GPS has helped in developing the precision agriculture and site specific farming.

In the past, it was difficult for farmers to correlate production techniques and crop yields with land variability. This limited their ability to develop the most effective soil-plant treatment strategies that could have enhanced their production. Today, more precise application of pesticides, herbicides, and fertilizers, and better control of the dispersion of those chemicals are possible through precision agriculture, thus reducing expenses, producing a higher yield, and creating a more environmentally friendly farm (U.S. Air Force, 2011).

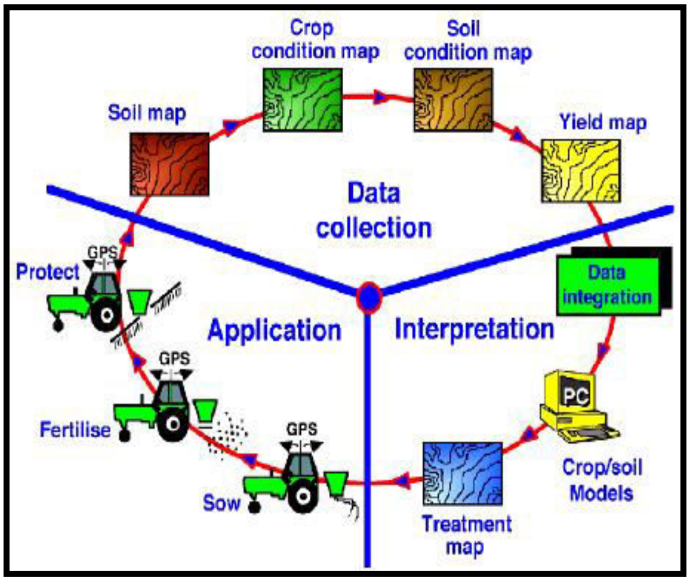
8.3.1 Application of GPS in Agriculture

With the rapidly growing population, the requirement and demand of food grains throughout the world is also increasing. The old techniques of farming in agriculture are not sufficient to cope up with rising demand of food grains. Since the advancement in space science has reached to the peak, this has also benefitted the agricultural development in many ways. Not just in the mapping of agricultural products and potentials but also in precision agriculture. World economy is taking a sharp turn from agricultural to industrial economy and this has put all the agricultural land throughout the world under intense pressure of yielding more form available land to meet the need of the current population. GPS-based applications in precision farming are being used for farm planning, field mapping, soil sampling, tractor guidance, crop scouting, variable rate applications, and yield mapping. The basic of GPS is to provide the location and the aim is to get closest accuracy, therefore mainly the application of GPS is to map different aspects of agriculture.

Earlier it was difficult for the farmers to correlate their production and yield with the variations of land, this led to stagnant production from each unit of land whereas the production is directly proportional to the land zone capabilities. Each piece of land comes up with different capacity as per its soil conditions. With the help of GPS, precision agriculture is trending and it gives information about the requirement of pesticides, herbicides and fertilizers. The soil sampling of the field also leads to the treatment of weaker pockets of land by mapping it.

Nowadays, transforming Indian traditional agricultural practices from subsistence to commercial and precision agriculture is a new approach, to get better increased average yield. Precision agriculture is a mixture of information, technology and management in order to achieve production efficiency, improve product quality, improve the efficiency of crop chemical use, conserve energy and protect environment (V. M. Abdul Hakkim, 2016). With the help of geo-spatial technologies, the farmers are now keener to know the real time information of their land holdings in order to come up with new ideas for good yields and production. The geo-spatial information on soil-plant-animal requirements and also prescribing the site specific treatments has made the farmers and agribusiness look to their land in completely different way.

Figure 8.2 Precision Agriculture Cycle



Source: Comparetti, 2011

India encountered agricultural boom after green revolution where the country witnessed increase in production of food grains, cereals, vegetables. This was mainly because of the use of High yielding variety (HYV) of seeds and better irrigation facilities in some parts of the country. Many places were untouched by green revolution because of the lack of HYV seeds and irrigation facilities. After India attained independence this was the first agricultural revolution which also made India an exporter of many agricultural produce. India's production of food grains has been increasing every year, and India is among the top producers of several crops such as wheat, rice, pulses, sugarcane and cotton.

India is an agrarian economy, and most part of the country practicing agriculture depends directly on the monsoon for irrigation because of the absence of artificial means of irrigation like wells, tube wells, pond, etc. The advancement of space science and with the launching of Indian weather satellites, the prediction and forecast of the real time weather condition over the sub-continent has helped the farmers to sow and harvest the crop accordingly.

GPS allows farmers to work during low visibility field conditions such as rain, dust, fog, and darkness. Weather plays an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop, incidence of pests and diseases, water needs and fertilizer requirements in terms of differences in nutrient mobilization due to water stresses and timeliness and effectiveness of prophylactic and cultural operations on crops (H. P. Das et. al, 2003).

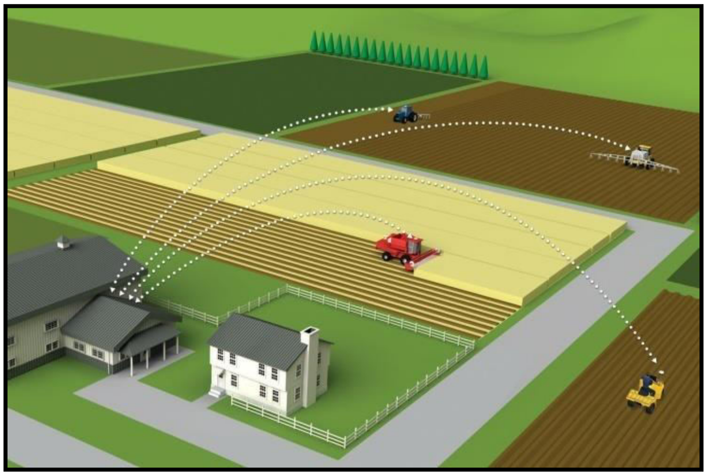
Figure 8.3 GPS application in crop production and agricultural field

Source: John Nowatzki, 2011

There are multiple applications of GPS in agriculture; the following important ones are listed below:

1- **Yield Monitoring:** Yield monitoring through GPS requires a whole new set of sensors for the continuous measuring of crops on the field. The GPS sensor is located at the top of the grain collector vehicle and elevator with is connected to the monitor. As the grains are conveyed, the amount of grains that strikes the force to the sensor displays the quantity or the recorded yield. The data is displayed on a monitor located in the combine cab and stored on a computer card for transfer to an office computer for analysis. Yield monitors require regular calibration to account for varying conditions, crops, and test weights. This activity basically requires grain monitoring, moisture monitoring and location monitoring sensors to get better accuracy and fine results (Borgelt, 1994). The map prepared using GPS in yield monitoring of different zones of the field helps the farmer to understand the property of each zone and later helps in decision making especially in regards to the next planting in a new season.

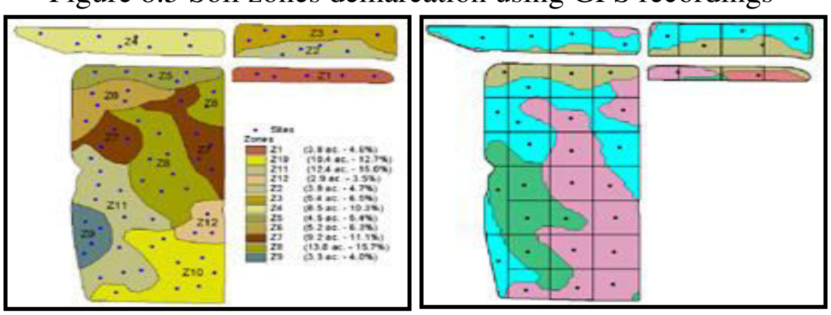
Figure 8.4 Yield Monitoring through GPS on an agricultural tract



Source: https://www.sprayerbarn.com.au/brands/trimble/yield-monitoring

2- **Soil sampling:** In order to collect soil sample the entire field is divided into management zones based on soil types, crop lines and other internal features. In case of division of field based on soil variability, soil samples are collected from all zones. The sample locations can be way pointed in the field and those waypoints marked on the mapping software. These soil samples are later sent to the laboratory for test and the soil maps are created and the decision regarding soil treatment, efficiency, ph value etc. Are visualized. With the help of GPS navigation in agricultural field, time and money can be saved as it allows us to understand the requirement of treating only soil zones that shows the need.

Figure 8.5 Soil zones demarcation using GPS recordings



Source: http://www.agronomicsolutions.com/gps-soil-sampling.cfm

3- **Weed location:** "A wild plant growing where it is not wanted and in competition with cultivated plants". Agricultural fields are often open to unwanted plants called weed. These unwanted plants not only become a hindrance to the crop but also take away the nutrients of the soil. In order to make the agricultural tract free from the weeds, the mapping of these weed is essential. For mapping of weed GPS a recording are used to specify the location of the weed growth and to what kind of crops the weed are growing with. Miller & Stafford (1991) proposed a map-based approach in which weed populations located on a map can be converted to a treatment or application map and used to control the sprayer. GPS can be used to extract the weed growth and patches on a large agricultural tract through linear sampling technique.

