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High Resolution Digital Elevation Model for Chamundi Hill of Mysuru city, Karnataka, India using Geospatial Technology

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Abstract: *A DEM is a quantitative model of a topographic surface in digital forms. The term Digital Elevation Model or DEM is frequently referred as digital representation of topographic surfaces or regular grid of spot heights. The study aims in derivation of high resolution analysis of elevation characteristics of hilly terrains such as contour, slope, aspect and hillshade using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM of 30mts resolution in GIS environment. The derived output is considered as input in ArcGIS to achieve slope, aspect and hillshade data of 12.4 mts resolution in the present study. The slope and aspect results show that the area has steeper slope in the western and northwestern directions. Thus high resolution DEM data has immense application in economic designing of railway tunneling, bridge constructions especially in hilly terrains and highly useful for the natural disaster management studies.*
Keywords: *DEM Generation, Slope, Aspect, Flow accumulation, Geospatial, Chamundi hill.*

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I. INTRODUCTION

The DEM is the most common form of digital representation of topography. The resolution, or the distance between adjacent grid points, is a critical parameter of any DEM with best commonly available resolution of 30 mts (Garbrecht and Martz, xx). DEM is simply called digital description of earth's surface or terrain condition of earth as a whole or part of it (Obi Reddy et al, 2017; Bolstad and Stowe, 1994). DEMs portray topography, landscapes and landforms analyses apart from modeling of earth's surface processes (Welch, 1990; Obi Reddy et al, 2017). DEMs play a significant tool for the extraction of three dimensional models (Gurugnanam et al, 2014; Swaraj and Anji Reddy, 2013). The DEM data sets should be visualized as continuous Earth surfaces with latitude, longitude and altitude, i.e. X; Y horizontal coordinates and elevation Z. Z is the vertical elevation value that is relative to a given datum for a set of x, y points (Bernhardsen, 1999; Bolstad and Stowe, 1994; Welch, 1990; Obi Reddy et al, 2017).

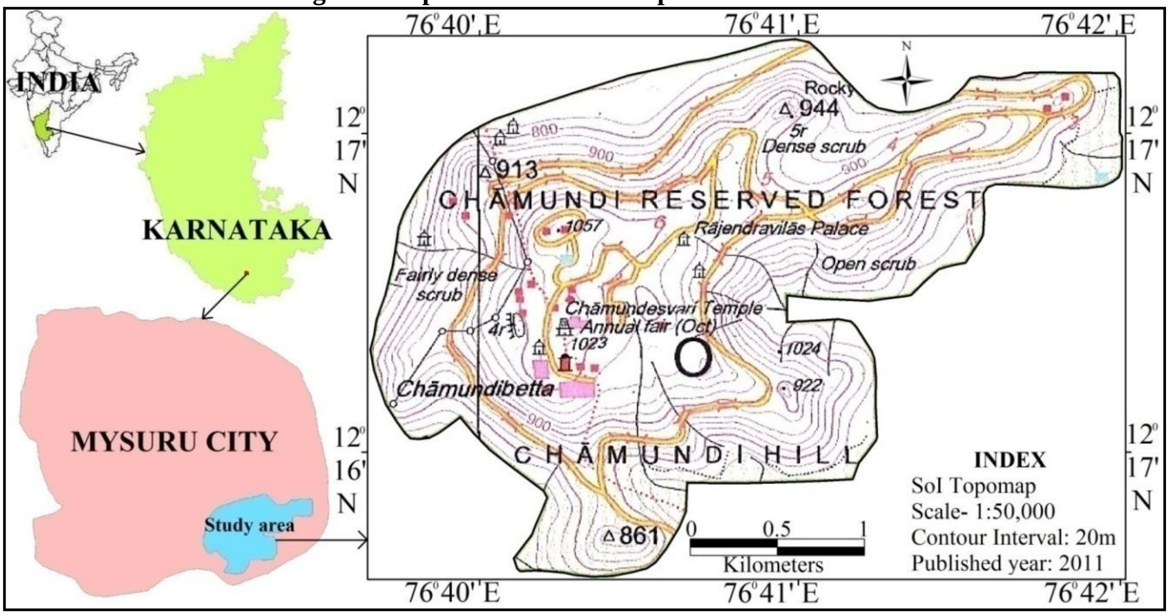
Digital Elevation Model is a quantitative representation of terrain and is consequential for geological and hydrological applications (Gurugnanam et al., 2014). DEM can yield maps of contour, slopes, aspects, hillshade, viewshed, drainage basin on catchments areas (Ertugrul et al, 2009). Information derived from a DEM, such as elevation, slope and aspect maps can also be used with the images to improve their capabilities for soil mapping (Lee et al., 1988; Ertugrul et al, 2009). Bayramin (2001) analyzed the use of DEM, satellite images, digital geological information to boost mapping potency and quality of soil maps and developed a pre-model for soil mapping where conventional soil surveys have not been completed yet (Ertugrul et al, 2009). Although the separate variables like toposhape and also the aspect (four main categories and eight sub-classes) are scrutinized as two main effective topographic factors in controlling soil moisture and vegetation development by plant ecologist for many years, the hillshade map was implied by Guth (1999) and suggested by Wise (2001) (Cadell, 2002; Kenneth et al, 2005). Therefore, few studies have been reported in plant ecology related to the hillshade phenomenon (Ali Najafifar et al., 2019).

