

# **Topographic Characteristics of Ramganga River Basin : Digital Elevation Model and GIS Based Study**

**Rameswar Mukherjee and Ram Bilas**

Surface topography of any drainage basin plays an important role in the development of drainage networks and its evolution. Basin hydrology is also controlled by topographic attributes as the overland flow, through flow and stream flow are largely determined by relief and slope. Topography largely affects the evolution of landforms and slope, vegetation growth, and soil development. So it is necessary to quantify the various parameters of topography in order to get the economic design for river utilization and control, as well as watershed development and planning. In the present study an attempt has been made to evaluate existing topographic condition of the Ramganga River Basin by using ASTER GDEM data. Geographic Information System (GIS) was used for calculating and mapping. The study reveals that the nature and variations of surface and relief parameters are largely affected by the topographic variability.

**Key Words:** Topography, relief, DEM, GIS.

## **Introduction**

For decades, Digital Elevation Model (DEM) has been used for mathematical analysis and mapping of surface topography and its various attributes (viz. relief, slope, aspect etc.) as well as modelling of the earth surface topography and drainage analysis. DEM data is progressively being used in earth science due to its numerous advantage and qualities e.g. cost effectiveness, continuous coverage of elevation data, high level of details, and automatic measurement of topographic properties (Hengl and MacMillan, 2009, Sairt et al. 2009). Presently, processing, modelling, and mapping of DEM data have been successfully done by using GIS. The basic

topographic properties that have been derived from DEM by using GIS are (1) elevation (2) properties (3) terrain curvature (4) convexity and (5) surface specific points and lines, i.e. peaks, pits, passes, inflection points, break points, ridges and valley lines (Jordan, 2003).

The configuration of the earth surface topography reflects the nature of the interaction between process and form. By measuring various topographic attributes along with existing drainage network can give us the impetus for understanding the denudational history of the present topography as well as the evolution of drainage network. The topography of drainage basins is a sensibly permanent characteristic which influences

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mainly the concentration or time distribution of the discharge from a drainage basin (Langbein, 1947). In the present work, various aspects of topographic properties of the Ramganga River Basin have been studied in order to evaluate the existing topographic condition and its nature and pattern of regional variability. The entire Ramganga Basin can be classified into two major physiographic units namely: The Himalaya Mountain and Alluvial Plain of Ramganga. About 23218.8 km<sup>2</sup> (75.79%) study area falls under the the alluvial plain and 7416.3km<sup>2</sup> (24.21 %) lies in Himalaya, out of which 63.34 percent (4993.70km<sup>2</sup>) is in Lesser Himalaya and 32.66 percent (2422.60 km<sup>2</sup>) in Shiwalik Himalaya. Lesser Himalayan rocks are deeply incised and dissected by the antecedent rivers of that region. It's northern and north eastern part is traversed by high mountain ranges, but the relief and slopes are gradually decreased towards the centre. Shiwalik Mountain shows extremely rugged and youthful topography. Along the Alluvial Plain of Ramganga (Rohilkhand Plain), topographic uniformity is observed but the nature of material brought down by rivers varies significantly that caused significant geomorphic variations in the plain (Singh, 1971). It represents degradational topography with incised river channel as well as dissected floodplain surfaces.

### Objective

The basic objective of this paper is to explain the topographic characteristics of the Ramganga River Basin.

### Database and Methodology

In the present study Advance Space Thermal Emission and Radiometer Global DEM (ASTER GDEM) data of 30 meter

spatial resolution has been used for topographic analysis. At first ASTER GDEM data were filled for splitting off tall cells or filling in sinks. Flow direction was calculated for each pixel using the filled DEM. After that, flow accumulation was derived from flow direction data and then, threshold value 100 was given on flow accumulation data in order to extract stream network. Finally, watershed of Ramganga and its sub-basins were delineated by giving outlet or pour points. The slope of the study area was calculated on a pixel-by-pixel basis within a moving 3×3 window, as the maximum rate of change in values between each pixel and its neighbors. The slope (s) was calculated using a second-order finite difference algorithm based on the four nearest neighbors:

$$s = \sqrt{[(\delta z/\delta x)^2 + (\delta z/\delta y)^2]}$$

(1.1) (Liu and Mason, 2009)

where  $\delta z/\delta x$  and  $\delta z/\delta y$  represent the rate of change in elevation in directions parallel to the x- and y-axes of the coordinate system.

Since, slope is usually calculated in radian, therefore it was converted into degree by using following formula:

$$s^{\text{degree}} = \arctan (g^{\text{radian}}) \times (180/\pi)$$

(1.2) (Liu and Mason, 2009)

The pixel DN values in a raster representing aspect (a) are compass directions or bearings, in degrees, measured in a clockwise direction from 0 to 360, where north has a value of 0, east 90, south 180 and west 270. Aspect was calculated as follows:

$$\tan a = \frac{(ez/ex)}{(ez/ey)}$$

(1.3) (Liu and Mason, 2009)

Mathematically Curvature (c) was calculated along the aspect direction (by using

following formula:

$$\tan a = \frac{(ez/eb^3)}{[1+(ez/eb)^2]^{3/2}} \quad (1.4) \quad (Liu \text{ and } Mason, 2009)$$

Where,  $ez/eb$  = the rate of change in elevation in respect to aspect directions.

Slope, Aspect, and Curvature maps were prepared in ERDAS IMAGINE 13.0 by using ASTER GDEM. Then, Average slope, Absolute Relief, Relative Relief, Dissection Index and Ruggedness Number were determined by dividing the whole study area into the 1km<sup>2</sup> grid in Arc GIS 10.1 through Fishnet command. Average slope map was prepared by dividing slope map into a 1km<sup>2</sup> grid. Mean slope value was calculated from zonal statistics as table operation. For calculating Absolute Relief, Relative Relief, Dissection Index, Ruggedness Number in each 1km<sup>2</sup> grid Zonal Statistics as Table operation was performed on ASTER GDEM data. Maximum value obtained from the Table operation was considered for Absolute Relief, the range was considered as Relative Relief and Dissection Index and Ruggedness Number were derived through raster calculator by using formula no 1.7 and 1.8 respectively. After getting the point values of surface and relief properties, we used IDW interpolation method for mapping. For a position x, and for i to n data points with z known values, the unknown weighted average (z(x)) is derived as:

$$T_i w_i z_i / \sum T_i w_i \dots \dots \dots (1.5) \quad (Liu \text{ and } Mason, 2009)$$

**Study Area**

Ramganga River is one of the largest tributaries of Ganga River. It has total 30635.1km<sup>2</sup> catchment area. It is the first major tributary that joined Ganga at Gangetic Plain

near Kannauj, Uttar Pradesh (Fig.1). The total length of Ramganga is about 587.42km, out of which, 157.57km is in the Himalaya and 429.85km in the Gangetic plain. Ramganga originated from a spring called Ramnali, formed in the Dudhatoli Crystalline Formation of Lesser Himalaya at an elevation of 2926m above sea level, at the place Diwali Khal, near Gairsen, Chamoli District, Uttarakhand. The river after its origin flows in a south-easterly direction for about 31.21 km and then the river course is deflected at the right angle and flows in a south-westerly direction. After flowing over the Lesser and Shiwalik Himalaya, the river enters into the Gangetic Plain region at Kalagarh, where a dam on Ramganga has been established in 1974. In Himalaya, the river flows over the Chamoli, Almorah, and Pauri-Garhwal Districts. After entering into the plain in Bijnor district, the river deflected its course towards west for about 12.77km, after that it is deflected again towards south-east. Below the foothill zone the river oscillates its channel south-east to south-west direction and flows through the districts of Bijnore, Moradabad, Badaun, Rampur, Bareilly, and Sahjahanpur and finally joins the Ganga near about Kannauj in Fatehgarh district. The river mainly receives water from springs and rainfall but also from snowfall during the winter season at the higher reaches (northern part) of the basin. Annual precipitation of the study area is 150cm.

**Geology and Geomorphology of Ramganga River Basin**

The entire catchment area lies over three major litho-tectonic zones: Lesser Himalaya, Shiwalik Himalaya, and Gangetic Plain. Lesser Himalaya is characterized by intra-crustal thrusts between Main Boundary Thrust (MBT)