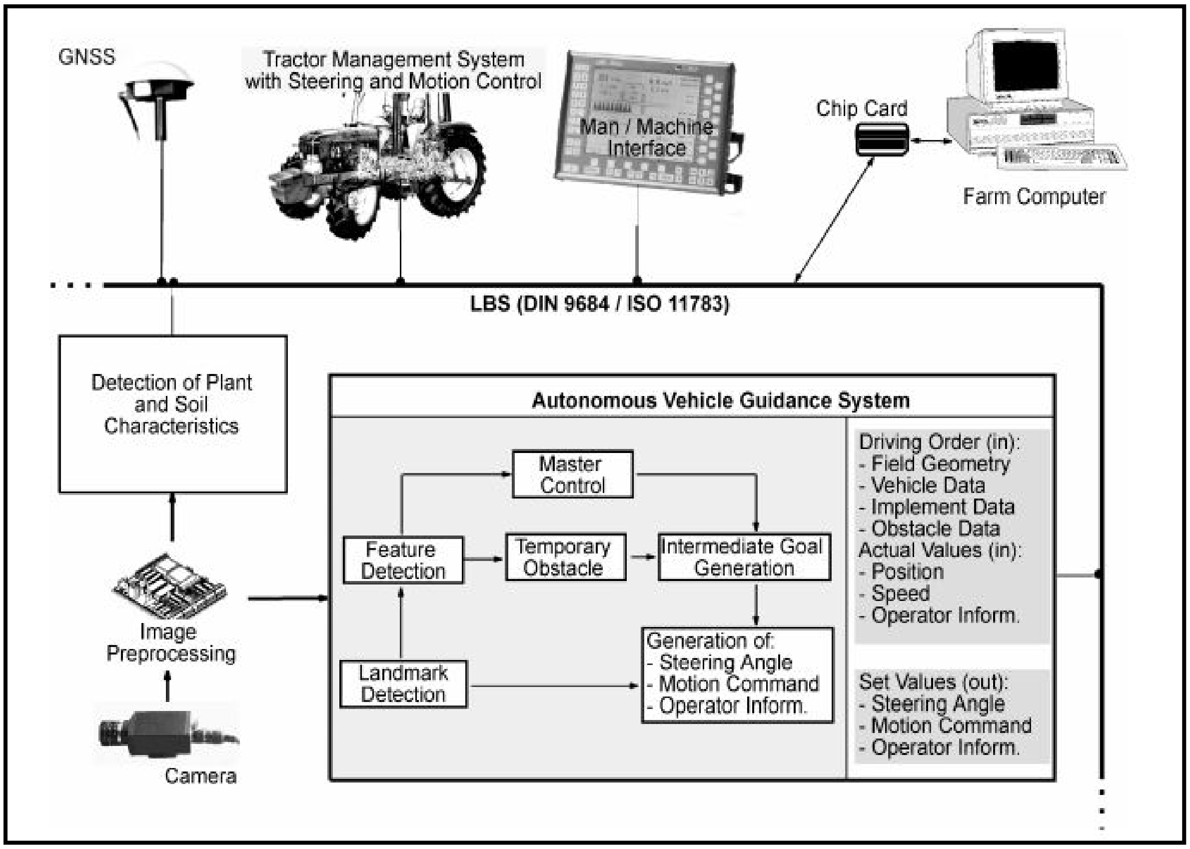
4- **Tractor Guidance:** Tractor guidance uses differential GPS (DGPS). This technique is developed in order to track the target line on agricultural field for plowing, sowing, fertilizing, pesticide spraying, harvesting, manuring, grass teddering etc. Since the world is facing a shift from primary economic activity to secondary, tertiary and quaternary, the number of farmers compared to the past has reduced. Considering the fact that the demand of the food grains has been increasing day by day with growing population, the requirement has to be fulfilled anyhow.

Figure 8.6 Tractor Guidance through GPS

Source: (Breen, 2017)

The use of GPS in tractor guidance has reduced the manual work and labour work to a great extent. For a country like India and China with large human resource, the agricultural semi skilled and unskilled labour are abundantly available but for countries like Canada, Japan, United States and many countries in Europe the man power is mostly engaged in secondary and other economic activities and it becomes difficult to find agricultural labour. Moreover these countries have large agricultural fields with low skilled farmers; the need is to speed up the practices. Agricultural field machinery - self propelled or tractor - implement combinations - are highly specialized means of production.GPS and geo-spatial techniques helps the land owners to use tractor guidance application which is governed by DGPS and save a lot of money, time and man power (Keiichi INOUE, 2019).

Figure 8.7 Standard Guidance system hardware construction



Source: (Jahns, 2016)

5- **Field Mapping:** GPS and GIS have advanced in last few decades. The advancement of space science has been beneficial to the agricultural sector also. Lately GPS has been used immensely for precision agriculture and farm planning. With the help of navigation, the spatial aspect of agricultural field and variability can be recorded and mapped through GIS. GPS is being used to correlate production techniques and crop yields with land variability. The correlation enables the farmers to develop the most effective soil/plant treatment strategies, hence enabling higher farm production. Today, farmers in developed countries use GPS mapping for more precise application of pesticides, herbicides, and fertilizers; better control and dispersion of these chemicals are possible through precision agriculture, thus reducing expenses, producing a higher yield, and creating a more environmentally friendly farm. Relying on visual cues is hectic when trying to determine the boundaries of a farm and it is tedious. GPS technology makes work more manageable, it really helps farmer overcome any challenges that they face while working in their fields (GPS technology as an integral part of precision agriculture, 2016).

Farm and field maps help in easy visualization of land variability in terms of soil status, crop production, yield mapping, pesticides and insecticide mapping. The maps related to the soil erosion of a particular field can also provide much information to a farmer to treat that pocket of land. This is an easy way for a common man to understand the dynamics of agriculture. This also helps in managing the farm logistics. The farmers nowadays use GPS to enhance their farm operation. The treatment of soil, weed, pesticides, insecticides can we well viewed from the maps generated through GPS coordinates and GIS software. The mapping of field also helps in planning the field for future crop and agricultural season. The prediction of a certain crop production keeping in mind the current production leads to the planning of field accordingly. In the past this has been a challenge for a farmer to correlate their production with land variability and this has been successfully been replaced by the use of GPS in precision agriculture. The exact information about the land and available maps opens vast prospects for the farmer for their landholding. The advancement of GPS provides better accuracy and this helps farmer to concentrate more on the area and zone that needs prior focus.

8.4 SUMMARY

GPS offers a variety of cost-effective alternatives for old methods of planting, harvesting or raising crops. It also provides with new method of investing lower amount and yielding higher output. Though GPS not only provides assistance to farmers with large farm holdings or agricultural tract but also to the farmers with fragmented and small size farms. Apart from mapping the variability of conditions within the farm, GPS can also help in mapping the aspects that are related to the agriculture practices directly or indirectly like nearby water bodies and farm animals.

For a country like India, the advancement of agriculture has started but the concept of precision farming is still a question for small farmers with small farm size. The shift from subsistence agriculture to commercial and plantation agriculture may take a little longer. The institutions like Indian Space Research Organization are doing wonderful work in order to bring the precision agriculture into dominance with their space science capabilities.

8.5 GLOSSARY

1. Precision Agriculture - Precision agriculture is one of many modern farming practices that make production more efficient. With precision agriculture, farmers and soils work better, not harder.

2. HYV Seeds - High Yielding Variety of seeds, the produce from these seeds are relatively more than the normal seeds.

3. Agricultural Tract - Land that is devoted to agriculture.

4. Yield - Yield is used to describe a certain amount earned on a security, over a particular period of time.

8.6 ANSWER TO CHECK YOUR PROGRESS

1- Define Precision agriculture.
2- Note down different application of GPS in agriculture.
3- Application of GPS in field mapping.

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8.8 TERMINAL QUESTIONS

1- Define Agriculture.
2- Name different application of GPS in agriculture.

UNIT 9 - PUBLIC SAFETY & DISASTER RELIEF

9.1 OBJECTIVES

9.2 INTRODUCTION

9.3 PUBLIC SAFETY & DISASTER RELIEF

9.4 SUMMARY

9.5 GLOSSARY

9.6 ANSWER TO CHECK YOUR PROGRESS

9.7 REFERENCES

9.8 TERMINAL QUESTIONS

9.1 OBJECTIVES

By the end of this unit you will be able to understand the following:

- Concept of public safety
- Concept of Disaster Relief
- Application of GPS in public safety and disaster relief
- Need of GPS in Disaster Management

9.2 INTRODUCTION

Public safety deals with the protection of its citizen and keeping them safe. According to the Merriam-Webster's Collegiate Dictionary, eleventh edition safety is "the condition of being safe from undergoing or causing hurt, injury, or loss". The concept of public safety involves many organizations and department in hierarchy.

The world is now changing to an urban economy. The rapid transformation of countries from rural to urban has also demanded the need of safer urban centers. The concept of smart city also means safe city. To have an attractive socio-economic condition in any area, safety is a pre-requisite. According to United Nations and World Bank, crime rates are one of the biggest obstacles in any city's development. Apart from the safety of citizens from crimes, the citizen's of any country are also to be saved from the natural and manmade disasters. This is one of the most important concerns of public safety throughout the world. The developing countries are still struggling with their critical infrastructure and public safety infrastructure. The authorities throughout the world have very well indicated their plan to secure the critical infrastructure which may act as the major driver in the growth of safety and security in any region.

9.3 PUBLIC SAFETY AND DISASTER RELIEF

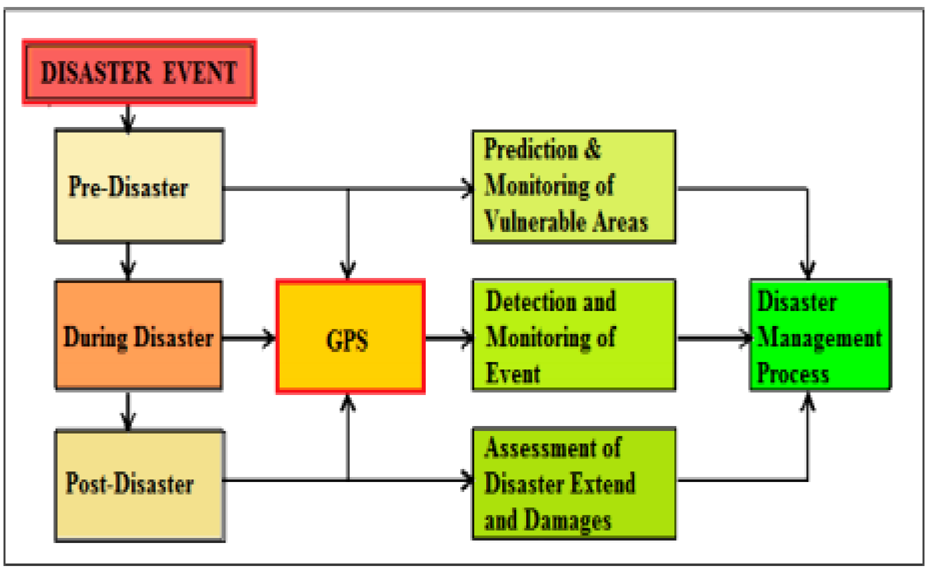
The geo-climatic condition of India makes it a country prone to almost all the disasters in the worlds. A disaster is a situation that disrupts the normal functioning of any society and causes loss to life and property. Disasters can be natural of human induced, but the impact of it over any society or region is the same. The basic classification of disaster is based on its occurrence; Natural or manmade. Disasters like flood, earthquake, volcanic eruption, landslides, cyclones and tsunami are considered as natural disaster as there is a natural phenomenon acting on its origin whereas, industrial and chemical disasters are considered as Manmade disasters as they are the result of distinct outcome of human actions.