II. METHODS AND MATERIALS

2.1 Study Area

Mysore is the old capital and second largest city in Karnataka state. Chamundi hill is situated 13 kms from Mysuru city centre and is considered as the home of Goddess Chamundeshwari Devi, the tutelary deity of Mysore Wodeyars. Chamundi hill is located in between $12^0 15'$ to $12^0 17'$ N latitude and $76^0 39'$ to $76^0 42'$ E longitude with an aerial extent of 7.5275 km^2 (Fig.1). The general elevation ranges from 765 to 1057 mts above MSL. A fine asphalted road takes the visitors to the hill top up to the temple of Chamundeshwari. Chamundi hill can also be reached by climbing up 1,000 steps laid out by the Maharaja in the 17^{th} Century. From the top of the hill, the viewers can take a beautiful view of Mysore's lakes, parks and palaces. The gigantic sculpture of the demon Mahishasura, from whom Mysore got its name is very close to the temple. Geologically, Chamundi hill is beautified by a (pink & grey) granite hill composed of igneous rock dated back to 800 million years (Crawford, 1969).

Figure1. Toposheet Location map of Chamundi Hill



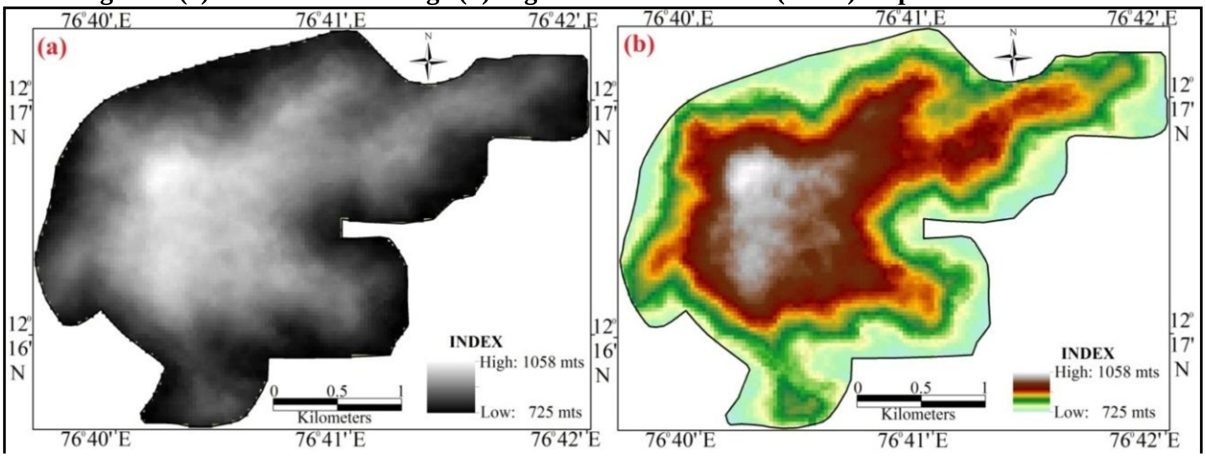
2.2 **Methodology**

Topographic maps from Survey of India on a 1:50,000 scale is used as a base map for the extraction of Chamundi Hill boundary (Fig.1). ASTER DEM data of 30mts resolution was acquired and added to ArcGIS software for preparation of Digital Elevation Model (DEM) such as contour, slope, aspect, hillshade and flow accumulation map (Beijing Rabus, 2008; Rodriguez et al., 2006; Smith, 2003; Gurugnanam and Kalaivanan, 2014). 1 meter contour map (Fig.3b) was generated by providing 1 meter Contour Interval (C.I) on ASTER DEM image using 3D analysis tool and later transformed into Feature to Raster map (grid data) (Fig.4) using Conversion tool in ArcGIS environment. The derived Feature to Raster class map measures approximately 12.4mts (12.38mts) in its resolution. Later slope, aspect, hillshade and flow accumulation layers are derived using 12.4mts Classified map for better high resolution DEM images to make it useful for various fields.

