**CHAPTER ONE**

**TERRAIN ANALYSIS: PRINCIPLES AND APPROACHES**

## Concept and definition of terrain analysis Q. What is terrain?

The concept is developed in response to the characteristics of terrain by an increasing variety of disciplines concerned with its practical uses. The disciplines are both scientific, such as geology, hydrology, geography, botany, zoology, pedology and meteorology; applied science, such as agriculture, forestry, civil and military engineering, urban and rural landscape design. The term terrain, long familiar in military use, has become popular with geographers especially in America where the term terrain is often used.

According to oxford dictionary, terrain is defined as a tract of land or country, which is considered with respect to the natural feature. In other wards, it is defined as a tract or region of land immediately under observation. From these definitions one can easily see that the term is confined with the surface configuration of the earth and their corresponding socio-economic attributes.

Terrain is used as a general term in physical geography, referring to the layout of the [land.](http://www.absoluteastronomy.com/topics/Land_surface) This is usually expressed in terms of the [elevation,](http://www.absoluteastronomy.com/topics/Elevation) [slope](http://www.absoluteastronomy.com/topics/Slope) and orientation of terrain features. Terrain affects surface water flow and distribution. It can also affect patterns of weather and climate over a large area.

The following are terms associated with the concept of ***terrain***:

* **Geomorphology** is not a close equivalent; it is more confined with landforms, and considers the processes involving the deformation of the earth surface due to some exogenic and endogenic forces.
* **Micro-relief** cannot be close equivalent with terrain because emphasizes the geometric orientation of land features too much exclusively, but doesn’t comprehend the earth’s surface.
* **Soil** cannot be close equivalent with terrain because concerned with materials and less concerned with geometry.
* **Landscape** is the closest equivalent with terrain, but both are narrow concepts than terrain because it strongly connotes the visual and artistic aspects of terrain. Terrain studies are regional studies with emphasis on relief and essential physical features like soil, vegetation, drainage and natural configuration.
* **Relief** is defined as the difference in elevation between two points. The two points may be close together (local relief), far apart (regional relief), or the highest and lowest points on a quadrangle or other defined area (maximum relief). In other words, terrain, or relief, is the third or vertical dimension of land surface. When relief is described underwater, the term bathymetry is used. Topography has recently become additional synonym, though in many parts of the world it retains its original more general meaning of description of places.

The understanding of terrain is critical for a number of reasons:

* + - The terrain of a region largely determines its suitability for human settlement: flatter, alluvial plains tend to be better farming soils than steeper, rockier uplands.
    - In terms of environmental quality, [agriculture,](http://www.absoluteastronomy.com/topics/Agriculture) and [hydrology,](http://www.absoluteastronomy.com/topics/Hydrology) understanding the terrain of an area enables the understanding of [watershed](http://www.absoluteastronomy.com/topics/Drainage_basin) boundaries, [drainage](http://www.absoluteastronomy.com/topics/Drainage) characteristics, water movement, and impacts on [water quality.](http://www.absoluteastronomy.com/topics/Water_quality) For instance, pollution sources and flow direction fall in this category. Models, such as USLE (Universal Soil Loss Equation), SWAT (Soil and Water Assessment Tool), and others can easily quantify the changes in the terrain conditions via time. Complex arrays of relief data are used as input parameters for hydrology transport models to allow prediction of river [water quality.](http://www.absoluteastronomy.com/topics/Water_pollution)
    - Understanding terrain also supports on [soil conservation](http://www.absoluteastronomy.com/topics/Soil_conservation) , especially in agriculture. [Contour](http://www.absoluteastronomy.com/topics/Contour_line) [plowing](http://www.absoluteastronomy.com/topics/Plough) is an established practice enabling [sustainable](http://www.absoluteastronomy.com/topics/Sustainable_agriculture)

agriculture on sloping land; it is the practice of plowing along lines of equal elevation instead of up and down a slope.

* + - Terrain is [militarily](http://www.absoluteastronomy.com/topics/Military) critical because it determines the ability of [armed forces](http://www.absoluteastronomy.com/topics/Armed_forces) to take and hold areas, and to move [troop](http://www.absoluteastronomy.com/topics/Troop)s and material into and through areas. An understanding of terrain is basic to both defensive and offensive strategy.
    - Terrain is important in determining [weather](http://www.absoluteastronomy.com/topics/Weather) patterns. Two areas close to each other geographically may differ radically in [precipitation](http://www.absoluteastronomy.com/topics/Precipitation_(meteorology)) levels or timing because of elevation differences or a "[rain shadow](http://www.absoluteastronomy.com/topics/Rain_shadow)" effect. For instance, areas found on either sides of a mountain with respect to wind direction will not have the same climatic characteristics.

