Spatial analysis of mobile signals in Himalayan hill cities

The speedy advancement of technology has brought human beings to an unprecedented era, where everyone has experienced mobile phone. It has presently become an essential commodity in our daily life. Mobile networking communication system has turned the world into a global village. So good network coverage is not only a political or corporate challenge, but also a scientific one for enhancing mobile services[1]. In the present study, we have chosen a critical terrain like Himalaya for evaluation of mobile tower connectivity. As it is an attractive tourist spot, educational hub and a religious destination, many mobile companies are trying to provide efficient and cost-effective network facility for wider and extensive parts of the Himalaya. Therefore, in the present study, our primary aim is to map and categorize uneven lands based on mobile signal availability.

The Himalayan region consists of varying terrain, which contributes to the obstruction in network facilities. Besides technical aspects like shadowing effects of hills, blocking effects by highly dielectric materials like forest cover and buildings are also important. People dwelling in the cities situated in the foothills of the Himalaya, viz. Dehradun, Mussorie and Haridwar face network problems during rainy seasons or other natural calamities like landslide, floods, etc., causing damage to towers or devices. The present study area includes these cities and major rivers like the Ganga, Yamuna, etc. bounded by 29°40′–30°40′N lat. and 77°50′–78°30′E long.

A mobile phone signal (or reception) is the strength (measured in dBm) of the connection to the mobile phone with its network. Mobile connectivity depends on various factors like the visibility of a mobile tower or line-of-sight (LOS), obstruction such as buildings and trees[2]. Sometimes bad weather and heavy traffic network also affect the signal. Another reason for cell signal fluctuation is the load on the tower, i.e. it is directly related to the number of mobile users. Urban areas must have good mobile signal due to more number of towers. But there are often dead zones (where the signal is blocked) caused by destructive interference of waves which have taken different paths. There could be signal bouncing-off buildings, trees, traffic, etc. Thus poor weightage was given to urban areas in the present study.

Viewshed analysis is a mathematical concept of viewing a particular object involving topography and viewer positions (H. M. Dodd, unpublished). It has been used in various studies such as rain shadow, landscape determination and wind energy[3]. In digital mapping, a viewshed may be a binary raster indicating the visibility of a viewpoint for or from an area of interest. A pixel with a value of unity indicates that the viewpoint is visible from the pixel, whereas a value of zero indicates that the viewpoint is not visible from that pixel. The analysis uses the elevation value of each cell of DEM to determine visibility to or from a particular cell. In the present study, many viewers' locations were fixed. Therefore, the derived output shows the total number of viewers that can be seen for a particular location (pixel). Viewshed technique applied in the case of wireless signal is also called 'communication shed or comm-shed'.

Figure 1 is a flow chart showing the basic steps followed in this study. DEM, mobile tower location and satellite images were selected as the primary data. The first two were chosen to get viewsheds of all the mobile towers, whereas land use/land cover was chosen to incorporate blocking effects. Later, all derived maps were reclassified into 10 scale; and 10 scale quantified signal availability weighted map was generated. All maps were calculated in ArcGIS platform. Finally, the derived results were analysed and verified considering five categories, viz. very poor, poor, moderate, good and very good.

The results of various steps shown in Figure 1 are represented in Figure 2. Starting from primary data sources (topography, mobile tower locations and satellite images) the final and intermediate maps are shown with linkages in Figure 2. Five important hill cities, viz. Mussorie, Dehradun, Haridwar, Rishikesh and Roorkee have also been plotted for better clarity in the results. Further, Figure 2 contains five important derived outputs – viewshed, reclassified viewshed, land use, reclassified land use and weighted final output.

Viewshed map indicates how many towers out of total 356 (maximum) can be visible from a particular location/pixel/grid. Spatial analyst (viewshed) tool of ArcGIS was used to derive this. The result was categorized into a few ranges based on statistical nature of the population as follows: 0, 0–3, 3–14, 14–24, 24–36, 36–52, 52–68, 68–85, 85–120 and 120–356. For each range a particular colour was assigned. For example, zero or 'no tower visible' was assigned blue colour. Most of the hilly terrains beyond Mussorie are marked with this. On the other hand, the green colour coverage areas have maximum mobile visibility; these mostly coincide with either plane land or city areas. The gradual gradation from green to red indicates moderate to poor connectivity. The derived map of viewshed again was reclassified into ten-scale, choosing different colour codes.