2.3 **Digital Elevation Model (DEM)**

A higher-resolution global DEM data set was released to the public by National Aeronautics and Space Administration/Ministry of Economy, Trade and Industry (NASA/METI) based on stereoscopic imagery from the ASTER satellite (Christian Hirt, 2014). The global ASTER DEM extends towards the pole regions ($\pm 83^0$ latitude) at 1 Arcsec resolution (30mts resolution) (Fig.2a & 2b) (Christian Hirt, 2014). DEM's in raster format show in gray scale where bright areas represent high elevations, dark areas represent low elevations (Xiong Ping, 2003). This is one of the most common forms of DEMs describe the terrain by a sampled array of elevations for a number of ground positions at regularly spaced intervals tends to be more effective (Xiong Ping, 2003). The quality of spatial analysis depends on data quality, data model relevance and on the way they interact (Burrough and McDonnell, 1998; Tomaz Podobnikar, 2009). The model (or nominal ground) is a conceptualization and representation (abstraction) of the real world, i.e., a selected representation of space, time, or attributes (Aalders, 1996; Tomaz Podobnikar, 2009). The utility of the DEM is evidenced by the widespread availability of digital topographic data and ever- increasing applications of DEM (Obi Reddy et al, 2017). They have been found useful in many fields of study such as geomorphometry, as these are primarily related to surface processes such as terrain analysis (Reddy et al., 2013), soil–landscape modeling, landslides zonation mapping, (Hengl and Evans, 2009), archaeology (Menze et al., 2006), forestry (Simard et al., 2006; Obi Reddy et al, 2013). The derivation of topographic attributes relies on digital elevation data sets that may be acquired from satellite imagery, digitizing the contour lines on topographic maps, or conducting ground surveys (Obi Reddy et al, 2013; Wilson and Gallant, 2000).

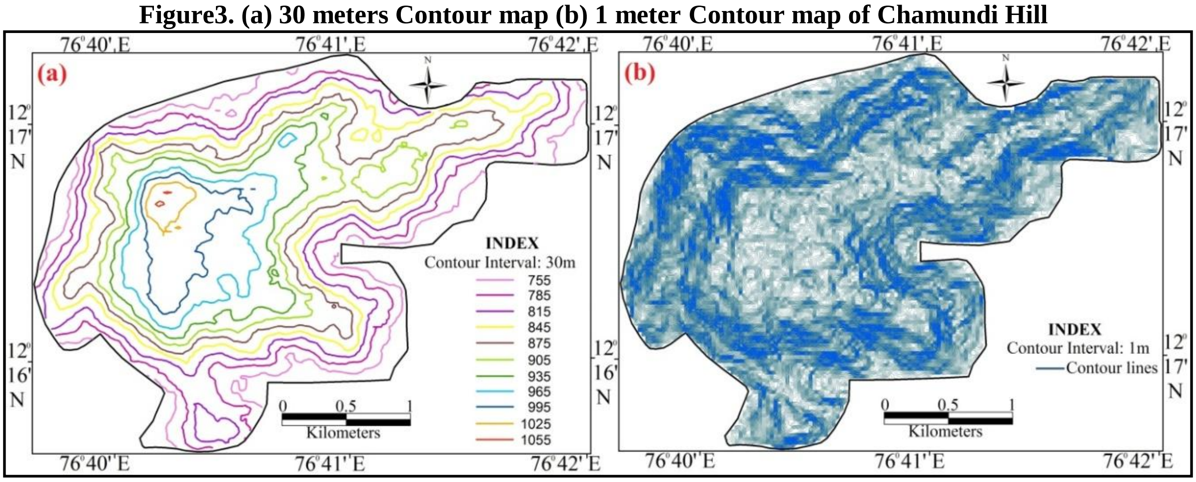
Figure2. (a) ASTER DEM Image (b) Digital Elevation Model (DEM) map of Chamundi Hill