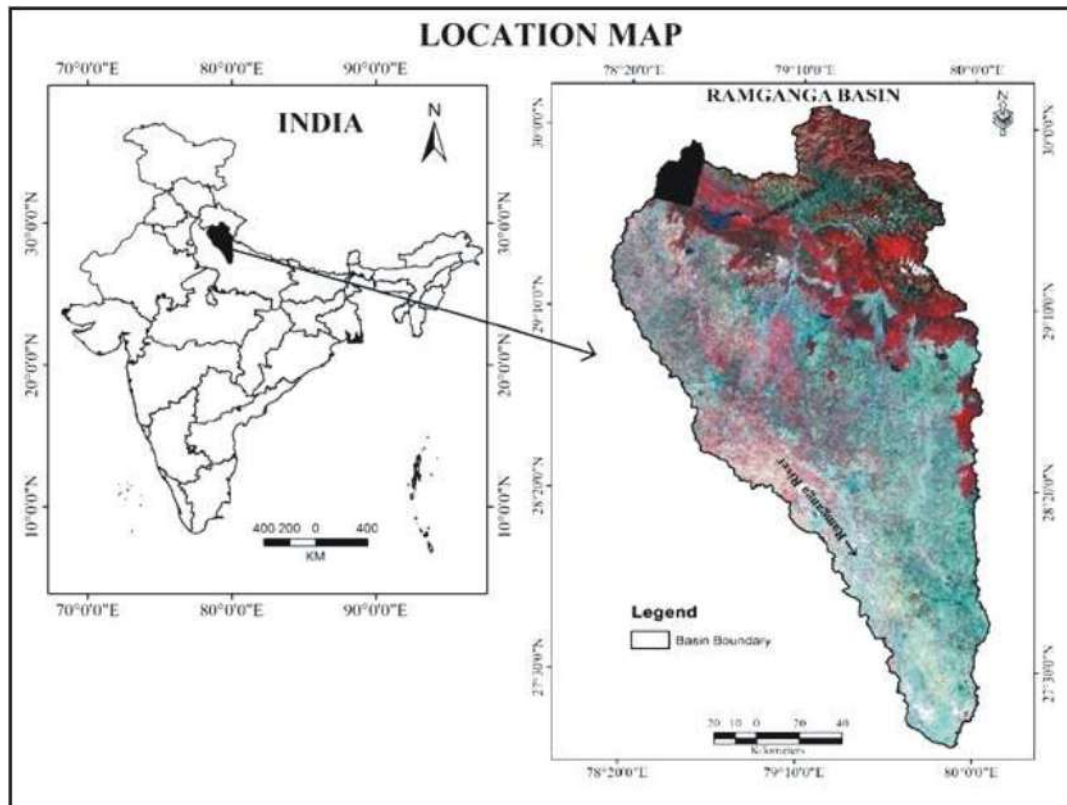


Fig.1

and Main Central Thrust (MCT). Lesser Himalaya exhibits rugged topography having intense crushing and shearing rock units. As a result of continuing continental convergence between northward advancing Indian Plate with Eurasian Plate, Lesser Himalayan belt has suffered from crustal shortening and continued push has also been responsible for the development of numerous transverse tear faults (Valdiya, 1980, 1983; Pathak, 2013). Lesser Himalayan rocks of the study area have been divided into three lithostratigraphic units: Almora Dudhatoli Crystalline, Calc Zone of Pithoragarh and Krol Groups. Almora

Dudhatoli Crystalline is divided into two groups: Almora and Ramgarh. Almora Group is separated from the underlying autochthonous metasedimentaries by the North Almora Thrust (NAT) and South Almora thrust (SAT) in the northern and southern flanks, respectively (Valdiya, 1980). Ramgarh Group of rocks is present in between SAT and Ramgarh Thrust (RT). Calc Zone of Pithoragarh is observed on the north-eastern part of the study area. It comprises of bedrocks belonging to Damtha and Tejam groups and Berinag Formation. Krol Belt is situated in the area between RT and MBT. Along the study area, six major rock formations are observed on Krol Belt, namely,

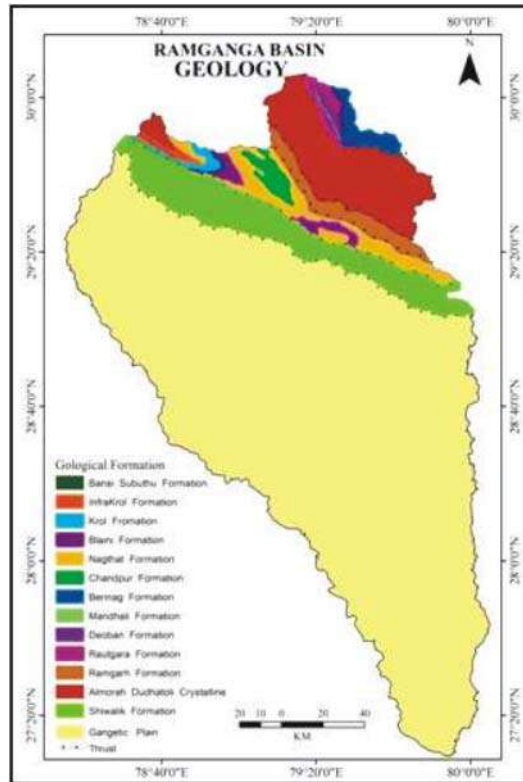


Fig.2

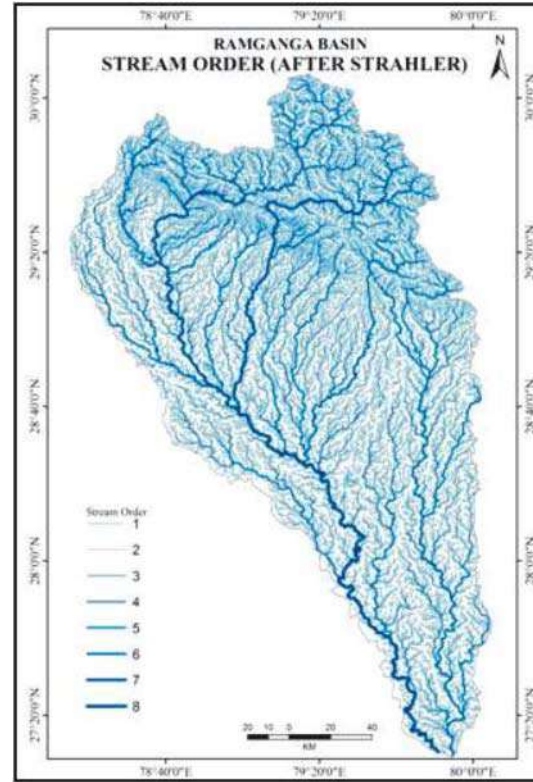


Fig. 3

Bansi and Subuthu, Infra Krol, Krol, Blaini, Nagthai and Chandpur Formations (Jha, 1996). The next litho-tectonic unit is Shiwalik Himalaya, composed of the molasse sediments of Mid-Miocene to Pleistocene age (Gupta and Joshi, 1990). Shiwalik Himalaya exhibits extremely rugged, youthful topography and subjected to continual upliftment and reshaping of the landforms (Valdiya, 1993). Shiwalik Mountains consist of two ranges separated by a broad flat synclinal valley, called Doon. They commonly exhibit a steep slope (scarp slope) to the south and gentle inner dip slopes (Dhital, 2015). Further south of Doon valley Himalayan Frontal Thrust (HFT) is present. It separates Himalaya

from Indo-Gangetic Plain. Ramganga enters into the Gangetic Plain near Kalagarh. Gangetic plain region of the study area is characterized by three Quaternary lithostratigraphic sequences that comprise (1) Varanasi Older Alluvium with two facies, i.e. sandy facies and silt clay facies, (2) Ramganga Terrace Alluvium and (3) Ramganga Recent Alluvium, the latter two constitute the Newer Alluvium (Khan and Rawat 1992, Khan et al. 2016). Varanasi older alluvium is associated with Upland Interfluvial Surface, Sandy Alluvial Ridges, and Older Terrace surface. Ramganga Terrace Alluvium is concerned with older and dissected terrace plain, inactive floodplains and Ramganga

Recent Alluvium closely corresponds with active and younger floodplains (Fig.2).

### Drainage

The Ramganga River is the master stream of the study area is of the 8<sup>th</sup> order (Fig. 3). By considering up to 4<sup>th</sup> order streams (from the higher stream order), Ramganga basin has total 41 tributary basins (Fig. 5). Among them one 7<sup>th</sup> order, five 6<sup>th</sup> order, fifteen 5<sup>th</sup> order and twenty 4<sup>th</sup> order tributary basins are present. Koshi is in 7<sup>th</sup> order; Mandal, Gangan, Gola, Deoha, Khoh rivers are in 6<sup>th</sup> order; Binau, Dev Gad, Gagas, Khansar, Khatron, Palain Sot, Sona, Tarag, Dhela, Baur, Sankha, Bahgul, Nakatia, Aril, Phika rivers are in 5<sup>th</sup> order; and Bimoli, Dhulwagad, Gabhini Gadhera, Gaujera, Ghurghat, Kaliganga, Kalron, Kuthrar, Lamro Gad, Mairasot, Mandwa, Mothu Gad, Nair, Naurar Gadhera, Phulai Sot, Siuni, Lapkana, Banaili, Pili, Sendha are 4<sup>th</sup> order streams.