With the speedy development throughout the world, almost no area in the world is uninhabited or untouched and possesses the threat of any form of disaster. Though, disasters are not new to mankind but their impact has doubled manifold through past few decades. It's because of the rapidly growing population throughout the world. Any event can only be called a disaster if it impacts the society negatively in terms of loss of lives and property. Therefore, it becomes very important to have effective public safety against disaster from grass root level. In India there are many departments that are actively involved the safety of public like Fire, Police, Central armed police forces, National disaster response force (NDRF) and its entire local and state level wings, Indian defense etc.

For the normal functioning of the society, their publics need to function normally throughout. This could only be made possible by the proper management of its civilians by their safety against any form of disaster. The ministry of home affairs is the nodal department that is responsible for disaster management in the country. Since, 2000 the government has been focusing on the preparedness, prevention, and mitigation along with the capacity building. There has been a paradigm shift from the response to a disaster to preparedness for a disaster. The government, international organizations, NGO's and others focuses on the preparedness of the disaster as the loss estimated post disaster is much more than the amount spent in pre disaster preparedness. In order to keep the community on its pace it is important to have an active disaster management plan on all levels.

GPS plays a very crucial role in all the phases of disaster. The main application of GPS is in the formation of Vulnerability, hazard and susceptibility man of any region for any particular disaster.

Figure 9.1 GPS Disaster management process



Source: (Kamil Muhammad Kafi, 2016)

9.3.1 Application of GPS in flood management

Nearly 75 percent of total rainfall in India is concentrated in the monsoon season. At this point for four seasons, the rivers witness heavy discharge of sediments and water load. Though floods cannot be stopped but can be managed in time with the help of space technology. The GPS has important role to play in flood relief. The most important application of GPS in disaster relief is generation of inventory maps, hazard mapping, and Hazard identification and preparation of response map and plan to manage post flood scenario. This can be done by the help of information about lithology, faults, location of slope, vegetation and land use pattern. GPS also helps to disseminate the information on real/ near time basis which helps in monitoring the advancement of flood. Earth observation satellites enable continuous monitoring of atmospheric and surface parameters that adds to the phenomena of precipitation. Preparation of response plan for flood can also be made with the help of GPS points collected of areas that are prone to flooding.

Meteorologists responsible for storm tracking and flood prediction also rely on GPS. They can assess water vapor content by analyzing transmissions of GPS data through the atmosphere (National Coordination Office for Space-Based Positioning, 2006). During the times of flood earth observation satellites along with GPS satellites helps in regular updation of flood condition, which can be tracked by mobile GPS application from home by civilians and relief team for carrying out rescue operations (P.S. Roy, 2010).

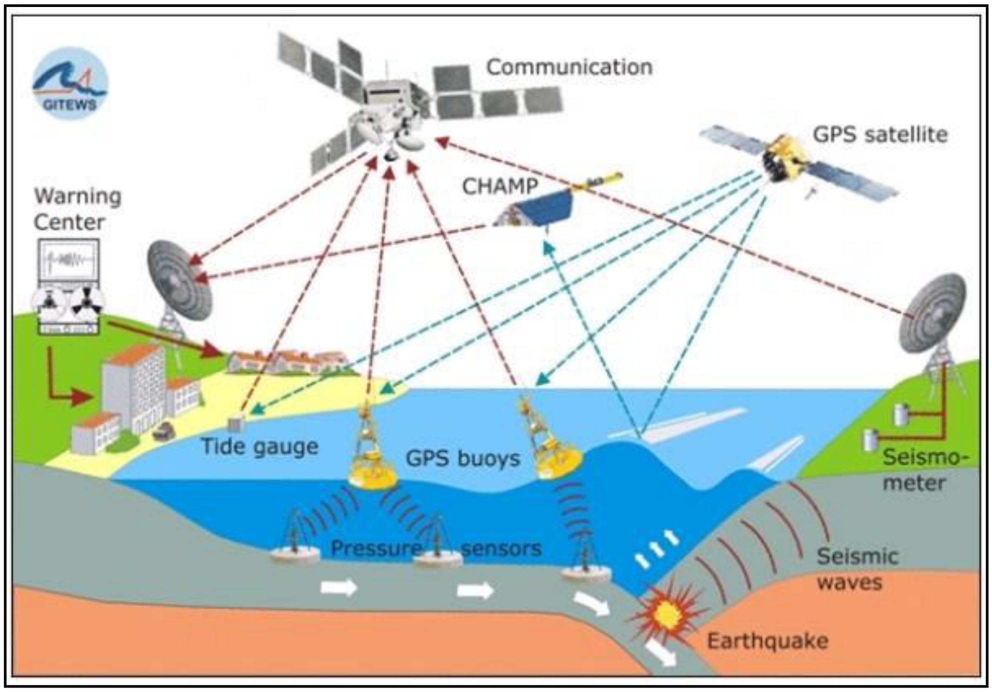
Flood risk zones map can be created using multiyear satellite data acquired during flood and area inundated.

9.3.2 Application of GPS in Earthquake management

Earthquake till date is considered the most devastating disaster of all mainly because of the uncertainty of occurrence. Any seismic event above the magnitude of 5 can cause varying amount of damage. The major causes of earthquake damage can be volcanic activity below the surface of the earth or the movement of tectonic plates. Mainly the earthquakes occur at the junction of two active tectonic margins. Alpine-Himalayan belt and Circum Pacific Belt are known to be the most active tectonic plates on earth. Therefore, these regions of the world are youngest in their origin and witness several earthquakes and volcanic eruption throughout the year. Earthquake is a result of sudden release of energy that forms within the earth crust. The movement of Indian plate towards Eurasian plate with a pace of 6 cm per year and resulting resistance from the Eurasian plate at a speed of 4cm per year generates immense amount of energy. In Indian context these active tectonics lies near Himalayan range where the Indian plate and Eurasian plate collide with each other and makes it a region very prone to seismic activity. The ongoing convergence and continuous collision of Indian and Eurasian plate has resulted in its fragility. Himalayan mountain range lies from west to east with a length of 2300 kms in north India. Being recent in origin, the events of earthquakes are very common here to see. In the past few decades India, in general and Himalayan belt in particular has witnessed some of the most devastating seismic events that have caused both loss of life and property. The entire region of Himalayas from Jammu & Kashmir to Nagaland is prone to high to moderate seismic activity. Much has been said and written about the collision of Indian and Eurasian plate but till date no technique is available to predict the timing of an earthquake. The presence of Main Central Thrust (MCT), Main Boundary Fault (MBF) results in regional compression in this area resulting into earthquakes time to time.

In regions like pacific ring of fire and Himalayan range the GPS has prominently helped scientists to anticipate earthquakes. The GPS monitoring stations helps the scientists to know the stress accumulation beneath the two plate boundaries and also the resulting movement of plates. GPS measures the size of an earthquake by examining the final displacement recorded in an event. This is done by examining the distance a station has moved in total in an earthquake by comparing its position prior to the event with its position following the event (Glasscoe, 1991).
Similarly like other disasters, Hazard Zonation mapping can be done using GPS. Another important role of GPS is to geo-tag the buildings based on vulnerability and prepare an inventory for further studies.

Figure 9.2 Early warning system using GPS



Source: (Blake, 2016)

9.3.3 Application of GPS in Wild Fire Monitoring and management

Like every other disasters, wild fires also need early, during and post management. Wild fires usually take place in summers or on the onset of summers and results in massive destruction on forest cover, wild life and economy. Preplanning of wildfires include locating and mapping of critical resources cultural resource sites; bridges and trail improvements; range structures; wildlife snags, critical habitat such as elk wallows, designated superior trees; remote homes and cabins; and section corners. Hazard maps can be prepared such as mine shafts; power lines and sub-stations; well sites and pipelines.
In detection of wildfires the use of GPS can be especially valuable since the accurate location of fires can help in taking timely action and also getting ready with the suppression resources. GPS can be extremely useful to new arriving personnel needing to check hotspots and spot fires;

equipment can be referenced for retrieval at a later date; critical rehabilitation needs can be identified for timely work; the location of damaged resources can be identified in a timely and accurate manner. Hydrophobic soil can be mapped, along with areas with fire vulnerability and hazard (Mangan, 1994).

9.3.4 Application of GPS in Cyclone monitoring and management

Cyclones are caused by atmospheric disturbances around a low-pressure area distinguished by swift and often destructive air circulation. Cyclones are usually accompanied by violent storms and bad weather. The air circulates inward in an anticlockwise direction in the Northern hemisphere and clockwise in the Southern hemisphere (National Disaster Management Authority, 2016).

India has a long coast line 7516.6 kilometers which makes it prone to disaster related to sea and ocean. India is covered with Arabian Sea in the west, Bay of Bengal in the east and Indian Ocean towards the south which is reason enough to have safe coasts. Bay of Bengal relatively is known to have cyclogenic area; hence it’s an origin to tropical cyclone. Every year many cyclones originate in Bay of Bengal, from a mere depression to super cyclone category. Because of the east coast origin of these cyclones, the eastern states of Orissa, Tamil Nadu, Andhra Pradesh, Telangana, and West Bengal are worst affected. Between1891-1977, Bay of Bengal has registered the occurrence of 400 cyclonic storms with varying degrees of intensity. The diameters of cyclones vary from 50-320 kilometers but their effects dominate over a large surface of the ocean and also on the lower atmosphere. The perimeter may measure 1,000 km but the powerhouse is located within the 100-km radius. Nearer the Eye, winds may hit at a speed of 320 km.