Throughout history, the knowledge and physical effects of terrain have played a dominant role in the development of society during both peace and war. Terrain is a portion of the earth’s surface that includes man-made and natural features. Terrain analysis is the process of analyzing and interpreting these features and the influence of weather and climate on them. Terrain data (or information) is raw data in any form about a segment of terrain. Knowledge of the natural as well as human terrain is extremely important during all phases and levels of development planning.

### Terrain analysis Vs Terrain evaluation

Land a resource includes all resources of the earth. Analysis refers to separating (breaking up) of any whole into its parts so as to asses the nature, portion, function, relationships and dissolving resolution of a whole in to parts. No need of considering the general look but observe the component in studies focusing on analysis. As a result, terrain analysis involves the simplification or resolution of the complex phenomenon by which the natural geographic environment (terrain in this case) is considered.

Land use

planning

**Terrain**

**evaluation**

**Terrain**

**Terrain**

**Analysis**

**Figure 1.1** the flow diagram indicating the overall processes in terrain evaluation

Land suitability classification

Applications

The actual and potential use of land is made after considering alternatives and this decision is land use planning. In addition, human and natural aspects should be considered in land evaluation. Land suitability referring to a process of identifying, which tract of land can be best used or most suitable.

**Terrain Analysis** involves the collection, analysis, evaluation, and interpretation of geographic information on the natural and manmade features of the terrain, combined with other relevant factors, to predict the effect of the terrain on social-economic activities. This can be done analytically and digitally. It is the systematic analysis of terrain features with its impact on human activities.

The analysis process can be undertaken visually with the help of electro-optical instruments or manually and digitally with powerful computer software. For instance, [remote sensing](http://www.answers.com/topic/remote-sensing-2) satellite data are used for mapping various aspects of terrain, such as land use and land cover, and soils. Software may then be utilized to derive terrain parameters, such as aspect, catchment area, and wetness index, which are then used to describe the morphology of the landscape and the influence of topography on environmental processes is said to be digital terrain analysis. On the other hand, an interpretation of radar images can often permit a fuller comprehension of the morphology of the landforms and the nature of the materials that form those landforms when compared with optical datasets. This interpretation is driven by a relationship between surface morphology and composition of particular landform units.

Terrain analysis, for instance, in **military science** is still important before, during, and after battle has ended. The battle will significantly alter the terrain, requiring updating of previously deformed terrain analysis. The terrain analyst may also need to update completed products that have potential value for the next battle. Here, terrain analysis is the process of interpreting natural and man-made features of a geographic area to determine their effects on human activities. Terrain analysis support during specific operation provides the planners and other personnel in field of physical geography with expedient, tailored, and updated products. Expedient responses, especially at division level, are necessary to properly and adequately inform commanders of the impact of terrain on the battle at hand.

**Terrain Analysis** is the process of understanding terrain in terms of attributes, i.e., geology, structure, soil, vegetation cover, drainage, slope, etc. On the other hand, terrain evaluation is an act of expressing the numerical value, studying, and characterizing terrain in terms of quantified values through a number of assessments. It is more inclusive and preferable to such terms as analysis, classification, quantification, assessment or appraisal.

Therefore, **terrain evaluation** is a process which involves a**nalysis** referring the breaking down of the whole in to parts; **classification** referring the reassembling the part to whole; and **appraisal** involves manipulation, interpretation and assessment of data for practical aims.

## Scope of terrain evaluation/analysis

Points to be considered during scoping:

* + - Users concerned on acquiring and classifying old information about the terrain and its practical uses from sources: survey, laboratory and statistical analysis.
    - It is concerned with the abstraction, classification and storage of such information to make it available cheaply, efficiently and quickly.
    - It considers the means by which such information is retrieved, reproduced and supplied to users in accurate and comprehensive manner.

Therefore, in light of what is noted in terrain evaluation, the concept has the bases in all pure sciences that deal with the surface of the earth and all applied sciences concerned with it uses (practical applications to day-to-day human activities). In addition, it involves both the theory and practice of the data acquisition, processing, and communication.