### Landscape Profile

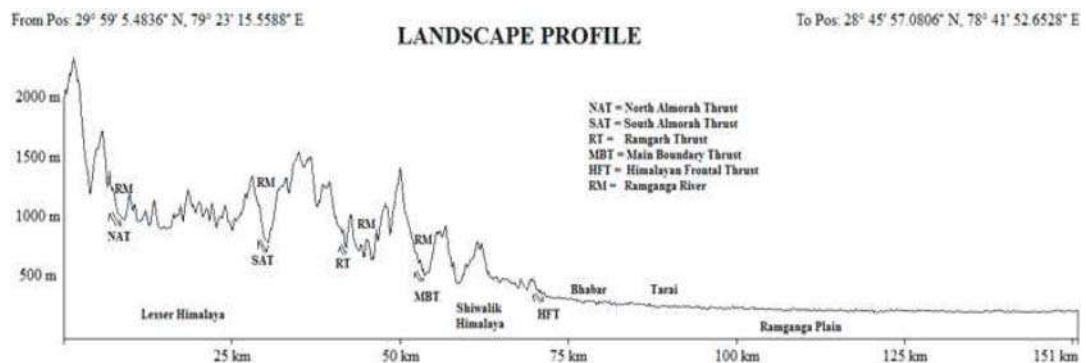
Landscape profile is prepared to represent the topographic surface in a vertical plan along the line. The profile is generated from ASTER GDEM data diagonally in NE-SW direction. The profile shows larger

variation in relief in Himalayan reach while along the Ramganga Plain it is nearly flat. The elevation is increased from south to north. Larger undulations in topography exists in between SAT and MBT. The positions of the major thrusts are shown in the Landscape Profile (Fig.4). The Northern part of the NAT is characterized by steep mountain ranges, but in between NAT and SAT, relief is reduced remarkably. This region is highly breached by streams and thus, several denudational and dissected hills are formed. In between SAT and RT mountain reaches are looked like towering ridges. The Northern part of the MBT is characterized with high mountain range but towards the south, elevation of the mountain ranges decreases. The Southern part of the HFT or foothill of Shiwalik is recognized as *Bhabar*, made up by coalescence of alluvial fans. The Southern part of *Bhabar* as well as in the distal end of the alluvial fan, the existing marshy tracts are known as *Tarai*. Further south of *Tarai* belt monotonous flat type Ramganga Plain came into existence.

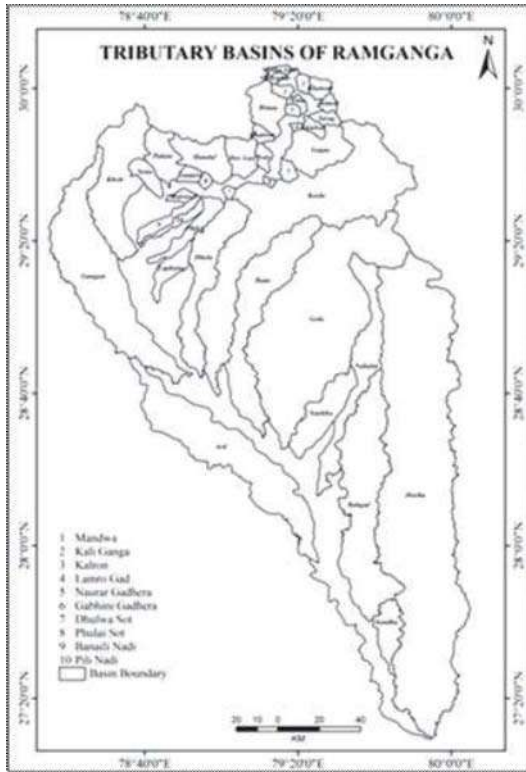
### Result and Discussions

#### Topographic Characteristics

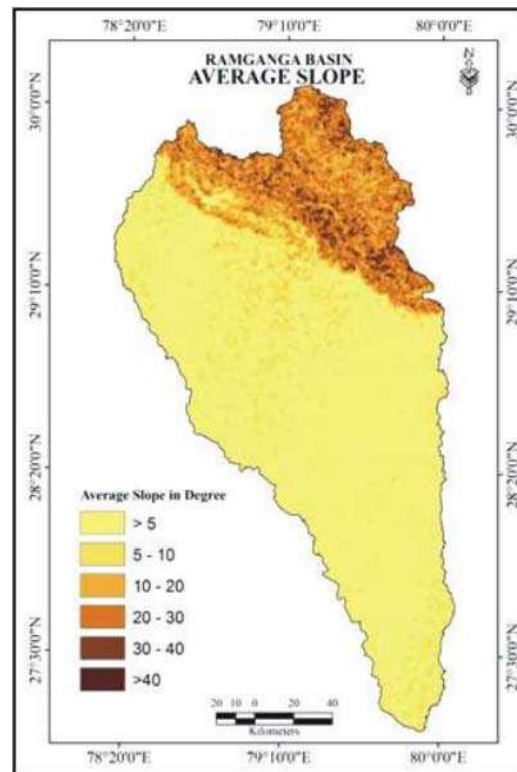
The nature, characteristics and



**Fig.4**



**Fig.5**



**Fig.6**

distribution of various topographic attributes are discussed under two headings: Surface properties and Relief properties:

**Surface Properties**

**Average Slope (AS)**

The term slope has two meanings for geomorphic applications; one refers to the angle of inclination to the earth surface, expressed in degrees or as a percentage, and the other is the inclined surface itself (Fairbridge, 1968; Chorley et al. 1985; Hugget, 2011). In Fluvial Geomorphology, the slope is considered as an integral part of drainage basin as it largely influences and controls water and sediment input to a particular stream as well as

transportation of them are also affected by channel slope (Fairbridge, 1968; Chorley et al. 1985). Presently, Digital Elevation Model (DEM) is widely used for deriving slope of any particular terrain. Through DEM data, the slope is determined by a plane tangent to a surface at any given point. It comprises with two derivatives namely: gradient and aspect. Analytically gradient is defined as the maximum rate of change in altitude and expressed as degree or percentage, and aspect, as the orientation of steepest gradient expressed in degree or to a compass bearing (Burrough, 1998; Hugget, 2011).

The Average Slope of the Ramganga basin ranges from 0 to 52.29. The maximum

portion of the study area (59.99%) is characterised by Very Gentle Average Slope ( $< 5^\circ$ ) category. It is widely distributed in the active flood plain, younger and older terrace surfaces Ramganga Plain. It is also infrequently distributed over the floodplains and lower valley slope at Shiwalik Himalaya (Fig 6). About 18.21 percent of the study area comes under the Gentle Average Slope category ( $5^\circ$ - $10^\circ$ ). It is specifically observed on *Bhabar* and *Tarai* region. Along the central and lower Ramganga Plain, Gentle Average Slope is widely distributed over interfluvial surface, older terrace plain and alluvial sandy ridges region. It is also widely distributed along the floodplain, terrace surface as well as lower valley-side slopes at lower Shiwalik Himalaya. Moderate AS accounts for 8.77 percent of the study area. It is concentrated in the north-western part of Shiwalik Himalaya and along the north-central part of Lesser Himalaya. It largely corresponds with mountainous upland with the denudational hill, the intermediate part of the higher mountain range, flat divides etc. Moderately steep AS accounts for 7.51 percent of the study area. But more than 70 percent of areas of Lesser Himalaya fall under this category. In Shiwalik Himalaya, it is also observed near the zone of MBT. Steep AS is characterised with 4.12 percent of the study area. It is specifically concentrated in the zone lying between SAT and MBT as well as along the north-eastern part of NAT. Highly steep AS is observed only on 1.39 percent of the study area. It is closely associated with high-rise mountain peak, located along the water divides of Ramganga and Sarda as well as Ramganga and Pindar river. It is also observed near the vicinity of MBT.

### Aspect

Aspect shows the prevailing direction that a slope faces at each pixel. It is represented in eight major compass directions or any of 360 degrees. Aspect map was created by using the ASTER DEM through ArcGIS 10.1. Aspect grid was divided into 9 groups, eight directional and one class representing the flat terrain. Flat areas correspond to very negligible part of the basin so that we have ignored this class. The Aspect Map (Fig. 7) is classified at  $45^\circ$  interval which represents eight major directions of the slope of the basin. Among the eight group most of the slope faces are directed towards South (13.44%) followed by South-west (13.04%), North (12.69%), West (12.67%), South-east (12.30%), East (12.20%), North-east (11.38%) and North-west (11.76%). Aspect is a very important parameter for drainage network development as we know that streams follow the direction of the slope. Aspect also indirectly influences drainage development as the growth of vegetation largely depends on of the orientation of the slope faces towards the direction of direct sun rays. Direct sun rays favour large plant growth. Where vegetation is a higher, density of drainage tend to be lower.

### Curvature

The curvature is defined as the slope of the slope (Chang, 2006). Curvature (c) represents the rate of change in surface orientation of a variable across an area. It is calculated from a surface (raster or vector), such as elevation, and describes the convexity or concavity of that surface (Liu and Mason, 2009). A positive curvature denotes convexly upward surface while negative curvature shows concavity. A zero value of concavity indicates perfectly rectilinear surface. About 77.02 percent of the study area has rectilinear slope surface while 11.57 percent area exhibits