2.4 Contour

Contour lines are the information describing the real topographic terrains that are traditionally traced out from topographic maps since nineteenth century (Robinson, 1971). At present, DEMs allow for fast automatic extraction of contour vectors with high positional accuracy and level of detail that cannot be achieved by manual drawing (Pyry Kettunen et al, 2017). The extraction of terrain feature lines is an important yet challenging problem in the processing and usage of contour lines (Chengming Li et al, 2018). In the present study, automated contour lines are generated by ASTER DEM map with 30mts and 1 meter Contour Intervals (C.I) using 3D analyst tool (Fig.3a & 3b) (Xiong, 2003). Derived contour map shows the quality resolution of 1m elevation intervals which has immense value in various mega structure constructions planning and its economic designs especially in hilly terrains. Contour lines represent vector form of line data storage that is extracted from DEM data of raster format (Totok, 2018). The resultant contour lines derived from grid form raster data has the characteristic of broken lines (Totok, 2018). As a result of the line drawing process using the vertex traced from raster grid show poor quality visualization, occurrences of many indentations with angles that are too sharp leading to broken contours at specific locations (Totok, 2018). The calculated accuracy concerns the location of the contour line but does not pay attention to geometric errors that may be present in the generalization contour line (Totok, 2018).

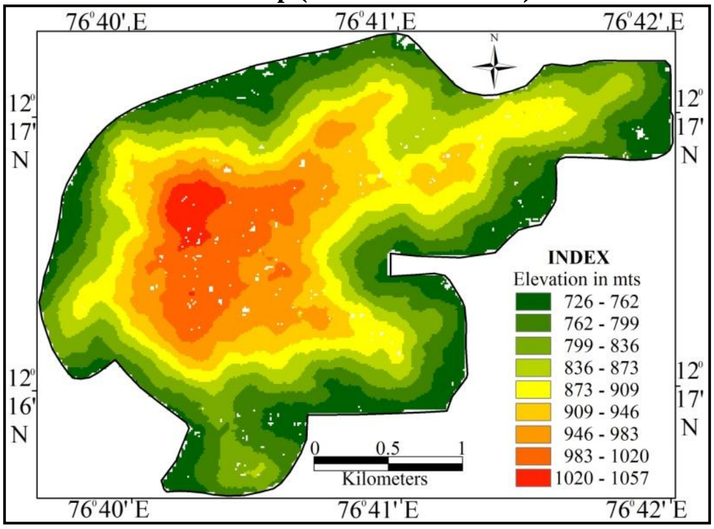
Figure3. (a) 30 meters Contour map (b) 1 meter Contour map of Chamundi Hill



2.5 Error in the Derived Feature to Raster Map

One of the challenges in cartography is the selection of data in accordance with resolution/ scale (Zahra and Thomas, 2019). The quality of extracted raster map (Feature to Raster) is derived based on the quality of contour lines generated from ASTER DEM data (Fig.4) (Totok, 2018). The vector data model stores the point data in vertices and draws the lines of each vertex according to the data. This is the result of a rigid contour line drawing at the interpolation point, which in this case is presented in the grid/pixel (Totok, 2018). Automatically generated contour lines in flat areas show greater obstacles (errors) or appearance of broken lines occurred in the derived output and these produce visually inaccurate data at certain specified locations.