There are exceptions for scope of terrain evaluation:

* + - **Atmosphere-** is too variable and ephemeral nature to be assigned into sufficiently small and closely definable tract of the earth’s surface.
    - **Permanent expanses of water-** Hence the surface is homogenous like lake, and the soil, vegetation, etc are not found.
    - The part of the earth crust at **a depth greater than six meters** (maximum depth): mining, deep well drilling and others are not part of terrain evaluation because they do not involve the exploitation of the immediate surface of the earth.

**N.B.** Using other indirect methods one can apply analysis of terrain features below the permanent expanses of water.

The three Basic requirements of terrain evaluation system are:

* + A method for dealing with it requires information from the potential users; what is the need of potential users in connection to terrain evaluation and terrain analysis?
  + Capability for acquiring, analyzing, thematazing and storing data about a terrain: its actual and potential uses require personnel.
  + The method of retrieving data, data storage and translating it into the form required by the land users (potential users). E.g. the idea of the user requirements is explained, who is the user of terrain evaluation? Actually there are earth scientists, civil and military engineers, agriculturalists of all types, recreational planners, meteorologists, etc are all the particular user of terrain evaluation and analysis.

## Interdisciplinary nature of terrain analysis

Different field of study deals with terrain analysis and evaluation from their own perspectives.

**Agriculturalists,** for instance are concerned with three properties of the land:

* + - **Soil fertility:** is a function of nutrient content, soil texture, soil moisture regime, and slope.
    - **Soil manageability:** consisting of the depth of the soil, which is affected by cultivation, hardness, permeability, relief, and slope.
    - The nature of the existing **vegetation or land cover**.

**Civil engineering-** involves the number of occupations that require terrain analysis, such as preparatory excavation for buildings, roads, railways, airfields, dams, bridges, canals, drains, etc. Here, soil physical characteristics are more important: soil bearing capacity, organic matter content, soil aeration, water retainage capacity, etc.

**Military Sciences-** activities includes many of the preparations of engineers. The military emphasis on terrain focuses on such aspects as artillery (line of sight), suitability of the ground for excavating trenches, fortification, laying mining fields, accepting parashoot dropping and sustaining the passage, armed leave passage of troops and of both trucked and untracked vehicles. Traficability of the ground primarily depends on soil strength, stickiness and the frequency of gradient exceeding certain critical figures for vehicular traffic.

**Meteorology and climatology-** concerned with the effect of terrain on weather and climate. Slope aspect and nature of soil surface will have an influence on wind including its direction and trend. The slope aspects have an effect on insolation. Fog, cloud cover, rain, etc are directly or indirectly influenced by the terrain.

**Hydrology-** requires the knowledge of terrain analysis specially related to surface and subsurface water, because terrain situation defines the moisture regime, such as river catchment. Specially, it is concerned with runoff regime and quantities, stream flow, through flow, ground water flow, ground water depth and others with practical applications on water supplies and erosion control.

**Urban and rural residential and recreational planners-** the terrain is an important determinant for landscape designs. Since we get better panoramic view of the upper ground, it is better for recreational activities. In developed countries the more valuable land is used for recreational and residential while the less valuable is used for agricultural activity, which is directly opposite to developing countries. On the other hand, in site selection for some recreational activities like golf fields, the importance of terrain analysis is very crucial where there is some sort of roughness of the tract.

**Cartography:** Terrain mapping is a method to categorize, describe and delineate characteristics and attributes of surficial materials, landforms, and geological processes within the natural landscape. Both methods are undertaken initially by stereoscopic interpretation of aerial photographs (supplemented with field-checking), and therefore require the mapper to have advanced skills in recognizing and interpreting terrain and natural slope processes from both aerial photos and fieldwork.

## Terrain data types and sources

There are a variety of approaches to studying topography or terrain features. Which method(s) to use, is depending on the scale and size of the area under study, its accessibility, and the quality of existing surveys. These are as follows:

**Direct survey:** Surveying helps determine accurately the terrestrial or [three-dimensional](http://en.wikipedia.org/wiki/Three-dimensional_space) [space](http://en.wikipedia.org/wiki/Three-dimensional_space) [position](http://en.wikipedia.org/wiki/Position) of points and the distances and angles between them using leveling instruments such as theodolites, dumpy levels and clinometers.

Although remote sensing has greatly speeded up the process of gathering information, and has allowed greater accuracy control over long distances, the direct survey still provides the basic control points and framework for all topographic work, whether manual or [GIS](http://en.wikipedia.org/wiki/GIS)-based. In areas where there has been an extensive direct survey and mapping program, the compiled data forms the basis of basic digital elevation datasets. This data must often be "cleaned" to eliminate discrepancies between surveys, but it still forms a valuable set of information for large-scale analysis.