Another important derived map is the classified land-use/land-cover map; this includes important classes like water, agriculture/barren land, city, vegetated and forested areas. The highest weighted value (10) was given to all water bodies, barren and agricultural lands with lesser chances of obstruction. Conversely, poor weighted values (1 and 2) were given to cities and forested areas. Accordingly, reclassified land-use map was generated for the next step of weightage calculation.

The weight for viewshed (0.7) was higher in comparison to land-use map (0.3), based on personal communication with mobile operators. Although the technical staff gave more importance to

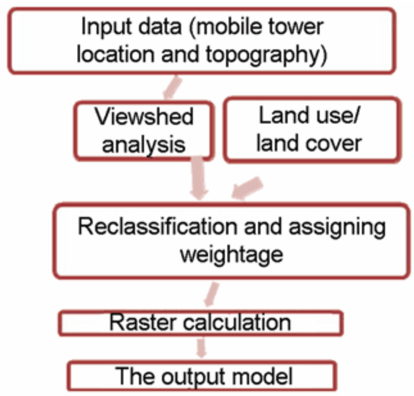

Figure 1. Flow chart of methodology.

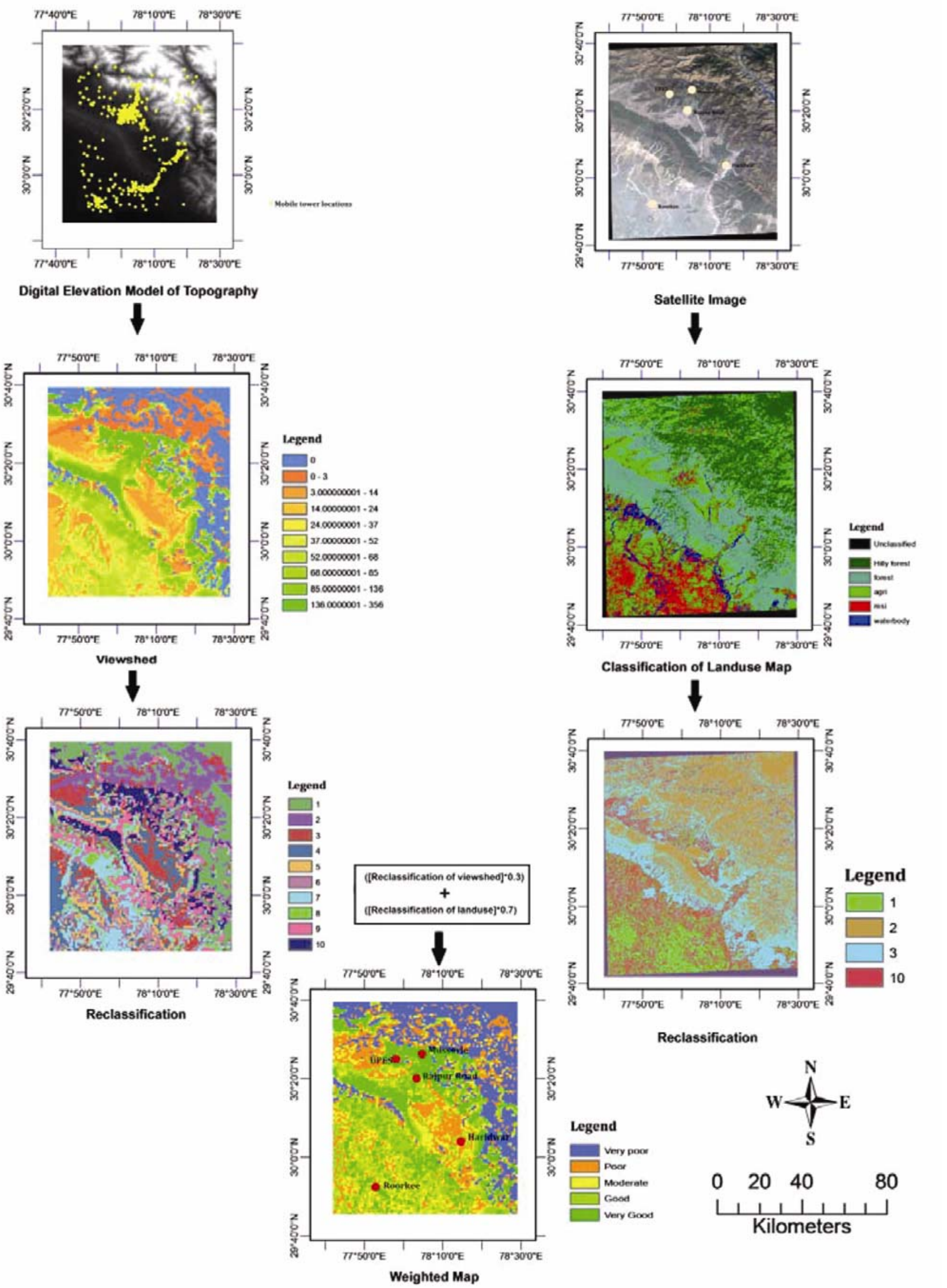

Figure 2. Flow chart of derived maps.

local connectivity factors, the shadowing effects of the hills cannot be ruled out. The final output map was the weighted map of connectivity. For evaluation of authenticity in our results, various locations were chosen for field visits involving our own cell phones. Among them, the location marked as 'UPES' (our university) is significant. As all categories of signal are present in the vicinity, the location was extensively studied. For example, the roads leading towards our university received poor signal, whereas the university fell under the good-signal category. Although cell phones are not suitable for quantification of signal strength, qualitative information was obtained after participatory interaction with the local people.

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Cross-calibration of Indian Mini Satellite-1 HySI data using Hyperion: effect on Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) has been widely used as one of the earliest indicators for estimation of various biophysical parameters such as green biomass, chlorophyll content, canopy water stress, Leaf Area Index (LAI) and Absorbed Photosynthetically Active Radiation (APAR)[1–5]. Remote sensing has become one of the primary sources to map NDVI owing to the presence of suitable spectral bands in the imagery. Also, attempts have been made to study the effect of spectral characteristics on the vegetation indices derived from remotely sensed images[6]. The presence of a large number of contiguous spectral channels of hyperspectral imagery along with their very narrow spectral bandwidths enables to derive spectra of different features[7]. Studies have been carried out to examine whether hyperspectral