Remotely sensed data can be used very efficiently to assess the severity and impact of damage due to these disasters. In the disaster relief part, GIS, grouped with global positioning system (GPS) is extremely useful in search and rescue operations in areas that have been devastated. (Nayak, 2014).

Figure 9.3 Location and approach of Cyclone on east coast of India

Source: Indian Meteorological Department

GIS is majorly used in map making with the help of geo-coordinates that are collected with the help of GPS. GIS is also used as data storage and information, analysis and retrieval. The GPS along with weather/meteorological satellite helps in disseminating near/real time information of the cyclonic activity and the pace of its approach towards the coast. With advancement in space science and positioning system, the accuracy has come down to meters and sub-meters in terms of navigation and spatial positioning. The accuracy of location helps in getting to know about the landfall of any cyclone and the amount of time left for the evacuation of people living at the coast. With the advancement in space technology by Indian Space Research Organization (ISRO) India has been able to manage 100 percent evacuation. India has been successful in keeping the loss of lives to the minimum with the effective disaster preparation and quick responding in cyclonic activities lately. The mobile GPS applications has enabled most of the population using smart phone to timely update themselves with the real time location of the cyclone.

9.3.5 Application of GPS in Landslide monitoring and management

Landslide is one of the major natural disasters that occur on the surface of earth. They are also the reason for heavy property and life damage. Landslides and avalanches are among the major hydro-geological hazards that affect large parts of India besides the Himalayas, the Northeastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhayans, in that order, covering about 15 % of the landmass. A vast portion of Indian landmass is covered by mountainous region from Jammu and Kashmir to Arunanchal Pradesh and hence, is prone to minor to severe landslides. Many landslides takes place every year, mainly during monsoons. One of the major causes of landslides is severe rainfall, as the water acts as a lubricant and the work of gravity follows. There are landslides that are induced by earthquakes and also that are caused by human actions like blasting, mining, and quarrying. Like every other case, the hazard must first be identified, analyzed and an appropriate strategy to mitigate its impact. Himalayas alone account for all major to minor landslides and also every form of landslides big and small, quick and creeping, ancient and new.

Figure 9.4 Landslide incidences in Middle Himalaya

Source: (Bhaduri, 2011)

GPS can be used in landslide for 3D monitoring together with GIS and remote sensing as it creates multiple hazard layers; new layers can be generated to visualize new hazard maps. For example, by merging the geology with inventories of water table with the help of GPS measurements, a landslide hazard layer can be generated. Also, adding surface geology elevation in the same procedure can offer liquefaction hazard by GIS level data (Sinan Jasim Hadi, 2011) . Creation of hazard maps, landslides inventories, and landslide risk Zonation maps using GPS for accuracy.

9.3.6 Application of GPS in Volcano monitoring and management

The earth interior is so hot that the rocks within melt and become a thick flowing substance called Magma. This floating material because of convection (Convection is the heat transfer due to the bulk movement of molecules within fluids such as gases and liquids, including molten rock) current rises up and fills up in magma chamber of the volcano. Because of the continuous rise in heat the magma rises and through the volcanic vent and ultimately erupts. Magma that has erupted is called Lava (USGS , 2011).

GPS in volcano monitoring places an important role, the basic role is to monitor volcanic deformation.

Figure 9.5 Volcano Monitoring with GPS

Source: Maite Agopian, 2018

The GPS is best suited for monitoring volcanoes; moreover the equipment or GPS receiver once installed can provide real/near time data for a longer period of time and does not require any human interference. Human interference at any potentially dangerous site is also reduces by the help of the installation of GPS receiver. Although GPS is less precise than borehole instruments at short periods, it is highly valuable at providing independent deformation estimates, particularly in remote areas where other geodetic instruments cannot be installed. GPS also has the advantage that it simultaneously measures all three components of position (Kristine M. Larson, 2001).

9.3.7 Application of GPS in Drought monitoring and management

Droughts are significant climatic phenomena that usually occur in south Asia which encounters severe shortage of water, economic losses and adverse social consequences. For last 20 years, the growth of population has also increased the demand of water and other natural resources.

Traditional method of drought assessment was dependent entirely upon rainfall data, which were not available for every region and were mostly inaccurate. The biggest disadvantage of these data was that they were not available in near/real time and hence updating the information was dependent on the availability of weather station's climatic data.

The application of GPS is almost the same like the ones we have in flood monitoring. The accurate location of the areas experiencing droughts can be mapped using GPS coordinates with historical data. The near/real time rainfall and temperature data can also be merged together to estimate the intensity of droughts that might prevail. The phenomena of drought are long prevailed, it just not happens in a year. Any region frequently missing the rains, with drying up of ground water sources ultimately leads to Drought.

GPS can also help locating nearby water bodies and sources that can be availed during the time of droughts.

9.4 SUMMARY

GPS can be used to deliver disaster relief to areas in less time, and more accurately. They can also be used to detect possible dangers in the area (incoming tsunami, wars, etc.). This can save lives and restore infrastructure which was possibly destroyed (i.e. cable lines, hydro-poles, etc.). They can also provide position information for the mapping of disaster regions where ones are not established already. This can become useful for knowing high impact areas, groups who need rescuing, etc. GPS can also be used for the detection of floods, monitoring of seismic precursors, events, etc. Lastly, they can provide positional information about civilians in need/in case of emergency. This is through the civilians' phones, computers, cars, etc. which contain GPS receivers (mostly).

Knowing the precise location of any disaster or hazard, the amount of causalities and estimated loss can be saved. This information is very important for the rescue, relief teams, public administrators, safety personnel. The advancement of space science has further enhanced the scope of GPS in public safety and disaster relief. In short, GPS modernization translates to more lives saved and faster recovery for victims of global tragedies.

9.5 GLOSSARY

- **Hazard-** A hazard is any source of potential damage, harm or adverse health effects on something or someone.
- **Vulnerability**- Vulnerability describes the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors.
- **Risk**- Risk (or more specifically, disaster risk) is the potential disaster losses (in terms of lives, health status, livelihoods, assets and services) which could occur to a particular community or a society over some specified future time period.
- **Convection-** Convection is the heat transfer due to the bulk movement of molecules within fluids such as gases and liquids, including molten rock.
- **Magma-** Magma is composed of molten rock and is stored in the Earth's crust.
- **Lava-** Lava is magma that reaches the surface of our planet through a volcano vent.
- **Cyclogenic-** Origin of cyclone.
- **Mitigation-** Mitigation is a type of long-term, pre-disaster planning which involves sustained expenditures on structural and non-structural efforts to reduce or eliminate future risks.

9.6 ANSWER TO CHECK YOUR PROGRESS

1. What is the importance of public safety?
2. Discuss the application of GPS in flood monitoring.
3. Discuss the applications of GPS in Landslide monitoring and management.

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9.8 TERMINAL QUESTIONS

1. Write a short note on Public safety and disaster relief.
2. Discuss the role of GPS in ensuring public safety against disasters.

UNIT 10 - SURVEYING & MAPPING

10.1 OBJECTIVES

By the end of this unit you will be able to understand the following:

- Concept of Surveying
- Concept of Mapping
- Application of GPS in Surveying and Mapping

10.2 INTRODUCTION

Surveying involves making large- scale measurements of earth surface. Surveying basically involves the reduction or enlargement of data for usable purpose or demand. Surveying involves mapping. Surveying gives the accurate position and location of any form. The two main functions are 1) the construction of maps using the relative horizontal and vertical positions and 2) the establishment of marks to control construction or to indicate land boundaries (Wright, 2019).

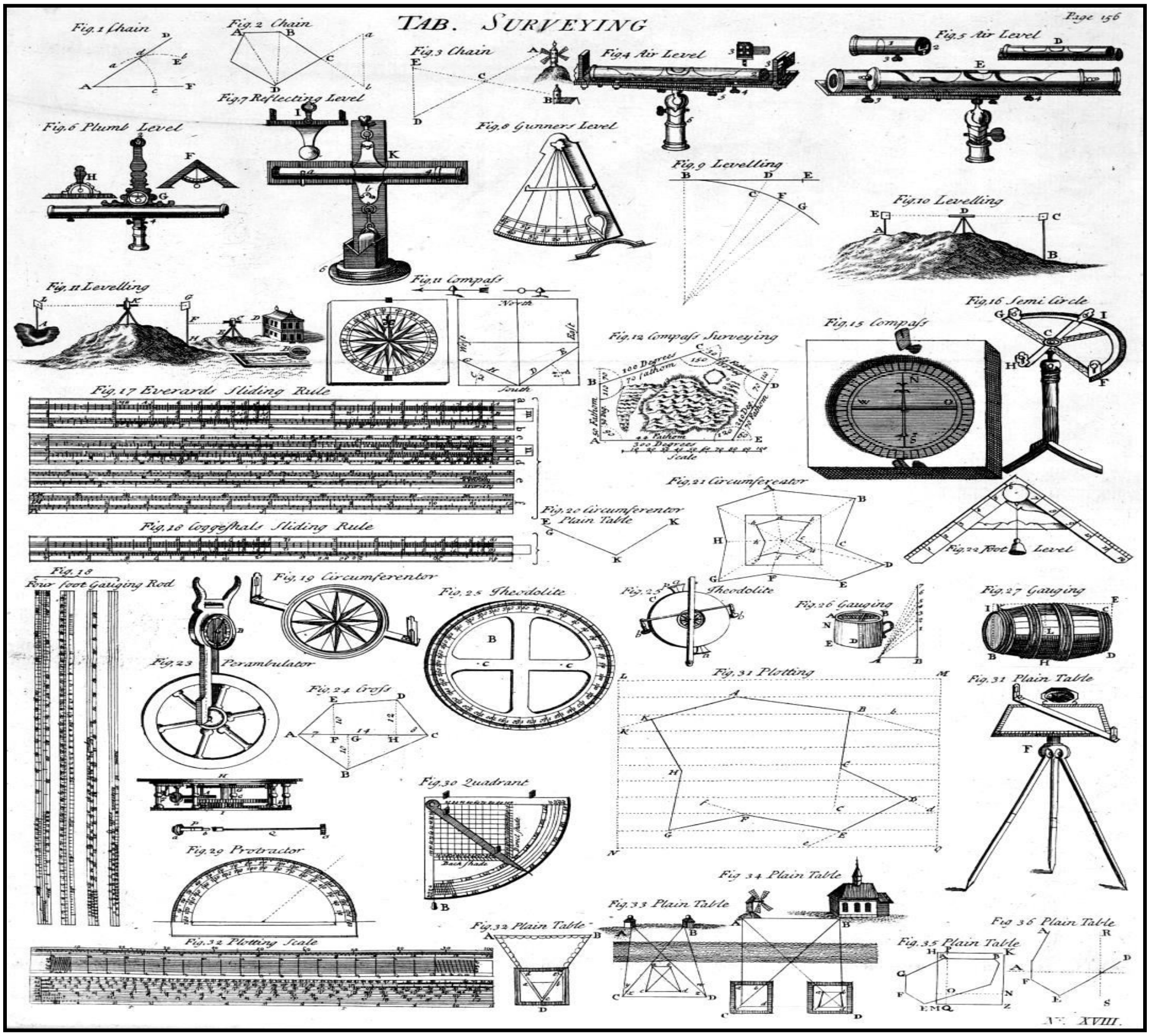
Before discussing further the concept of surveying and mapping let us all know few definitions of both.