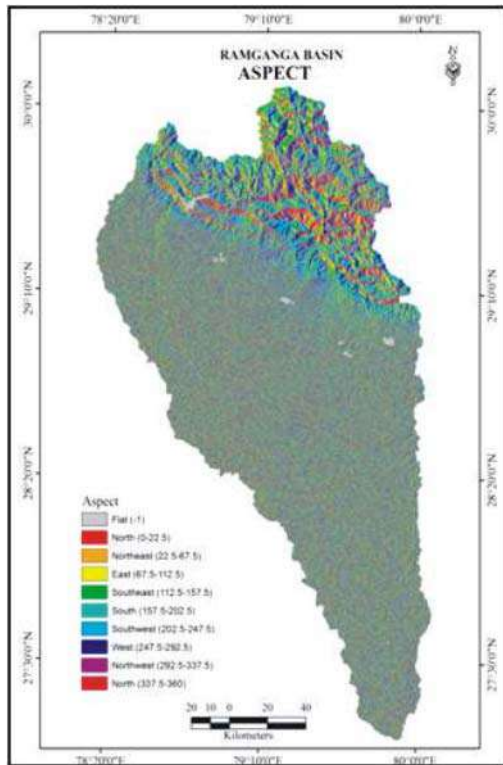


Fig. 7

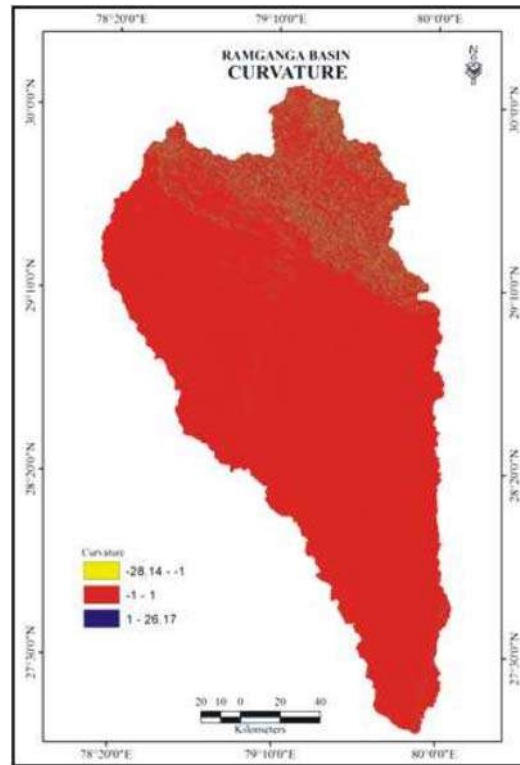


Fig.8

concavity and 11.41 percent shows convexly upward surface (Fig. 8).

### Relief Properties

#### Absolute relief

Absolute Relief refers to the maximum elevation of any area above the mean sea level. According to Singh (2004), Absolute Relief is the function of geotectonic and constructive and destructive processes. It is very useful to determine the erosion surface in respect to the present day landforms. It is used to estimate the intensity of denudational processes operating on any surface. It provides impetus to assess the landscape evolution of any surface.

#### Distribution of Absolute Relief

Absolute relief of the Ramganga Basin ranges from 133.693m to 3068m above MSL. We have divided absolute relief of the basin into 10 categories, ranging from below 150m to above 2100m (Fig. 8). Maximum areal coverage of absolute relief is observed in the 150-200m category, which accounts for 36.55 percent of the total area followed by 29.85 percent for 200-300m. Minimum distribution (2.10%) of absolute relief of the study area falls under the >2100 m category. It has been observed that the contour of 300m closely corresponds to the contact zone between Himalaya and Ramganga Plain. Therefore the zones lying below 300m contour is designated as a Gangetic plain region. About 75.79 percent

of the Ramganga is in the plain region while rest of the part is in Lesser and Shiwalik Himalaya. The absolute relief zone of below 150m is observed at or near the confluence zone between Ramganga and Ganga as well as Ramganga and Deoha. 150-200m absolute relief zone is lying on the middle to lower part of the basin. 200-300m zone is observed along the *Tarai* and *Bhabar* zones or piedmont alluvial zone of the study area. 300-600m zone is distributed as continuous linear stripes from north-west to south-east direction along the lower Shiwalik region. From that area, most of the foothill-fed streams are originated. Among the mountain-fed tributary river Maira Sot and middle and lower part of the Sona, Phulai Sot, Gaujera, and lower part of Palain Sot are lying in this altitude zone. 600-900m absolute relief zone is observed mostly on middle and upper Shiwalik as well as southern part of Lesser Himalaya. It is also distributed as linear stripes nearly parallel to the 300-600 absolute relief zone. The upper part of Sona, Palain, Gaujera, Phulai Sot and also in narrow stripes of Koshi, Baur, Gola, Deoha are also falling under this zone. 900-1200m absolute relief zone is mostly distributed on Upper Shiwalik and Lesser Himalayan part. It is observed on Baur, Gola, Deoha as narrow strips and valley sides of upper Ramganga and Koshi valley and those of lower part of Binau, Nair, Gagas, Naurar Gadhera, Dev Gad as well as southern and western part of Mandal and northern part of Palain Sot and Khoh. 1200-1500m absolute relief category covers largely on the northern part of Ramganga and Koshi Valley. It is also distributed in the northern part of Khoh and central part of Palain, Dev Gad, and lower part of the Naurar Gadhera, Lamro Gad, Kalron, Siuni, and Kuthrar. Maximum area of Gagas

river is lying under this category. 1500-1800m absolute relief category is largely found on Upper Koshi. It is also observed on the lower part of Ghurghat, Kaliganga, Khansar, and western part of Siuni, middle and upper part of Kalron, Binau, Khatron, Nair, Dev gad, Mandal, Gola and the northern part of Deoha, Baur, Khoh river. 1800-2100m absolute relief category corresponds to the crests of the mountain and the water divides of Koshi river with Ramganga, Saryu and Baur river aligned in Northern, North-Eastern part respectively. It is also observed along northern part of Mandal, Dev gad, Nair, Binau, the middle part of Kaliganga, Tarag, Bimoli as well as southern part of Mothugad, Ghurghat, Khansar, and Mandwa. Some of the notable peaks of that area are Goryal ka Dhar (1950m), Jharapani Dhar (1995m), Jaurasi Dhar (1835m) etc. More than 2100m category is characterised with steep valley side slopes, and water divides of northernmost tributaries of Ramganga like Binau, Ghurghat, Mandwa, Khansar, Bimoli, Tarag etc. This zone is characterized with peak Chorara Khal Dhar (2363m), Diwali Khal (2442m), Musa ka keth (2950m), Dudhatoli ki Dhar (3068m) Diwalikhal (2609), Chaterasin (2515m) etc.

### **Relative Relief (RR)**

It is the difference between highest and lowest elevation point of an area. The relative relief of the basin has been calculated through Raster Calculator in Arc GIS 10.1 by using following formula:

$$RR = \text{Maximum Elevation} - \text{Minimum Elevation} \quad (1.6)$$

### **Distribution of Relative Relief**

About 64.98 percent of the total basin is characterised with very low relative relief

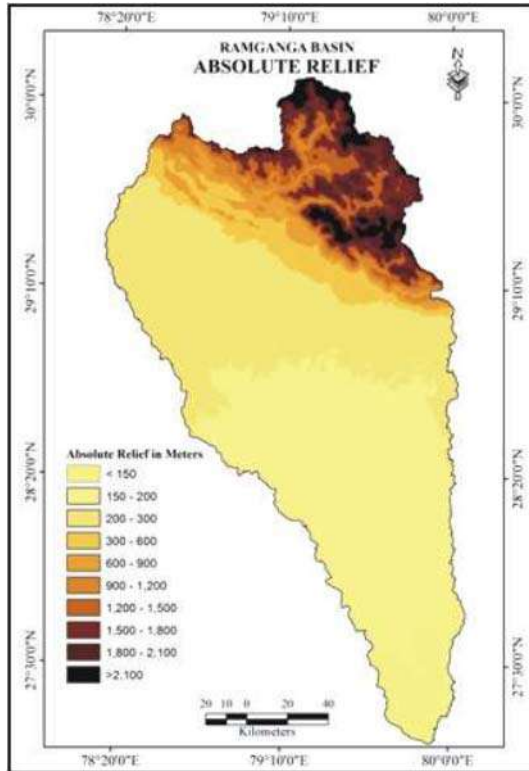


Fig. 9

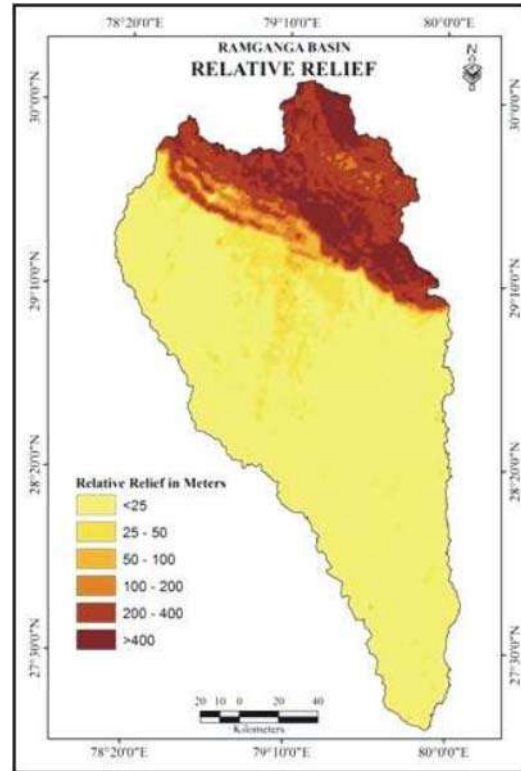


Fig.10

(<25m), as about 75.79 percent of the study area lying on the monotonous featureless (nearly) or flat type Ramganga plain region (Fig.10). Low relative relief (25-50m) is largely associated with the piedmont alluvial plain of Gola, Baur, Koshi, Dhela, Deoha river. It is also observed as small patches in lower and middle part of the study area. Moderate relative relief (50-100m) comprises with the zone of Himalayan Frontal Fault and Lower Shiwalik region. It is characterised with the valley of Sona, Palain, Mairasot, Gaujera and north-western part of Baur. Moderately high (100-200m) is mainly associated with lower and middle Shiwalik region. It is characterised with the valley of Sona, Palain, Gaujera, Phulaisot,

northern and central part of Koshi, small patches of moderately high RR also observed as small patches along the northern part of Gagas, Binau river basin. High (200-400m) accounts of 12.89 percent of the study area. It is observed along the upper reaches of Deoha, Gola, Koshi, Khoh, Sona, Palain, Mandal, Phulaisot, Dev Gad, Gaujera, Devgad, Nair, Gaujera and the others situated in north-western part of the study area. More than 85 percent of the Gagas river basin is lying under this zone. Very high relative relief (>400m) occurs on upper reaches of almost all the tributaries situated along the north and north-western part of the study area. It is also observed along the northern part of Gola and

Deoha as well as middle part of Himalayan Koshi basin (Ranikhet, Almora region).