**Remote sensing:** [It](http://en.wikipedia.org/wiki/Remote_sensing) is a general term for geodata collection at a distance from the subject area. Remote sensing (RS) data, including those derived from aerial photographs, are used for terrain evaluation and landform studies. Remote Sensing images are used for the study of fluvial landform, rock types, geological structures, water bodies and stream networks, and soil erosion. Digital elevation data to conduct such studies are available from the Shuttle Radar Topography Mission (SRTM) provided by the National Aeronautics and Space Administration (NASA), the National Imagery Mapping Agency (NIMA), the German Space Agency (DLR) and Italian Space Agency (ASI).

**Aerial and satellite imagery:** Besides their role in photogrammetry, aerial and satellite imagery can be used to identify and delineate terrain features and more general land- cover features. Certainly, they have become more and more prominent as part of [geo-](http://en.wikipedia.org/wiki/Geovisualization) [visualization:](http://en.wikipedia.org/wiki/Geovisualization) [maps](http://en.wikipedia.org/wiki/Maps) or GIS systems. False-color and non-visible [spectra](http://en.wikipedia.org/wiki/Spectra) imaging can also help determine the lie of the land by delineating vegetation and other land-use information more clearly.

**Photogrammetry:** It is a measurement technique for which the [co-ordinates](http://en.wikipedia.org/wiki/Co-ordinates) of the points in [3D](http://en.wikipedia.org/wiki/Three-dimensional_space) of an object are determined by the measurements made in two photographic [images](http://en.wikipedia.org/wiki/Image) (or more) taken starting from different positions, usually from different passes of an aerial photography flight. In this technique, the common points are identified on each image. A line of sight can be built from the camera location to the point on the object.

**Radar and sonar:** Satellite [radar](http://en.wikipedia.org/wiki/Radar) mapping is one of the major techniques of generating Digital Elevation Models (see below). Similar techniques are applied in [bathymetric](http://en.wikipedia.org/wiki/Bathymetry) surveys using [sonar](http://en.wikipedia.org/wiki/Sonar) to determine the terrain of the ocean or lake floor. In recent years, [LIDAR](http://en.wikipedia.org/wiki/LIDAR) (Light Detection and Ranging), a remote sensing technique using a laser instead of radio waves, has increasingly been employed for complex mapping needs such as charting canopies and monitoring glaciers.

## Forms of terrain data

Terrain is commonly modeled either using vector ([triangulated irregular network](http://en.wikipedia.org/wiki/Triangulated_irregular_network) or TIN) or gridded ([Raster image](http://en.wikipedia.org/wiki/Raster_image)) mathematical models. In the most applications of environmental sciences, land surface is represented and modeled using gridded models. In civil engineering and entertainment businesses, the most representations of land surface employ some variant of TIN models. The widely used terrain data forms are:

**Raw survey data:** Topographic survey information is historically based upon the notes of surveyors. They may derive naming and cultural information from other local sources (for example, [boundary](http://en.wikipedia.org/wiki/Boundary_%28topology%29) delineation may be derived from local [cadastral](http://en.wikipedia.org/wiki/Cadastral) mapping. While of historical interest, these field notes inherently include errors and contradictions that later stages in map production resolve.

**Remote sensing data:** As with field notes, remote sensing data (aerial and satellite photography, for example), is raw and uninterpreted. It may contain holes (due to cloud cover for example) or inconsistencies (due to the timing of specific image captures). Most modern topographic mapping includes a large component of remotely sensed data in its compilation process.

**Data in topographic mapping:** In its contemporary definition, topographic mapping shows relief. In Ethiopia, EMA topographic maps show relief using [contour lines](http://en.wikipedia.org/wiki/Contour_lines) of 20 m contour interval. The EMA calls maps based on topographic surveys, together with other ground and air survey operations. These maps show not only the contours, but also any significant streams or other bodies of [water](http://en.wikipedia.org/wiki/Water), [forest](http://en.wikipedia.org/wiki/Forest) cover, built-up areas or individual buildings (depending on scale), and other features and points of interest. Existing topographic survey maps, because of their comprehensive and encyclopedic coverage, form the basis for much derived topographic work.

Many government and private publishers use the artwork (especially the contour lines) from existing topographic map sheets as the basis for their own specialized or updated topographic maps. Topographic mapping should not be confused with [Geologic mapping](http://en.wikipedia.org/wiki/Geologic_map). The latter is concerned with underlying structures and processes to the surface, rather than with identifiable surface features.