Traditional definition of Surveying: *The art of making measurements of the relative positions of natural and man-made features on the earth's surface and the presentation of this information either graphically or numerically* - NJDOT Survey Manual, p.3

Modern Definition of Surveying: *The art and science of determining angular and linear measurements to establish the form, extent, and relative position of points, lines, and areas on or near the surface of the earth or on other extraterrestrial bodies through applied mathematics and the use of specialized equipment and techniques* - J.P. La Putt (1987)

The process of surveying also includes **Cartography** (the science of map making). This includes production and designing of maps using the data collected through surveying and existing data. The final map generated provides information. This ancient method of map making has now been replaced by the use of high resolution satellite images providing nearly 0.30 meters of spatial resolution. These images are than digitized using Geographic information system (GIS). GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

Figure 10.1 Historical Survey tools



Source: (ANZLIC, 1988)

The earliest record of land surveying was seen in Egyptian civilization 3000 BCE. They used surveying for marking farms that were washed by river Nile. They used geometry and measurements to make perfect square farms holdings. The school of surveying was established by Romans basically to teach town planning, map making and building roads and transport services. Under the Romans, land surveying was established as a profession and land surveyors established the basic measurements under which the Roman Empire was divided, such as a tax register of conquered lands (300AD).

The modernization in surveying and mapping came in the time of British colonization "much of the survey work undertaken to open up the country and provide land holdings to settlers was carried out using Gunter's chains, measuring wheels, circumferenter, Kater's compass and even pacing where approximation sufficed … so long as the corners of the land were clearly staked and marked by the surveyor, the accuracies of measurement and direction were left to chance" (Hallmann, 1994)

Figure 10.2 Surveying using modern technique

Source: www.mapmatic.com

Surveying and mapping is important for the national, regional and local governments because they contain basic information that is necessary for these authorities to carry out their planning and policies. The policies are basically formed keeping in mind the geo-socio-political behavior of any space. The implementation of policies for development and distribution of resources whether natural or man-made are based on the information that is extracted out of the maps generated using horizontal and vertical datum.

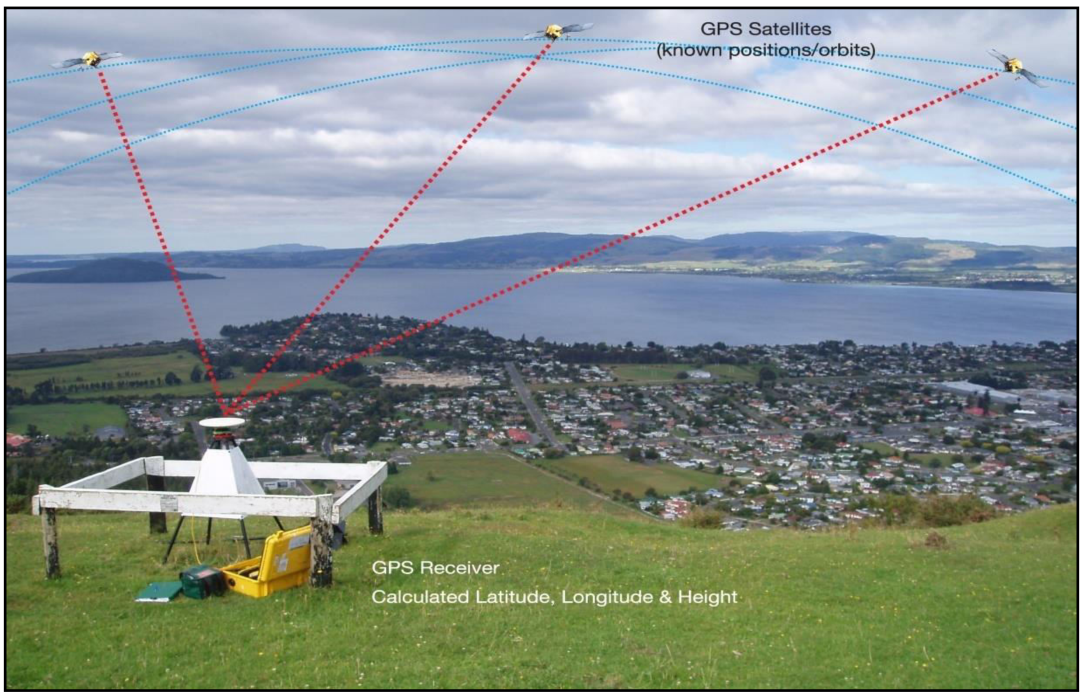
The modern day surveying has replaced the traditional method in a big way. The modern techniques of photogrammetry, use of aerial photographs and GPS has brought more accuracy to the work. This has also reduced the time that was earlier taken in conducting a survey and mapping. The amount of money and man power has also reduced, with better results.

10.3 SURVEYING & MAPPING

Surveying and mapping community were the first to make the efficient use of GPS which brought great accuracy to their work and saved a good amount of time. Since then all the surveys conducted and mapping done is done using the GPS navigation and location services. This technology which was earlier developed for defense services were later rapidly adopted for surveying by many departments of the government. The advantage of GPS is that it does not require any measurements of angles and immediate points in order to get the coordinates. GPS is survey is also easy to carry out and conduct at any given point without worrying about the chain and tapes that were earlier used. The hand held GPS is user friendly and very easy to use and work upon.

Surveyors are supposed to map the features of earth surface and even under water with maximum accuracy. Mapping through the surveys may include land boundaries, monitoring the changes in the shape of structure or the sea floor. The basic and historical requirement of surveys included Line of sight between their instrument in order to conduct such work, this also many a times leads to high inaccuracy but with the help of advanced GPS receivers and the higher accuracy of geographical coordinates. GPS can be set to one single point, or it can be used in a moving configuration to map out the boundaries of various features. This data can then be transferred into mapping software to create very quick and detailed maps for customers (University of Tasmania, 2014).

Figure 10.3 GPS receiver and its point positioning



Source: (ANZLIC, 1988)

10.3.1 Applications of GPS in Surveying and Mapping

GPS helps in accurate modeling of the physical features right from mountain and rivers to cultural features like streets, buildings and other transportations and resources. There has not been much change that has taken place in the technique of surveying except for the change in instruments. The historical instruments are now being replaced by the modern equipments like GPS. The GPS receivers are now being used worldwide for better accuracy. Surveying of roads, terrain, lakes, etc. is done mostly by GPS these days, providing a cluster of accurate control points. It is easy to use GPS in ocean and coastal surveying as these water bodies doesn't have any land based reference points.

Geodetic GPS with post processing corrections can provide accuracy of the order of sub meter, therefore can be effectively used for any surveying project. It can provide very accurate controls required for Satellite Photogrammtery for mapping and creation of stereo-model. It incredibly boosts the process like creation of a new map, updating of existing map, etc. therefore, the use of GPS has maximum been done by surveying and mapping industry.

10.4 SUMMARY

GPS has tremendously helped in achieving near and real time data with highest accuracy. GPS also provides with faster delivery of required information needed by the decision makers. In terms of surveying and mapping the use of GPS has greatly reduced the time and man-power that used to get involved in surveying. A single surveyor can now accomplish a team work in much lesser time.

10.5 GLOSSARY

- **Photogrammtery-** Photogrammetry is the science of making measurements from photographs. The input to photogrammetry is photographs, and the output is typically a map, a drawing, a measurement, or a 3D model of some real-world object or scene.
- **Surveying-** The profession or work of examining and recording the area and features of a piece of land so as to construct a map, plan, or detailed description of it.
- **Mapping-** Graphical representation of a procedure, process, structure, or system that depicts arrangement of and relationships among its different components.
- **Cartography-** Science of Map making

10.6 ANSWER TO CHECK YOUR PROGRESS

1. What do you mean by Surveying and Mapping?
2. Differentiate between traditional and modern surveying.

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10.8 TERMINAL QUESTIONS

1. Define Traditional and Modern Surveying.
2. Explain the importance of GPS in Surveying and Mapping.

UNIT 11 - ROADS AND HIGHWAYS

11.1 OBJECTIVES

By the end of this unit you will be able to understand the following:

- Definition of Roads and Highways.
- Difference between Roads and Highways.
- Application of GPS in construction and planning of Roads and Highways.

11.2 INTRODUCTION

The development of any economy relies greatly on the quality and quantity of roads it has. A good road network always accelerates the economy by helping cities and towns to connect with rural regions and economy. Roads play a vital role in linking major mode of transports like Airports, railways and sea ports. India has one of the largest road networks in the world it measures 5,482,809 km.

Roads in any area can be divided into the following:

- Expressways
- National Highways
- State Highways
- Major District roads
- Other district roads
- Village roads and
- Other urban roads

There has been immense and tremendous increase in the volume and density of roads after independence in India. This is largely because of the schemes like “Pradhanmantri Gram Sadak Yojna” which brought roads to the rural parts of India.