### Dissection Index (DI)

It is the ratio between absolute relief and relative relief. Dissection index implying the degree of basin dissection or vertical erosion and determine the stages of landform evolution of any watershed (Singh and Dubey, 1994). The Dissected index of the Basin has been calculated through Raster Calculator in Arc GIS 10.1 by using following formula:

$$\text{Dissection Index (DI)} = \frac{\text{Relative Relief (RR)}}{\text{Absolute Relief (AR)}} \times 100 \quad (1.7)$$

The value of Dissection Index (DI) varies from 0 to 100. The value close to 0 indicates the absence of vertical erosion. Generally flat type alluvial plain region corresponds to very low to low DI. The value close to 100 indicates steep wall like escarpment.

### Distribution of Dissection Index

The major parts (44.81%) of the basin fall under very low dissection index category (< 10). It is largely distributed on the north-western, northern, and central section of the alluvial plain region and most of the sections of Gagas, Khoh, Aril, Deoh, Baur, Nakatia and Deoha river basin (Fig. 11). Low dissection index (10-20) is distributed mostly on alluvial plain region but it is also present in the northern part of Dev Gad, Mandal, Mairasot, Madwa, Khansar, Bimoli, and almost in entire reach of Mothu Gad, Ghurghat, and Kaliganga river basin. It is also observed on the Lower Siwalik Himalaya, situated in the central and North Western part of the basin. In Phika, Lapkana, Dhela basins and alluvial reaches of Koshi, Baur, Gola and water divides of Deoha river are also characterised with the Low DI

category. It is also observed at the confluence zone of Ramganga and Ganga river. This zone is experienced with the flood in every year which breached loose, unconsolidated deposits of that area several rills and gullies have been developed because of that near the confluence zone (Ganga-Ramganga) DI is higher than the other portion of the alluvial plain. Moderate dissected index (20-30) accounts for 11.55 percent of the study area. It is widely distributed in the northern, north-western part of Himalayan Ramganga river, central part of the Himalayan Koshi and the northern part of the Gola and Deoha. High dissection ratio (30-40) is mostly observed along the Shiwalik Hill and south-western part of Lesser Himalayan region. It is also observed as small patches in the northern part of the study area. Very high dissection index (>40) is observed along Lower Shiwalik, and Main Boundary Thrust (MBT) region.

### Ruggedness Number (RN)

Ruggedness generally means the degree of the corrugation of the earth surface. It is the product of relative relief and drainage density. Relative relief shows the altimetric difference of a basin while drainage density reflects the level of dissection of topography (Strahler, 1968).

$$\text{Ruggedness Number (RN)} = \frac{\text{Relative Relief (RR)} \times \text{Drainage Density (DD)}}{K} \quad (1.8)$$

Where K = 1000

Relative Relief is expressed in meters and Drainage Density in km/km<sup>2</sup>.

### Distribution of Ruggedness Number

Very low ruggedness number (<0.2) accounts 77.20 percent of the study area. It

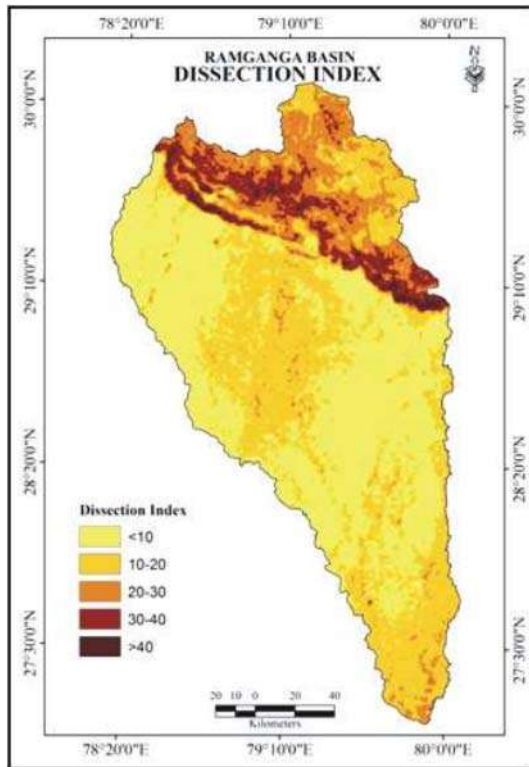


Fig. 11

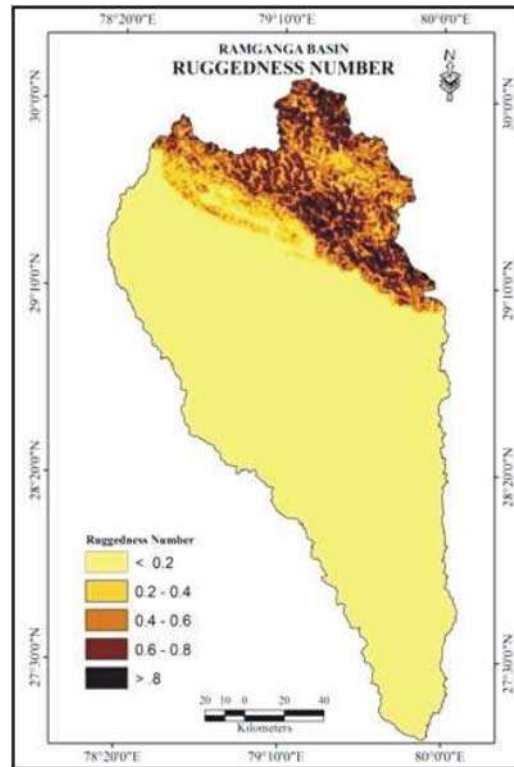


Fig. 12

covers entire (almost) Ramganga Plain (Fig. 12). As the level of dissection in the alluvial plain is low, the region is characterised with very gently sloping flat type surface. In the Lower Shiwalik region, it is also distributed along the Ramganga valley floor and its lower valley slope region. Low Ruggedness Number (0.2-0.4) covers 6.46 percent of the study area. It is observed along gently and moderately sloping region of Shiwalik. It is also observed along the Lesser Himalaya at northern Koshi, Gagas, Binau, Nair, etc. Moderate ruggedness number (0.4-0.6) comprised with Upper Shiwalik, MBT zone, and Lower Shiwalik at a north western portion of the basin, located on

upper reaches of Baur, Gola, Deoha basin. It is also distributed on upper reaches of Gagas, Koshi, Binau, Mothu Gad etc. High ruggedness number (<0.8) is mainly observed along the Lesser Himalayan basin, lying in the north-western part and north-eastern part of Shiwalik Himalaya. It corresponds with moderate to a steep hillside and valley side Slopes. Very high ruggedness number (>0.8) occurs in the zone of high relief zone with higher drainage density of the study area. It is found in northern most part of the study area, along Mothu Gad, Mandwa, Khansar, Bimoli, Tarag, Kuthrar, Binau, Gagas basin etc. It is also observed along Almora and Ranikhet region of Koshi river basin as well as Northern part of Gola and

Deoha river.

### Conclusion

Ramganga basin exhibits contrasting topography. Surface and relief properties show remarkable variation between Himalaya and Gangetic foreland. Lesser Himalayan part of the study reach exhibits corrugated topography with the intense crushing of the rock units. It also exhibits numerous transverse tear faults and lineaments. Streams of this region are largely controlled by the underlying structure. Topographic properties of this region largely vary due to the continual upliftment of the rock mass along with dissection of the landscape by numerous streams. Altitude of this area ranges from 600 to 3000m. The Lesser Himalaya of the study area is characterised with high mountain ranges, located in the northern and north-eastern part of it, but the relief is gradually decreased towards the centre. The central part this is characterized with flat top divides, undulating topography, moderate to moderately high slope, deep and narrow valley tract, river terraces (up to 5 tiers). Shiwalik Himalaya is lying between MBT and HFT of the study area. It is about 7 to 22 km wide. Absolute relief of it ranges between the 300-2100m. Along the Shiwalik much higher mountain ranges are observed in the northern section. Higher mountain range, water divides, structural hills of Lesser and Shiwalik Himalayas are associated with steep average slope, higher

absolute relief, moderately high to very high relative relief, high to very high dissection index and ruggedness number, while flat divides, denudational hill, dissected hills are subjected to moderate to moderately high type among all the relief properties. Valley slopes, terrace plain region are characterized with lower absolute relief, moderate to moderately high relative relief, low to moderate dissection index and ruggedness number. About 75.79 percent of the Ramganga basin comes in the Gangetic plain. Ramganga river system established its drainage network over the Rohilkhand plain, it is a geomorphic sub-unit of the upper Gangetic plain. Rohilkhand plain consists of Varanasi older alluvium; Ramganga terrace alluvium and Ramganga recent alluvium. This plain is characterised with flat type, nearly featureless plains, and lacks with topographic prominence (Singh, 1971). Monotony of the topography is broken by river bluffs, natural levees, paleochannels, upland interfluvial surfaces and sandy alluvial ridges (Bhurs). Absolute relief ranges between 130m to 300m. Relative relief and dissection index are less pronounced. Average slope is very gentle to gentle types. Ruggedness number is very low.