Figure4. Feature to Raster map (12.4 mts resolution) with Elevation values



III. RESULTS AND ANALYSIS

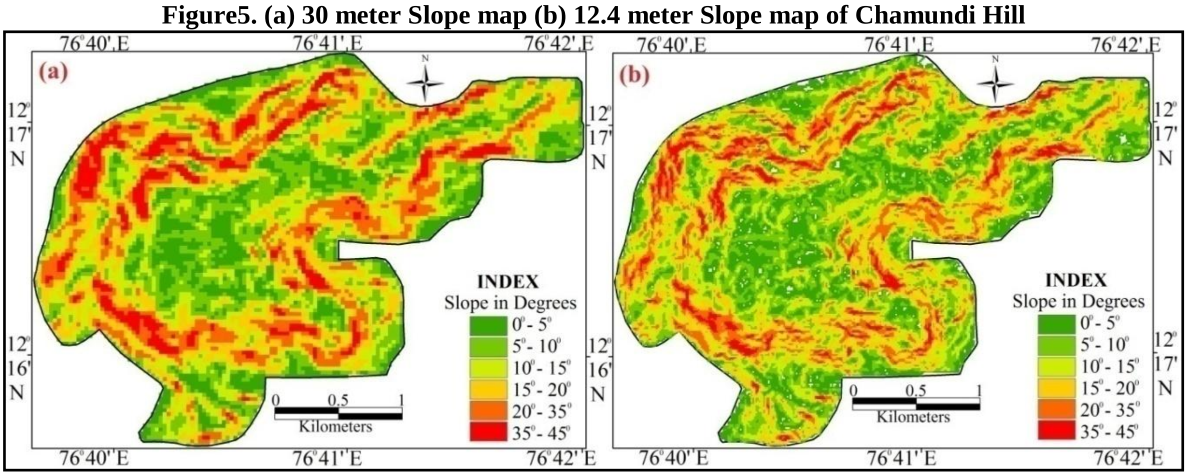
3.1 **Slope**

Slope provides the distribution of various slope classes and helps in understanding the runoff characteristics. Slope map which depict the steepness of slope over an entire ground surface have previously been prepared on a small scale to show broad classes of slope values (Raisz and Henry, 1937). The concept of measuring slope from a topographic map is a familiar one for most professionals in the landscape planning/ surveying professions (Yi Hu et al, 2011). Slope is defined by a plane tangent to a topographic surface, as modeled by the DEM at a point (Gurugnanam et al, 2014). The DEM data were given as input for the preparation of Slope map (Gurugnanam et al, 2014) measured by calculating the tangent of the surface. The tangent is calculated by dividing the vertical change in elevation by the horizontal distance. Slope is normally expressed in planning as a percent slope which is the tangent (slope) multiplied by 100 (Obi Reddy et al, 2017).

Percent Slope = Height / Base * 100

This form of expressing slope is common, though can be confusing since as 100% slope is actually a 45^0 angle due to the fact that the height and base of a 45^0 angle are equal and when divided always equals 1 and when multiplied by 100 equals 100%. The slope information is useful in understanding the topography, geomorphology, soil types and their erodability, surface drainage (Manjare, 2013; Obi Reddy et al, 2017). ASTER DEM derived slope map represents 30 mts resolution (Fig. 5a); while derived feature to raster map (Fig.4) portray high resolution slope map of 12.4 mts (Fig.5b).

Figure5. (a) 30 meter Slope map (b) 12.4 meter Slope map of Chamundi Hill



Chamundi hill had a hexagonal shape with steep slopes and were highly dissected in the northern and in the western sides indicating the mature stage as per the geographical cycle of erosion (Joshua and Abhilash, 2017). Maturity in the cycle of erosion, steep slope, high dissection, high slope in degree and in percent and high concavity might hinder the developmental programme (Joshua and Abhilash, 2017). Slopes are calculated in the percentage-wise and categorized into six classes namely 0 -5^0 (Nearly level), 5 -10^0 (Very gentle slope), 10 -15^0 (Gentle slope), 15 -20^0 (Moderate slope), 20 -35^0 (Strong slope) and 35 -45^0 (Moderately steep slope). Chamundi hill varies according to the direction in which most parts of central region show gentle slope and plateaus; while steeper slopes are confined to western and most parts of northwestern regions.