Highways are major roads connecting big cities and are relatively heavy metalled with good durability and constructed to meet the need of heavy freight movement. The maintenance of highways in India is done by National Highway Authority of India (NHAI).

Despite the roads being important to the economy, the conditions of roads in India are grossly inadequate with bad quality. With the advancement in technology, the quality of roads is improving. The authorities are bringing new techniques for the construction and maintenance of roads. The electronic mapping has manifold advanced the use of GPS in the location and navigation services. The use of GPS has also strengthened the accuracy of location services.

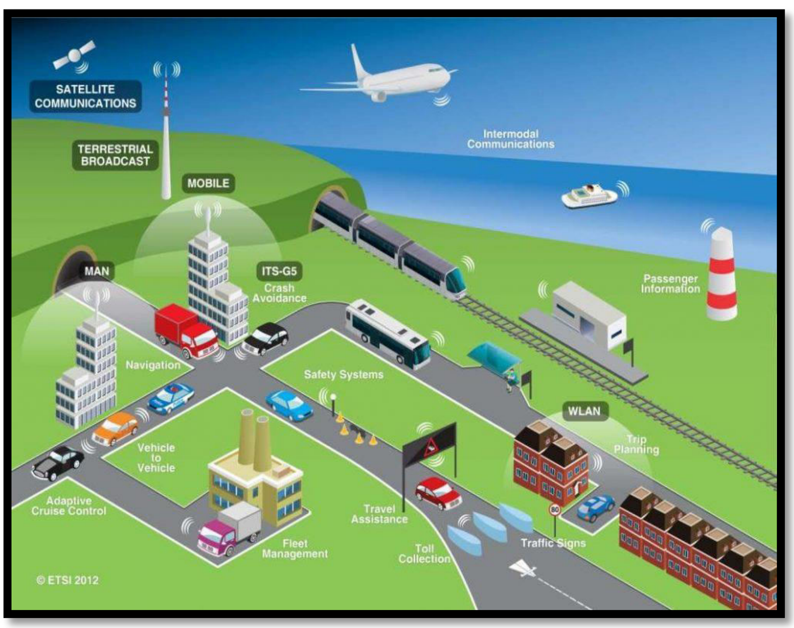
11.3 ROADS AND HIGHWAYS

Transportation is one of the biggest areas where the use of GPS has flourished. The whole purpose of GPS is to provide accurate navigation of any object or space. GPS are nowadays used by vehicles, traffic police, public work department and road safety. It is estimated that delays from congestion on highways, streets, and transit systems throughout the world result in productivity losses in the hundreds of billions of dollars annually. Other negative effects of congestion include property damage, personal injuries, increased air pollution, and inefficient fuel consumption (U.S. Government, 2006). The poor quality of roads is one of the biggest reasons for productivity losses of billions of dollars.

The application of GPS in transportation and all its aspects have increased manifold. The main application of GPS for and in roads can be listed below:

1. The availability and accuracy of the Global Positioning System (GPS) offers increased efficiencies and safety for vehicles using highways, streets, and mass transit systems. With the help of GPS, commercial and heavy load vehicle's routing can be managed specially over the highways. GPS with the help of GIS can further help in traffic management strategies. The capabilities to integrate data feeds and share dashboard views make GIS ideal for viewing a comprehensive picture of current traffic conditions (ESRI, 2011).
2. The major aspect of GPS is used in Traffic engineering on highways and different roads. Where intelligent transport system is an example of GPS application on roads. With heavy increase in the number of public and private vehicles, it is difficult for the traffic controllers to screen every single vehicle for speed, traffic rule violation and route guiding. Therefore, the intelligent transport system consists of the following:
    a. Automatic vehicle location
    b. General fleet operation
    c. Dynamic route guidance

Figure 11.1 Intelligent Transport System'

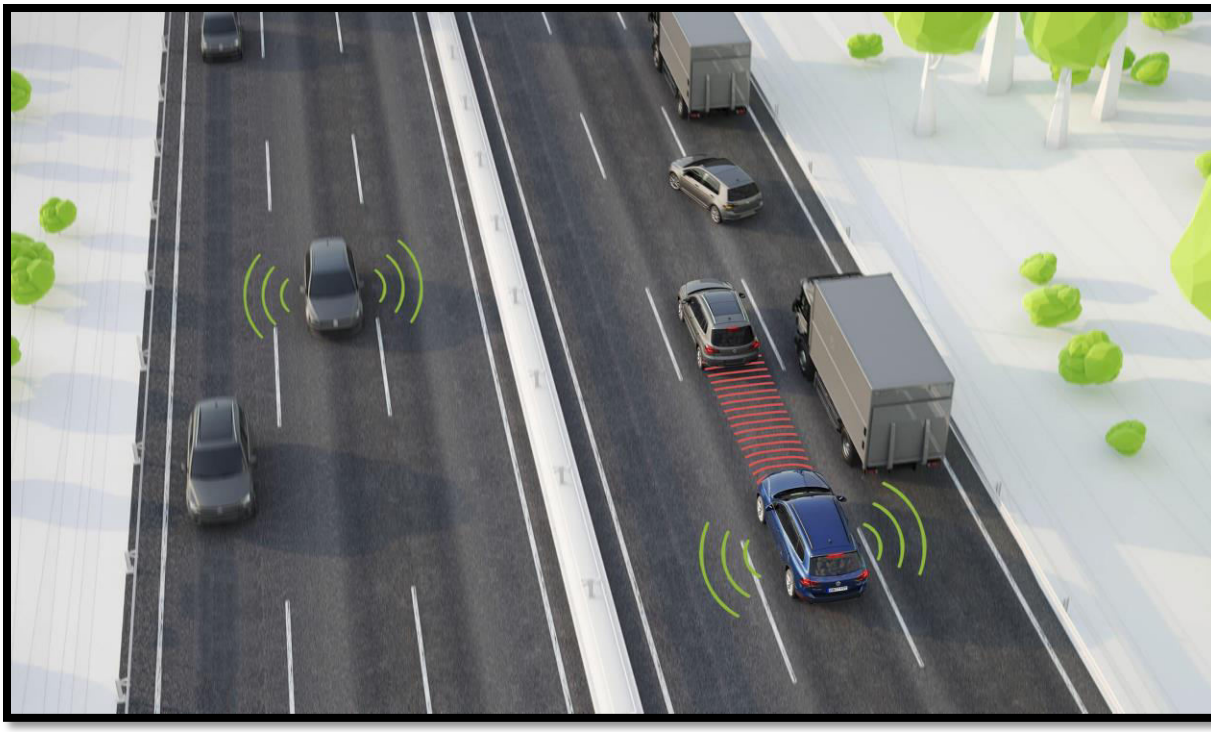


Source: (Bora, 2019)

The Intelligent Transport System is a system related to mobility that has increased in refinement through the use of information technology (IT). It is an operational system of various technologies that, when combined and managed, improve the operating capabilities of the overall system.

3. GPS technology is also used in construction of roads. GPS is usually equipped in earth moving equipment such as dozers, motor graders and excavators, these equipments quickly help in highway construction as it speeds up the work and saves time. The cost of out-fitting the equipment with GPS, training the operators, and preparing 3D plans, is equal to the cost of the survey crew during the initial year. It has been considered way better than the conventional technology in terms of its productivity (Ewers, 2016).
4. Automatic Vehicle Monitoring is another important application of GPS in Roads. It's an important component of Intelligent Vehicle Highway System. The Global Positioning System (GPS) offers an efficient and economic method to the users, who need only provide suitable receivers to obtain precise coordinates and other related information, using the GPS satellite system (Choudhary, 2009). With the help of GPS recordings when integrated with database management in Geographic information system (GIS) gives reliable and efficient system for vehicle monitoring, navigation and tracking. Also GPS becomes all the way more useful when integrated with GIS as the data and recordings collected by it are displayed with the help of GIS and is way too easy for the common people to understand.
5. GPS is also used to track and forecast the movement of freight. In this era where most of the work is done online, the movement and estimated delivery time is marked by the use of GPS. Globally in every field now, right from online food orders to booking a cab all requires the location and estimated delivery time. This service has received an amazing growth with the use of GPS technology. The online shopping services are directly dependent on the use of GPS and further looks for the serviceable or non-serviceable areas.
6. The use of GPS is nowadays is highly done by the traffic police on the highways in order to maintain security and traffic rules intact. All the vehicles are installed with GPS receivers and are also connected to the traffic authorities through surveillance. This helps them to know the vehicles violating the rules on highways. Many countries like United Arab Emirates have been using this technology. Recent researches include the use of GPS in extracting the information of location of potential critical situations warnings for the drivers, such as traffic violations or crashes. Additional research is being conducted to examine the potential for minimal vehicle control when there is a clear need for action, such as the pre-deployment of air bags. The position information provided by GPS is an integral part of this research

Figure 11.2 GPS equipped vehicle



Source: (DEWSOFT, 2000)

7. Toll collection on the expressways is automated in most of the developed countries. Basically the construction of expressways and highways is a costly affair and requires whole lot of capital investment. Usually to construct such big projects, government involves private enterprises for investment. After the construction gets over toll booths are made in such expressways to collect toll from the people using it to recover the money invested. For a country like India, toll both means long queue and traffic jams therefore the concept of Automatic Toll collection is to be installed in expressways in India. These toll booths are installed by GPS. Here the technology used has a unique identity for every vehicle and also the latitude and longitude of the booth is set. The position of the sim is checked against the geo-faces of the toll plaza. The amount to be paid by every respective vehicle is debited by their account linked to their sim card and GPRS service. This technology has helped in reducing the long queues at toll booths and also the fuel wastage. Also the people who try to escape the toll plaza by changing the routes can be detected and heavily fined against it (Nagothu, 2016).

Figure: 11.3 Automatic Toll collection system

Source: (Satyasrikanth P, 2016)

8. GPS is also used to survey the road and its network. The information about the location of specific services is usually taken by GPS and is stored in the database of GIS. This includes services like Emergency, Fuel station, service stations and, maintenance. This information is important for the passenger on the road, who might end up needing any of these services while travelling on the road.