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# Morphometric Analysis of Baitarani Drainage Basin, Odisha

**Siva Prasad Panda**

Basin morphometry is a means of numerically analysing or mathematically quantifying different aspects of a drainage basin. In the present study, an attempt has been made to carryout morphometric analysis of the Baitarani basin. The morphometric parameters considered for analysis include the linear, areal and relief aspects of the basin. The Baitarani basin covers an area of 10,982 sq km. It is a 6<sup>th</sup> order drainage basin that is characterised with dendritic drainage pattern. The mean bifurcation ratio is 4.58 which indicate that the basin is largely controlled by structure. The basin has medium drainage density of 0.64 per km<sup>2</sup> and is elongated in shape. The length of overland flow values of the basin is 3.13, indicating high relief. The study has strengthened in understanding the hydrological, geological and geomorphological characteristics of the Baitarani basin.

**Key Words :** Drainage basin, morphometric parameters, stream ordering, ratio bifurcation.

## Introduction

Morphometry is an essential means in geomorphic analysis of an area. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1966). Morphometric methods, though simple, have been applied for the analysis of area-height relationships, determination of erosion surfaces, slopes, relative relief and terrain characteristics as a whole. The morphometric analysis of different basins have been done by various scientists using conventional methods (Horton,

1945; Smith, 1950; Strahler, 1957) and earth observation data and GIS methods (Narendra and Rao, 2000). The use of earth observation data and GIS techniques in morphometric analysis have emerged as powerful tools in recent years particularly for remote areas. In the present study using Earth Observation Data and GIS technology have been effectively used to compute basin morphometric characteristics by taking linear, areal and relief parameters of the Baitarani river basin. Such analysis aided in understanding the hydrological, geological and topographical characteristics of the very complicated and unique Baitarani drainage

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basin.

The river Baitarani is one of the important east flowing rivers of peninsular India located in northern Odisha. The river is flashy in nature having a total length of 355 km. and an area of 10,982 km<sup>2</sup>. The basin is situated approximately between east longitude of 85° 10' to 87° 03' and between north latitude 20° 35' to 22° 15'. The basin is surrounded by the Brahmani basin on the south and west and Subarnarekha basin on the north, the Budhabalanga and the Bay of Bengal on the east. The basin covers an area of 10,982 km<sup>2</sup> of which 10,246 km<sup>2</sup> (93.3%) lie in Odisha and 736 km<sup>2</sup> (6.7%) in Jharkhand. The northern portion comprises of rugged hilly terrain. The basin perimeter measures 622.22 km.

### Materials and Methods

The delineation of Baitarani basin is done from SOI topographical sheets no. 73F, 73G, 73J, 73K, and 73L using ArcGIS 9.3 software. Morphometric analysis has been carried out of the following parameters: stream order (U), stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), mean bifurcation ratio (Rbm), relief ratio (Rh), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), form factor (Rf), circulatory Ratio (Rc), elongation ratio (Re) and length of overland flow (Lg). The methodology for the calculation of above mentioned parameters is given (Table 1).

### Results and Discussions

The study of basin morphometry relates basin and stream network geometries to the transmission of water and sediment through the

basin. Systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear, areal and relief (gradient) aspects of the channel network and contributing ground slopes. In the present study, the morphometric analysis has been carried out about parameters as stream order, stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circularity ratio, form factor, basin relief, relief ratio, channel gradient using mathematical formulae as given in Table 1 and the results are summarized. The properties of the stream networks are highly important to study the landform making processes. Morphometric parameters such as basin relief, basin shape and stream length also influence basin discharge pattern strongly through their varying effects on lag time. The natural runoff is one of the most potent geomorphic agencies in shaping the landscape of an area. The land area that contributes water to the main stream through smaller ones forms its catchment area or the drainage basin. The arrangement of streams in a drainage system constitutes the drainage pattern, that in turn reflects mainly structural or lithological controls of the underlying rocks. The drainage pattern of Baitarani basin is dendritic to sub-dendritic in nature.

### Linear morphometric parameters

Linear aspects of the basins are closely linked with the channel patterns of the drainage network wherein the topological characteristics of the stream segments in terms of open links of the network system are analyzed. The

morphometric investigation of the linear parameters of the basins includes stream order ( $S_i$ ), bifurcation ratio ( $R_b$ ), stream length ( $L_i$ ), mean stream length ( $L_{sm}$ ), stream length ratio ( $RL$ ), length of overland flow ( $L_g$ ), basin perimeter ( $P$ ), basin length ( $L_b$ ), sinuosity index. Some of the important linear aspects have been computed (Tables.1).

### Stream Ordering

The foremost in a drainage basin analysis is the designation of stream orders, which is helpful not only to index the size and scale but also to afford an approximate index of the amount of stream flow which can be produced by a particular network. In this study the designation of orders by the Strahler's system is followed, which is a slightly modified version of Horton's system.

There are about 1389 streams over an area of 10,982 sq. km (Fig.3). First order streams constitute 77.68 percent while second stream order constitute 16.2 percent third, fourth, fifth and sixth stream order constitute only 4.61 percent, 1.3 percent, 0.14, 0.07 percent, respectively. It is observed that there is a decrease in number of streams as the stream order increases, showing the law of lower the order, the higher the number of stream.

### Stream Number

The streams, after the drainage network elements have been assigned, their order, number and segments of each order are counted and number of stream segments present in the order is found out. The number of streams decreases as the order increases.

The total number of all streams in all segments is 1389. Among this, the first order streams are 1079, which accounts for 78 percent to the total number of streams. The second order streams are 225 which contribute 16 percent. The streams of successive orders constitute the remaining 4 percent.

The first order streams in the Baitarani river basin are originated from the Eastern Ghats, arrange of mountains running east-west for the entire basin. The minimum number of first order streams are in the coastal region. The high amount of the first order streams should be taken care of, because there is a possibility of sudden flash floods in the down streams after heavy rainfall.

### Bifurcation Ratio

Bifurcation Ratio ( $R_b$ ) which is related to the branching pattern of the drainage net work is defined as a ratio of the number of streams of a given order ( $N_i$ ) to the number of streams of the next higher order ( $N_{i+1}$ ) and is expressed in following equation :

$$R_b = N_i / N_{i+1}$$

Where,  $N_i$  = number of stream of a given order.

$N_{i+1}$  = number of streams of the next higher order

It is a dimensionless property and shows the degree of integration prevailing between stream of various orders in a drainage basin. Horton (1945) considered  $R_b$  as an index of relief and dissection. A perusal of the table 3.6 is showing that the  $R_b$  between different successive order is also constant ranging from 3.52 to 9 with the mean bifurcation ratio of 4.58