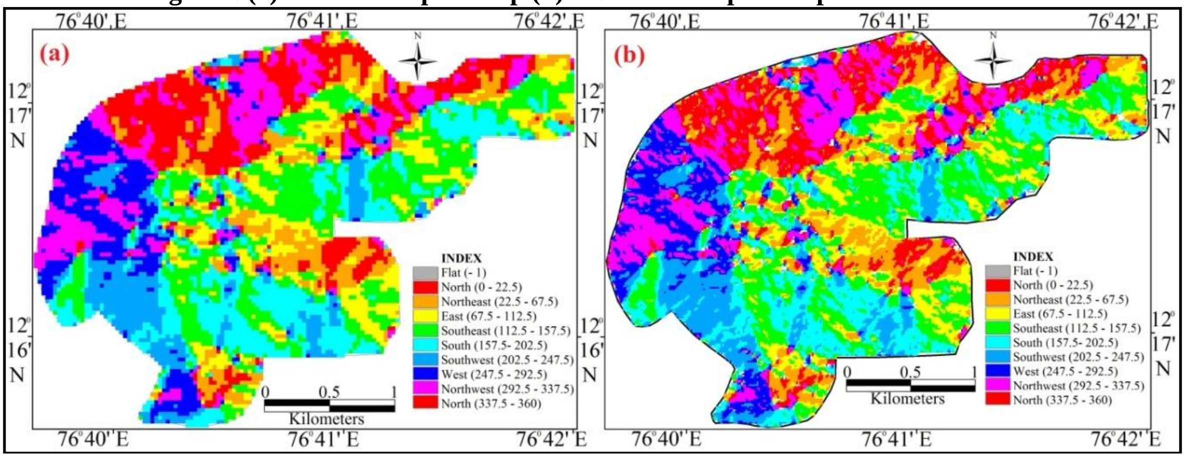
3.2 **Aspect**

Investigation of an aspect helps to identify the slopping directions and easy way to view the steep areas. Aspect is calculated using the north-south and east-west gradients (Jonathan Bennie, 2008) as expressed in the following equation:

Aspect = ArcTangent (EW/NS)

The above equation is adjusted to reflect aspect in degrees ranging from 0^0 to 360^0. Where 0^0 represents a cell with no slope (skyward aspect) and the values from 1^0 to 360^0 represents azimuths in clockwise degrees from North (1^0), later by East (90^0) and then South (180^0) and so on and ends with 360^0 at the North. The aspect of a slope can make very significant influences on its local climate and influence on temperature (Yang et al, 2020). DEM data and slope values are used to generate the aspect map to identify the slope directions. The map shows that most of the aspect is towards westward, northward and northwest facing; eastward dipping slopes occupy least area (Gurugnanam et al, 2014a) (Fig.6a & 6b). The sun's radiation is traditionally described often by aspect representing most of the steep slopping towards almost west, northwest, south and south east (Alina et al, 2013).