11.4 SUMMARY

GPS is one of the most important technologies to be used on the roads and transport system as `the sole purpose of GPS is to provide latitude and longitude information of any object. GPS has brought a boom in the navigation sector; this service is freely available by United States throughout the world. The application can also be accessed by mobiles. GPS can expect even more effective systems for crash prevention, distress alerts and position notification, electronic mapping, and in-vehicle navigation with audible instructions. GPS in modern times has tremendously reduced the time that was taken for the construction survey of roads. Similarly, the cost of the construction has also reduced to great amount as earlier there were many people deployed for this work which now can alone be managed by GPS (Mahajan, 2013).

11.5 GLOSSARY

- **Violation -** An action that breaks or acts against something. This is particularly used with respect to the breaking of rules put forward by the government authorities.
- **Expressways -** Expressways are highways with six to eight lane controlled access road network and are the highest class of roads in India. The expressways are very high quality with modern features likes access ramps, Grade separation, lane dividers and elevated section.
- **Surveillance -** The careful watching of a person or place, especially by the police or army, because of a crime that has happened or is expected. Here it is used in terms of vehicles that are suspected to break the rules are put under surveillance.

11.6 ANSWER TO CHECK YOUR PROGRESS

1. What are different types of roads?
2. Discuss the application of GPS in Intelligent Transport system.
3. Discuss the use of GPS in Road Construction.

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11.8 TERMINAL QUESTIONS

1. Write a short note on Automatic toll collection.
2. Discuss Automatic Vehicle Monitoring.

UNIT 12 - NAVIGATION

12.1 OBJECTIVES

By the end of this unit you will be able to understand the following:

- Concept of Navigation
- Ancient techniques of Navigation
- Role of GPS in Navigation

12.2 INTRODUCTION

According to Webster dictionary "*the science of getting ships, aircraft, or spacecraft from place to place specially: the method of determining position, course, and distance traveled*".
Through times immemorial, Navigation plays an important role to figure out the reliable way to know where we are or the location of any object. By now we have understood GPS as a tool, has revolutionized the navigation system at the global level. Knowing position and timing of any object or place or thing has greatly helped in many aspects of day today life. Navigation can be required in any form of transportation like land, water, sea and air. The modern technique of navigation has just eased the navigation and transportation system. It does not only help the transport sector but also provides information to many other departments like Police, Health, Revenue etc.
GPS is a satellite navigation system and therefore there can be no one or no such object that cannot be tracked by the navigation satellites. This system consists of three segments namely: space, control and user segment. The space and control segment is looked after by the United States military. This was initiated for defense purpose in 1973, so this is a U.S. owned utility that provides users positioning, navigation and timing (PNT) services.

12.2.1 Ancient technique of navigation

In the ancient times the navigation was extremely difficult with no scientific instruments. The marine navigation in the ancient ages was based on the predictable winds and currents. The ancient mariners used to follow the coast closely to save them from getting lost.
Determining latitude can be accomplished relatively easily using celestial navigation. In the Northern Hemisphere, mariners could determine the latitude by measuring the altitude of the North Star above the horizon. The angle in degrees was the latitude of the ship (Bratcher, 2008).

Figure 12.1 Early tools used by ocean navigators (Maps, compasses, astrolabes, and calipers)

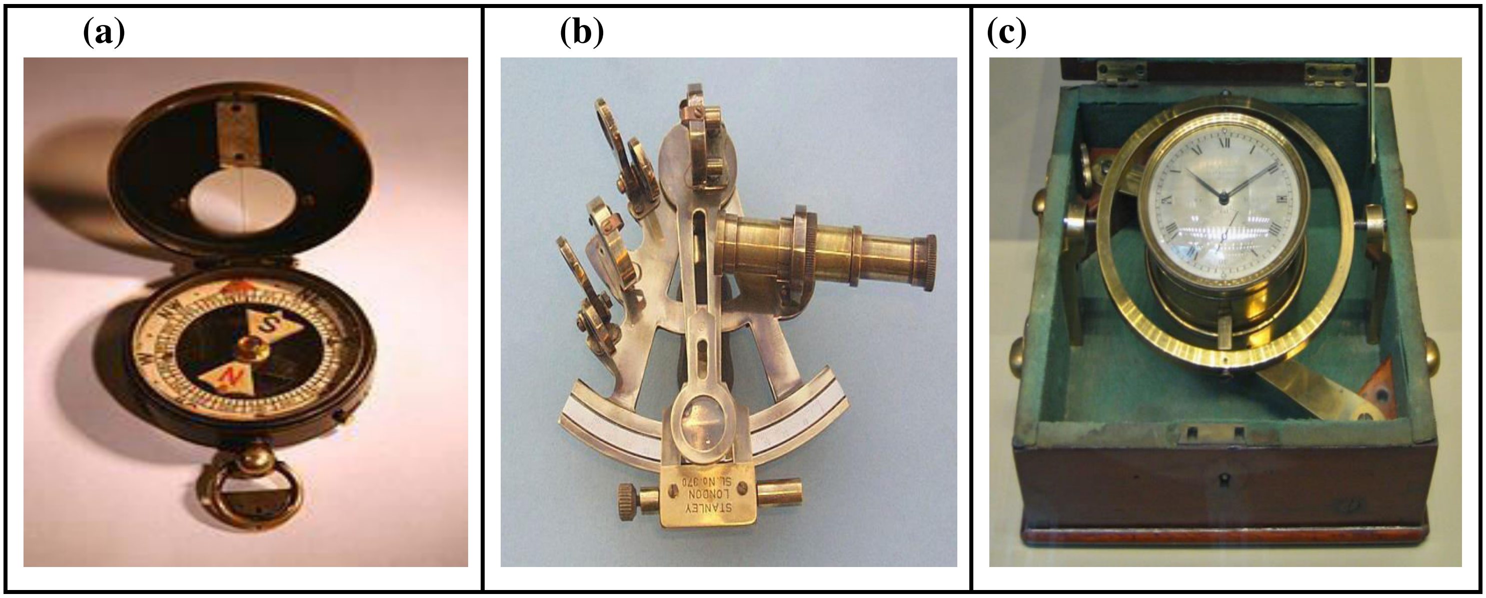
Source: (Bratcher, 2008)

The very first sailors and mariners used to observe the celestial bodies like the position of sun and other stars like North Star. Sometimes the sun and the stars aren't visible and but there were weather-wise limitations. This is how the celestial bodies helped the ancient sailors find their way back.

The earliest instruments used for the purpose of navigation are magnetic compass, sextant, chronometer etc. There have been many other instruments that were used in the past by the mariners for navigation but the major instruments have been discussed below.

a) **Magnetic Compass:** The earliest tool used by the mariners for navigation was a magnetic compass. The needle of this compass always points north and therefore the user know which direction they are heading. With the help of the magnetic compasses the sailors started to sail away from the coast and continental shelf in the vast oceans. A magnetic compass was one of the very important components of the age of discovery from 15th to 18th century.

Figure 12.2 Ancient Navigation tools a) Magnetic Compass, b) Sextant, c) Chronometer



b) **Sextant:** An instrument with a graduated arc of 60° and a sighting mechanism, used for measuring the angular distances between objects and especially for taking altitudes in navigation and surveying. It became one of the most important instruments for celestial navigation, the mariners in the olden days used to define the celestial bodies based on the observation of sextant (Garber, 2013).

c) **Chronometer:** A timepiece or timing device with a special mechanism for ensuring and adjusting its accuracy, for use in determining longitude at sea or foe any purpose where very exact measurement of time is required. John Harrison, a self taught clock maker with the help of his friend astronomer Edmond Halley invented chronometer in 1730. Throughout the history of navigation in water, latitude could be found much accurately but there was a constant problem in defining accurate longitude. This chronometer helped in determining the longitude with great accuracy.

12.3 NAVIGATION

Navigation has become important with every aspect of life. Now it has become impossible to get lost in any part of the world, because you are constantly under the observation of satellites that determines your position with an accuracy of less than a meter. The advancements of navigation have also sorted the transportation system of any means. The modern navigation system has also majorly helped in search and rescue operations. Apart from helping us reach our destination, satellite navigation can do all kinds of other things, from tracking parcels and growing crops to finding lost children and guiding the blind (Woodford, 2019).

12.3.1 Application of GPS in Marine Navigation

Heavy movement of cargo is often transported through ships. And largely to know the location, position of the vessels GPS is of great help. This information is required to know the status of vessels in open sea and to know the estimated time required for the vessel to reach its destination in due time and most economical way. GPS in marine world is used for many purposes like underwater surveying, buoy placement, and navigational hazard location and mapping. Commercial fishing fleets use GPS to navigate to optimum fishing locations, track fish migrations, and ensure compliance with regulations.

Figure 12.3 Marine Navigation GPS mobile app window screenshot

Source: http://ios.dailydownloaded.com

The role of GPS is also important in maritime port services and management activities. GPS coupled with GIS helps in automated container placement. It also facilitates pick-up, transfer, placement of containers and parking of ships. The dominant use of GPS with GIS has reduced the cases of lost and misdirected containers at the ports.

GPS information is embedded within a system known as the Automatic Identification System (AIS) transmission. The AIS, which is endorsed by the International Maritime Organization, they help in traffic control in sea ways (National Oceanic and Atmospheric Administration, 2006).

12.3.2 Application of GPS in Air Navigation

Aviation industry is one of the fastest modes of transportation and is relatively costly. Aviation industry has used GPS since it was started by U.S. Air force in the beginning. GPS is not just used foe navigation but has played a very important role in the safety of aircrafts. This space based service helps in three dimensional position determinations for all phases of flight right from departure, en-route, and arrival. The user segment of the aircraft shows the movement on the monitor at the cockpit and then the journey starts.

Many new air routes have been made possible and are continuing with time. flight management systems (FMS) and area navigation (RNAV) systems, an increasingly popular method of navigating that allows pilots to make more efficient use of the national airspace system. The increasing number of users is attributable to more economical and accurate satellite signal receivers and computer chips (FAA, 2009).