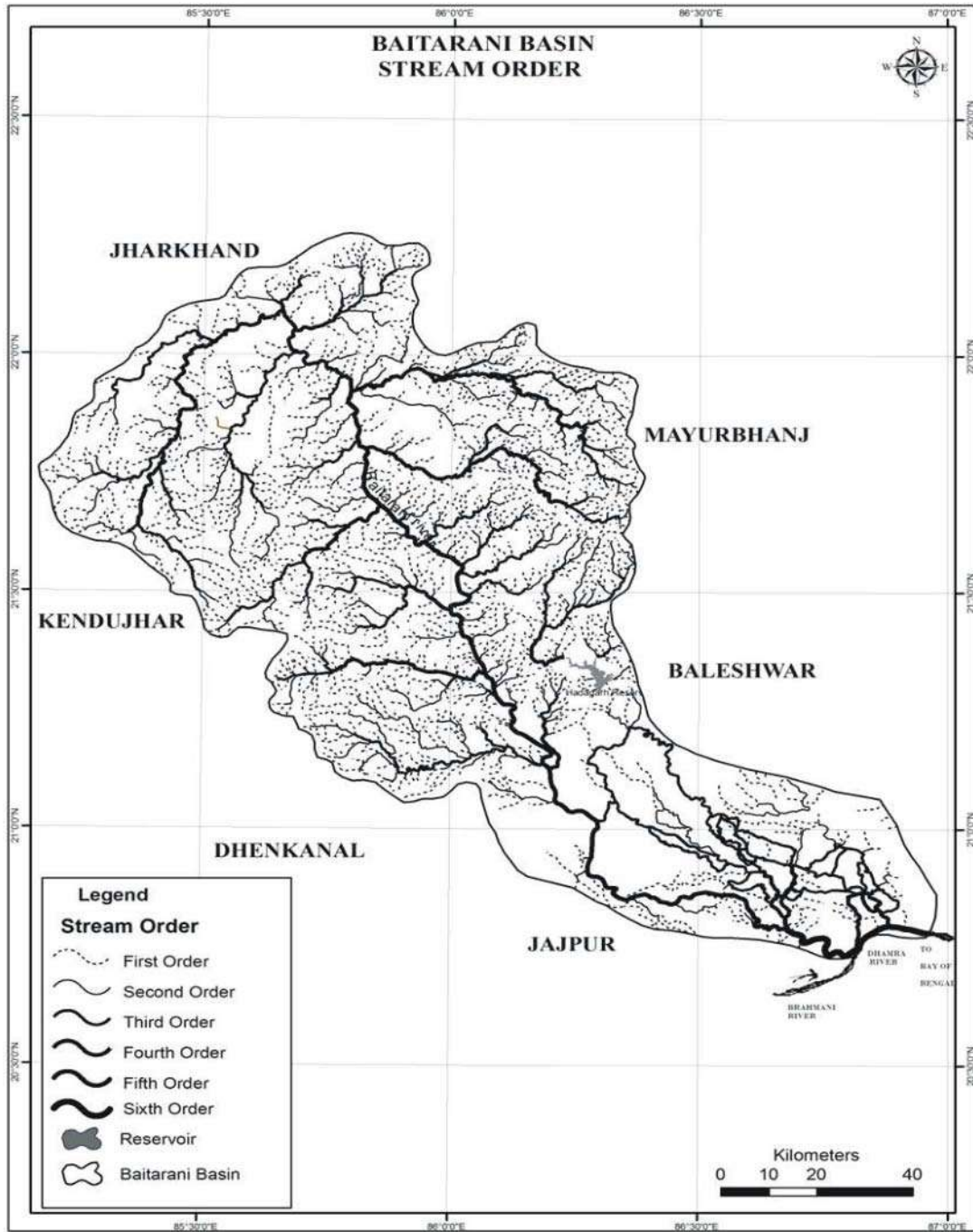


Fig.2

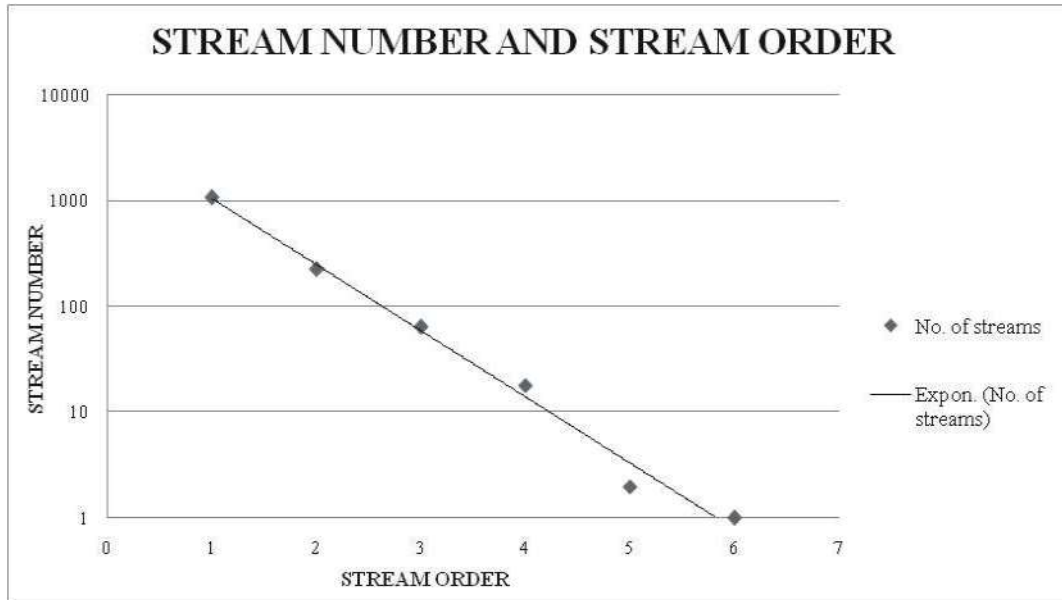


Fig. 3

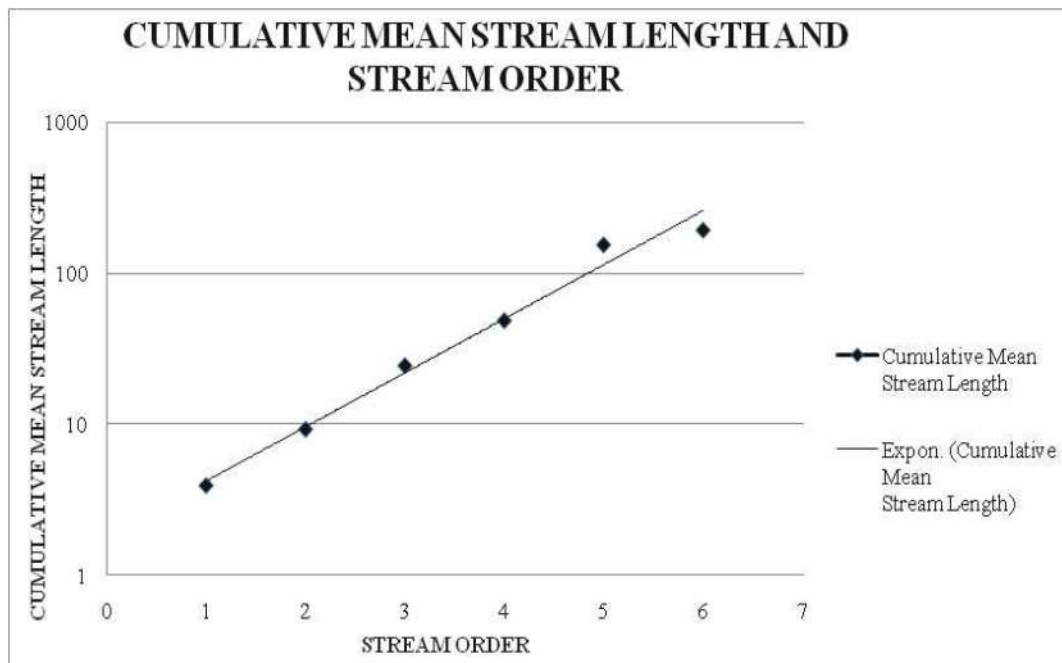


Fig. 4

which is indicative of a dendritic drainage pattern and nearly homogeneous conditions in the development of the stream network. But regional variations in the topography and morphological conditions are revealed in the varied bifurcation ratios between different orders. But in general the stream numbers and stream length confirm to the laws of morphometric analysis where as the mean stream area and mean stream slope do not reveal the conformity thereby indicating differential topography and geology influencing the development of the streams and their network.

### **Stream Length**

Stream is indicative of chronological development of the stream segments including tectonic disturbances. Thus, mean stream length reveals the characteristic size of components of a drainage network and its contributing surfaces. Stream length shows the landform evaluation, geological structure and occurrence of floods. Intensity of floods will be higher due to high stream length.

It is evident that the length of the first order streams constitutes 59.58 percent of the total stream length while the second, third, fourth, fifth and the sixth order constitute 16.91, 13.76, 6.18, 3.2 and 0.55 percents, respectively (Fig.4). The total percentage of the first and second order stream length constitutes 90.56 percent of the total stream length. It can be inferred that the total length of stream segments is maximum in first order stream and decreases as the stream order increases.

### **Stream length Ratio**

The length ratio is the ratio of the mean length of a given order to the mean stream length of the next order. It is then computed for each pair of orders for the Baitarani river.

$$\text{Stream Length Ratio } LI = LI/RL$$

Where

LI = Cumulative mean length of the given order;

LI = mean length of the 1<sup>st</sup> order

RL = constant length ratio and I = given order

The regression line plotted in semi - log graph (fig.4) tends to validate Horton's law of stream length as the correlation coefficient is 0.895.

### **Length of Overland Flow (Lg)**

Lg is one of the most important independent variables affecting both hydrologic and physiographic development of drainage basins and relates reciprocally to the average slope of the channel and is quite synonymous with the length of sheet flow to a large extent. It indicates the length of the runoff of the rain water on the ground surface before it gets concentrated into definite stream channels and it approximately equals to half of reciprocal of drainage density (Horton, 1945). The length of overland flow depends primarily on the degree of relief fragmentation, and hence on the drainage density. In this study, the length of overland flow of the Baitarani basin is 3.13 kms, indicating a high surface runoff in the basin and it further confirms the high susceptibility of the basin for both soil erosion and flooding.