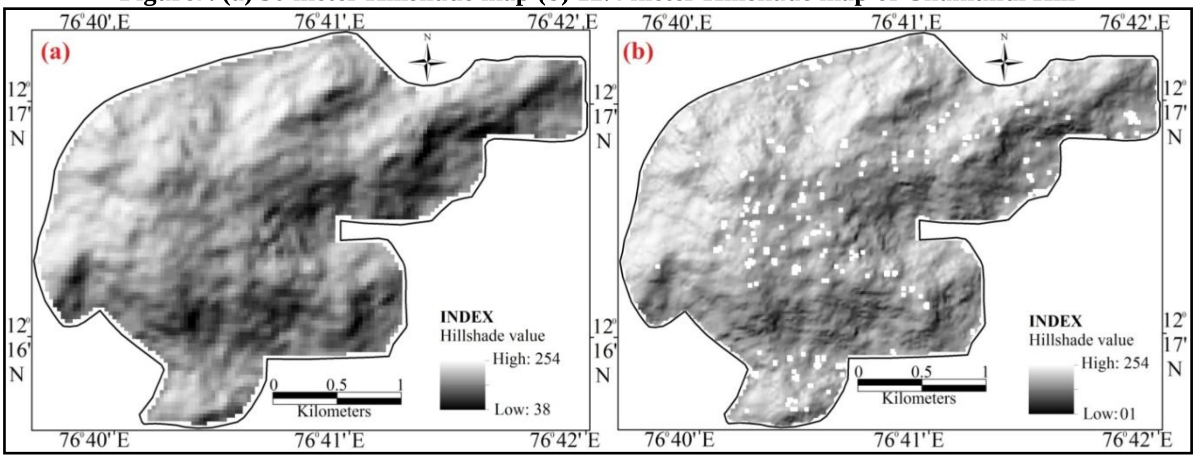
Figure6. (a) 30 meter Aspect map (b) 12.4 meter Aspect map of Chamundi Hill



3.3 **Hillshade**

Analytical hill shading is a technique for producing shaded relief maps automatically. Relief shading is employed to visually enhance the terrain features by simulating the appearance result of daylight falling across the surface of the earth. Hill Shading estimates surface reflectance from the sun at any altitude and any azimuth.

Figure7. (a) 30 meter Hillshade map (b) 12.4 meter Hillshade map of Chamundi Hill

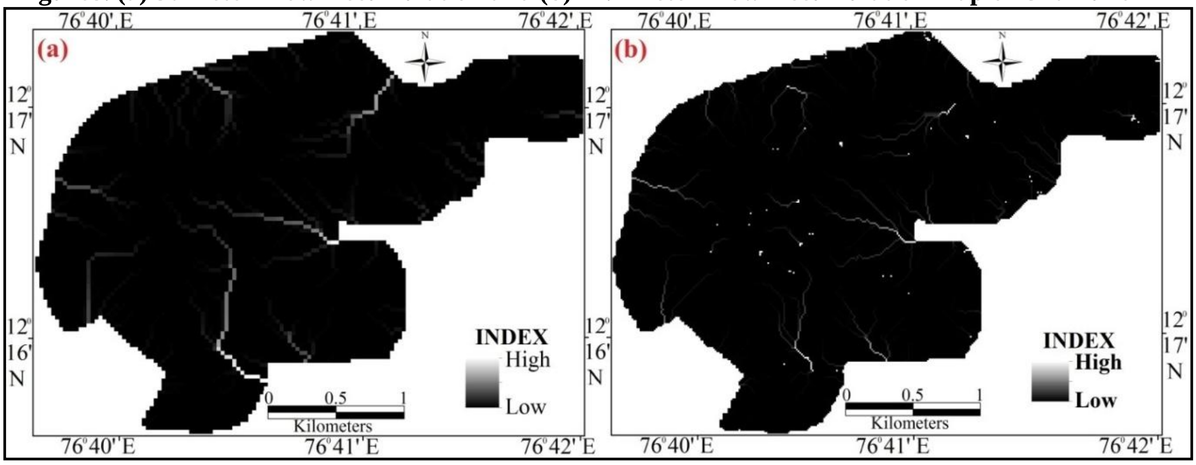


The use of the hillshade map for estimating solar radiation is possible through developing GIS (Alina et al, 2013). Using hillshade regime is more convenient than using aspect in ecological studies due to its ability to observe daily and annual solar radiation regimes and the ability to represent the statistical analysis in fuzzy sets (Ali Najafifar et al., 2019). The sun angle of the map shows from NW direction (Ali Najafifar et al., 2019). The height of the terrain, as within the map, shows black tone for valleys and white tone for the elevated portion. The hillshade map in range of 0-255 was made during the peak of summer heat (Ali Najafifar et al., 2019). The higher elevation was noticed as 254, and the lowest was 38 in case of 30 mts resolution; while the lowest was 1 for 12.4 mts resolution derived DEM (Fig.7a & 7b).