images provide advantage over multispectral datasets for the retrieval of vegetation properties[8]. It is observed that the existence of correlativity and mutual compensation in different bands of hyperspectral datasets allows viewing NDVI as a spectral transformation feature in image processing[9]. In this study, an attempt was made to retrieve NDVI from atmospherically corrected IMS-1 HySI (Hyper-Spectral Imager) data. The NDVI values so-obtained were compared with respect to those of MODIS standard 500 m NDVI product[10]. The comparison showed considerable mismatch and hence, an attempt was made to re-compute NDVI image after inter-sensor calibration of HySI with respect to Hyperion. This communication reports the effect of cross-calibration of Indian Hyperspectral Sensor IMS-1 HySI with respect to Hyperion[11] on NDVI values and their comparison with respect to those of MODIS product.

IMS-1 launched in April 2008 by PSLV C-11 carried a HySI for observation of Earth along with a Multispectral Camera (MX)[12,13]. The HySI sensor was designed for 64 contiguous channels with a spectral separation of 8 nm and spatial resolution of 506 m. An attempt was made earlier to retrieve acceptable reflectance profiles from HySI data using two atmospheric correction algorithms employing different inter-sensor-calibration techniques[14]. In this paper, the study area for 24 May 2009 of Rishikesh and surroundings, with scene centre latitude and longitude, 30.0018° and 78.4334° respectively, has been taken from HySI data (Figure 1). The Digital Number (DN) image was converted to radiance and then, atmospherically corrected using FLAASH[15]. NDVI values were computed from the so-forth reflectance image obtained. The NDVI image from HySI was then compared with that of MODIS NDVI product MOD13A1 which is a 16-day composite product at 500 m resolution[16]. Out of the 64 spectral bands of HySI, the bands whose central wavelength was close to those of the corresponding MODIS bands were chosen to compute the NDVI image. It was found that NDVI values obtained from HySI did not match well with those of the corresponding MODIS product of similar time period. Hence, an attempt was made to cross-calibrate the spectral bands of HySI data with respect to those of Hyperion.

In this approach, radiance values of pseudo-invariant features from the two sensors were compared and it was found that the values obtained from HySI differ from those of Hyperion in majority of the

Figure 1. IMS-1 HySI data for the area under study.