Figure 12.4 GPS showing the navigation route in cockpit monitor

Source: Garmin.com

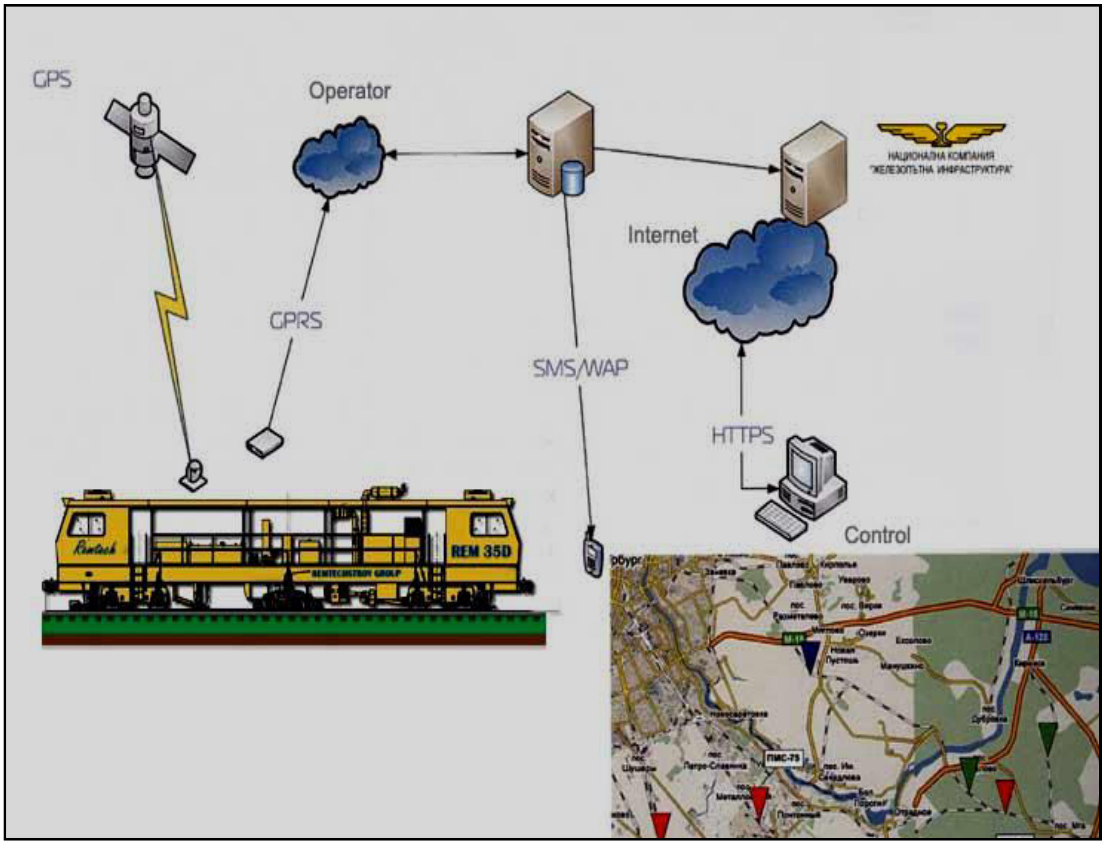
12.3.3 Application of GPS in Rail Navigation

Railway as a means of transport is considered to be the safest means of transport. The other impressive feature of this transport is that this means allows the movement of huge number of passenger at the same time and freight inland. Maximum cargo that is transported through ships is dumped into the ports and these ports are well connected through the railway lines in order to further transport and distribute the containers.

GPS has greatly helped in safety and punctuality of rail transport. In a country like India, United States, and many European countries the network of railway is immensely dense. Thousands of trains run in all the directions in a day and also at night. The dense movement of train brings the need of real time train information, which is only possible through GPS. A relay of telephone calls and information through station officers has become a thing of past. The satellites based tracking facility provided through GPS helps in getting the real and near time train information that reduces the risk of any train accident. With the help of real time data the safest route, free route and the train speed can be known. The train crossing at the same time can also get the information about its location and along which lines it can safely travel, known by the industry term movement authorities. The onboard computers which forms a part of user segment can screen and analyze the data and can control the movement of trains manually or automatically.

India has one of the most dense railway networks in the world. But most of the times the train are delayed and passengers face problems with delaying with a prior notice. The Indian Institute of Technology, Kanpur has formed a system that uses GPS satellites and mobile communication technology to relay information, and trials undertaken on specific Shatabdi and Rajdhani trains provided impressive results (Safe, Punctual and Cheap – The Benefits of Railway GPS, 2011).

Figure 12.5 System for safety and protection of Railways

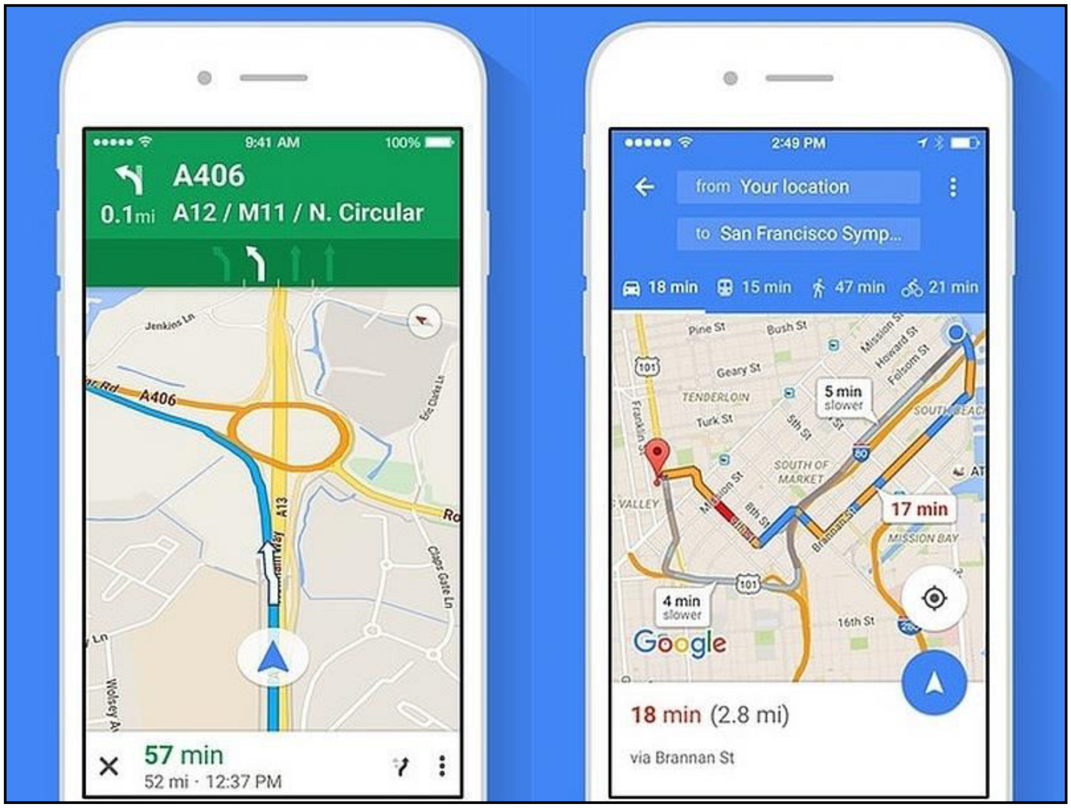


Source: http://www.remtech.info/REM35D.htm

12.3.4 Application of GPS in Road Navigation

The application of GPS in road navigation has also been discussed in the previous units. Transportation is one of the biggest areas where the use of GPS has flourished. The whole purpose of GPS is to provide accurate navigation of any object or space. GPS are nowadays used by vehicles, traffic police, public work department and road safety. It is estimated that delays from congestion on highways, streets, and transit systems throughout the world result in productivity losses in the hundreds of billions of dollars annually. The availability and accuracy of the Global Positioning System (GPS) offers increased efficiencies and safety for vehicles using highways, streets, and mass transit systems. With the help of GPS, commercial and heavy load vehicle's routing can be managed specially over the highways. GPS is also used to track and forecast the movement of freight. In this era where most of the work is done online, the movement and estimated delivery time is marked by the use of GPS. Globally in every field now, right from online food orders to booking a cab all requires the location and estimated delivery time. This service has received an amazing growth with the use of GPS technology. The online shopping services are directly dependent on the use of GPS and further looks for the serviceable or non-serviceable areas.

Figure 12.6 Navigation on road on a mobile app



Source: Screenshot of Google map

We all have seen this (Figure 12.6) window on our mobile and laptops screen. Google maps provide the GPS service with real time navigation and also the expected traffic on the respective route. GPS has made the navigation much easier also for the people who are moving to new cities and have no clue about the rotes and traffic situations.

12.4 SUMMARY

The initial purpose of GPS was to provide navigation services to the United States Air force. The beginning was solely for the defense services, later when the GPS services were made open to the civil use it brought a boom in the field of transportation and navigation. The main purpose of this satellite based navigation system was to provide accuracy in positioning of the objects. GPS brings the accuracy of less than a meter in positioning and so in navigation. The transport industry has reduced the accidental incidences and damages that used to occur because of the lack of real time information.

The advancement of technology has now reached our pockets in our mobile phones within an app. This has allowed all the users to take advantage of this service that is provided to us for free. The use of GPS has changes the era of navigation completely and more in a positive way.

12.5 GLOSSARY

- **Celestial-** Positioned in or relating to the sky, or outer space as observed in astronomy
- **Freight-** Goods transported in bulk by truck, train, ship, or aircraft.
- **Aviation-** Also called air transport refers to the activities surrounding mechanical flight and the aircraft industry.
- **Marine-** Relating to the act or practice of sailing over the sea or relating to sea.

12.6 ANSWER TO CHECK YOUR PROGRESS

1. Define Navigation.
2. Discuss ancient tools of Navigation.

12.7 REFERENCES

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12.8 TERMINAL QUESTIONS

1. Discuss the ancient tools used for navigation and how they helped the sailors across the sea.
2. Write a short note on the application of GPS in Rail navigation.