3.4 **Flow Accumulation**

Basin boundaries are determined according to the drainage networks derived from flow accumulation values (Ibrahim and Turkay, 2018). Flow accumulation is especially important to understand topographic controls on water, carbon, nutrient and sediment flows within and over full watersheds (Hiep et al, 2011). Flow accumulation maps are automatically extracted of drainage network in the present study from both 30 mts and 12.4 mts resolution (Fig.8a & 8b). Flow accumulation is highly essential in many hydrological and topographical analyses, since it identifies the contributing area at each grid cell in the domain (Chase Wallis et al, 2009). A lower limit value is determined considering the precision and size of the study on this model, and according to the highest cell value obtained from the flow accumulation model (Gurugnanam et al, 2014). By considering the water flow directions and flow accumulation model in the drainage network, main stream and side branches are created (Sangeetha et al, 2019). Water flow direction within the flow accumulation model is from cell with lower values to those with higher values. Drainage network maps are drawn for flow accumulation model representing the existence stream paths and possible drainage network paths (Hongming et al., 2017) (8a & 8b).

Figure8. (a) 30 meter Flow Accumulation and (b) 12.4 meter Flow Accumulation map of Chamundi Hill



VI. DISCUSSION

The study indicated that the Chamundi hill is oriented in the direction of north-east to south-west resembling a hexagonal shape (Joshua and Abhilash, 2017). The study of Chamundi hill reveals that western and northern sides are steeper and broader than eastern and southern sides (Joshua and Abhilash, 2017). The western side of the Chamundi hill has very high relief and highly dissected (Joshua and Abhilash, 2017). Contour lines do not show smooth lines since they have traced from gridded raster data (Totok, 2018). The produced data tend to be of poor quality of contour lines in flat land, even though the contour lines not intersecting each other (Totok, 2018). Visually, contour lines that are automatically derived from GIS environment have a broken view as the effect of the vertex limitations within the contour line (Totok, 2018). Aspect plays an important role in evaporation and temperature change and often is used as a criterion for assessing the solar radiation exposure. Conventional methods to provide the information related to measuring aspect and slope in the site are unable to analyze daily and annual solar radiation changes and local shading (Seyed et al, 2017). Then, A Study by Hammer et al. (1995) indicated that slope class maps produced from 10 mts (Ertugrul et al, 2009). DEM appear to have great potential use for soil survey and land use planning (Ertugrul et al, 2009). Delineation of terrain parameters, such as slope, drainage network, watershed boundaries are very important for many geoscientific studies (Leilei et al, 2019). These parameters are often required in preparation of development and conservation design for natural resources, infrastructure development, town planning, etc (MUD, 2015). In the present study, high resolution derived DEM data play an important role in deciding the dam location, catchment as well as the submerge areas watch towers for military hostiles, tunneling, bridges, cell phone towers, safest locations during natural disasters and others fields (Ghaffari, 2011). Slope categories integrated with duration of rainfall, soil types are very much useful in determining of landslide susceptible in a hilly town (Emmanouli et al, 2020).

V. CONCLUSION

The result of DEM evaluation shows a relatively acceptable accuracy of about 12.4 mts in resolution successfully extracted from 1meter contour which is a low cost valuable data. However, it should be emphasized that the quality of the derived contour line also depends on the topographic condition of the mapped area. The presented 12.4 mts resolution of meaningful data (maps) are still limited and requires further refinement through extensive field visits and collection of GCP's needs of accurate elevation assessment towards landforms perception. The output maps area valuable data produce economic design and planning of mega infrastructures such as railway tunneling, highways, bridges, water pipes, power lines and better analysis in mitigation of natural disasters accurately on hilly terrain areas such as Western Ghats and Himalayan regions. These data are also efficient and effective in delineating the features of drainage networks like size, length, and slope to determine the characteristics of basin and sub-basin. The accuracy is acceptable on the basis of suitable data sources and proper operations.

CONFLICT OF INTEREST

There is no conflict of interest between authors.

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