**Table 1.** Morphometric parameters and their mathematical expressions

S. No	Parameter	Symbol	Formula	Reference	Result of the Morphometric analysis
1	Stream Order	$N_u$	Linear Aspects Hierarchical rank	Strahler (1950)	
2	Bifurcation Ratio	Rb	$Rb = Nu/Nu+1$ Where $Nu$ = Total no. of stream segments of order 'u' $Nu+1$ = Number of stream segments of the next higher order	Schumm (1956)	
3	Mean Bifurcation Ratio	$Rb_m$	$Rb_m$ =Average of bifurcation ratios of all orders	Strahler and Chow (1964)	4.58
4	Stream Length	$L_u$	Length of the stream (kms)	Horton (1945)	7052.93
5	Mean Stream Length	$L_{sm}$	$L_{sm} = L_u / N_u$ $L_u$ = Total stream length of order 'u' $N_u$ = Total no. of stream segments of order 'u'	Strahler and Chow (1964)	1175.5
6	Stream Length Ratio	$R_L$	$R_L = L_{sm} / L_{sm-1}$ $L_{sm}$ = Mean stream length of a given order and $L_{sm-1}$ = Mean stream length of next lower order	Horton (1945)	2.9
7	Basin Length	$L_b$	$L_b = 1.312 * A^{0.568}$ Where = A = Area of the basin	Schumm (1956)	217.44 km
8	Basin Perimeter	P	P = Outer boundary of drainage basin measured in kilometers	Schumm (1956)	629 km.
9	Sinuosity Index	SSI	$SSI = O_L / E_L$ $O_L$ =Observed (actual) path of the stream $E_L$ =Expected straight path of the stream	Schumm (1956)	2.27
10	Length of Overland flow	$L_g$	$L_g = 1/2 * 1/D_d$ Where, $D_d$ = Drainage Density (Km/Km <sup>2</sup> )	Horton (1945)	3.13
11	Basin Area	A	<b>Areal Aspects</b> Area from which water drains to a common stream and boundary determined by oppo-	Strahler and Chow (1964)	10,246 sq. km

12	Drainage Density	$D_d$	site ridges $D_d$	Horton (1945)	0.64
13	Stream Frequency	$F_s$	$F_s = N_u/A$ Where, $D_d =$ Drainage density (km/km <sup>2</sup> ) $A =$ Area of the basin (km <sup>2</sup> )	Horton (1945)	0.13
14	Circulatory Ratio	$R_c$	$R_c = A/A_c$ $A =$ Basin Area $A_c =$ Area of a circle having the same perimeter as the basin	Miller (1953)	0.35
15	Form factor	$R_f$	$R_f = A/L_b^2$ Where, $A =$ Area of the Basin (km <sup>2</sup> ) and $L_b =$ Basin Length (km)	Schumm (1956)	0.217
16	Drainage Texture	$D_t$	$D_t = N_u/P$ Where, $N_u =$ Total no. of stream of all orders and $P =$ Basin perimeter measured in km	Horton (1945)	2.21
17	Infiltration Number	$I_r$	$I_r = D_d * F_s$ Where = Drainage density (km/km <sup>2</sup> ) and $F_s =$ Stream frequency	Zavoianca (1985)	4.92
18	Compactness Constant	$C_c$	$C_c = 0.2821 P/A^{0.5}$ Where $A =$ Area of the basin (km <sup>2</sup> ) and $P =$ Basin perimeter measured in km	Horton (1945)	1.75
19	Elongation Ratio	$R_e$	$R_e = 2\sqrt{(A/q)}/L_b$ ; where, $A =$ Area of watershed, $q =$ 3.14, $L_b =$ Basin Length	Schumm (1956)	0.544
20	Relief Ratio	$R_r$	<b>Relief Aspects</b> $R_r = H/L_b$ Where $H =$ Basin Relief (m) and $L_b =$ Length of basin (m)	Strahler (1957)	0.01
21	Absolute Relief	$R_a$	Maximum height of relief	Hadley and Schumm (1961)	1165
22	Relative Relief	$R_{hp}$	$R_{hp} = H * 100 / P$ Where, $H =$ Maximum basin Relief $P =$ Perimeter	Melton (1957)	0.19
23	Basin Relief	$H$	$H = Z - z$ Where, $Z =$ Maximum elevation of the basin (m)	Strahler (1957)	1163

24	Basin Slope	$S_b$	And $z$ = minimum elevation of the basin $S_b = H/Lb$ Where $H$ =Basin relief (m) and $Lb$ = Length of basin	Miller (1953)	5.35
25	Dissection Index	$D_i$	$D_i = H/R_a$ Where $H$ = Basin Relief (m) and $R_a$ = Absolute Relief (m)	Magesh et al., (2012)	0.998
26	Ruggedness Index	$R_i$	$R_i = Dd * H / 1000$ Where $Dd$ = Drainage density and $H$ = Basin Relief	Strahler (1957)	0.74

### Sinuosity Index (SI)

Sinuosity is highly significant in studying the effect of terrain characteristics on the river course. The calculated value of the Baitarani basin is 2.27 that the stream course is irregular and tortuous. It is a significant quantitative index for interpreting the significance of streams in the evolution of landscapes and beneficial for geomorphologist, hydrologists, and geologists.

### Areal Morphometric Parameters

Area of a basin ( $A$ ) and perimeter ( $P$ ) are the important parameters in quantitative geo-morphology. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff. The maximum flood discharge per unit area is inversely related to size. The total area of the Baitarani drainage basin is 10,982 km<sup>2</sup>. The areal aspects of the drainage basin such as basin area ( $A$ ) drainage density ( $Dd$ ), stream frequency ( $F_s$ ), texture ratio ( $R_t$ ), elongation ratio ( $R_e$ ), circularity ratio ( $R_c$ ) and form factor ratio ( $R_f$ ) were calculated and results have been given (Table 1).

### Drainage Density

Drainage density of the basin is defined as the length of streams per sq. km. area. The basin is elongated in shape and exhibits a dendritic pattern of drainage (Strahler, 1969) with acute stream junction angles. Because of the hard and resistant rocks and vegetation cover, the basin also reveals a low stream frequency. The drainage density of an area reflects the texture of topography and nature of its dissection. The evolution of different types of texture depends on different lithology and structure and hydrology of the area. The nature of infiltration of precipitation and presence or absence of vegetative cover controls the drainage density. The drainage density of the basin is 0.64 which is of coarser texture. Most of the tributaries in this area are seasonal in character. In winter these rivulets are usually dry or have a small amount of water which originate from small springs in the hillocks of the surrounding areas joining the main stream at different points along the course.

### **Stream Frequency**

Stream frequency is the number of stream segments per square kilometer of area. It is obtained by dividing the total number of streams by the total drainage basin. In the Baitarani basin the stream frequency is 0.13 (Table.1). Stream frequency is observed to be more when the overland flow gets plenty of time to cover a considerable distance, thereby develop small stream channels. The process of physical as well as chemical erosion takes place to have a permanent depression on the land. The stream frequency reduces with decreasing in the hardness of the surface rock and decrease in the time of overland flows. Surface water either sweeps down rapidly or due to the existence of loose bed rock most of the surface, runoff is converted into ground water. Slope of the land also plays a leading role in the stream frequency. Steeper slope has less frequency and gentle slope has more frequency. The occurrence of stream segment depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability. Stream frequency is low at the mouth of the river which is attributed to the flat topography and small ridges with numerous tributaries and distributaries that result in elongated drainage with highest Fs. Poor Fs could be attributed to rugged topography and steep barren slopes.

### **Circularity Ratio**

The basin shape is largely controlled by geological structure which is an important geometry of the stream work. Miller (1953) defined the basin circularity ratio is the ratio of

the basin area ( $A_u$ ) having the same perimeter as the basin. The basin circularity is 0.35.

Basin Circularity ( $R_c$ ) =  $A_u/A_c$  = Area of the basin/Area of the Circle having same perimeter ( $P$ )

### **Elongation Ratio (Re)**

Schumm's 1956 used an elongation ratio ( $R_e$ ) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The value of  $R_e$  varies from 0 (in highly elongated shape) to unity, *i.e.* 1.0 (in the circular shape). Thus higher the value of elongation ratio more circular shape of the basin and vice-versa. Values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). The elongation ratio of the basin is 0.544 which represents the basin is elongated shape.

### **Form Factor (Rf)**

Form factor is the numerical index which is commonly used to represent different basin shapes (Horton 1932). Its value varies between 0.1-0.8. Smaller the value of form factor, more elongated will be the basin. A perfect elongated basin has a form factor of 0.217. The basins with high form factors have high peak flows of shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flow of longer duration. In Baitarani basin  $R_f$  value is 0.217 indicating it to be elongated in shape and suggesting flatter peak flow for longer duration.

### **Drainage Texture (Rt)**

It is the ratio of total stream numbers to

the total perimeter of the basin (Horton, 1945).

$$R_t = N_u/P$$

Texture ratio is an important factor in the drainage morphometric analysis which is depending up on the underlying lithology, infiltration capacity and relief aspect of the terrain (Nageswara, 2010). Smith (1950) has classified drainage density into five different texture *i.e.* very coarse (<2), Coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). In the present study texture ratio of the Baitarani river basin is 2.21, which indicate coarse texture.

#### **Infiltration Number (If)**

The infiltration Number is defined as the product of Drainage Density (Dd) and drainage Frequency (Fs). The Baitarani basin has the high infiltration number, *i.e.* 4.92. The higher the infiltration number the lower will be the infiltration and consequently, higher will be run off. This leads to the development of higher drainage density. It gives an idea about the infiltration characteristics of the basin which reveals impermeable lithology and higher relief.

#### **Compactness Constant (Cc)**

Compactness constant articulates the relationship of a hydrological basin with that of a circular basin having the same area as the hydrologic basin (Nooka Ratnam et al., 2005). If the watershed was a perfect circle, then Cc would be equal to unity.

$$\text{Compactness Constant (Cc)} = 0.2821 P/A^{0.5}$$

Where, A= area of the basin (km<sup>2</sup>) and

P = basin perimeter measured in km

The compactness constant of the basin is 1.75. Thus, the basin is elongated and has

enough time for discharge.

#### **Relief Morphometric Parameters**

The relief aspects of the drainage basins are significantly linked with the study of three dimensional features involving area, volume and altitude of vertical dimension of landforms to analyze different geological characteristics. Some of the important relief parameters that are related to the study (Table 1) have been analyzed.

#### **Relief Ratio (Rh)**

Relief ratio is defined as the ratio between the total relief of a basin, *i.e.* elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956).

$$\text{Relief Ratio} = \frac{\text{Maximum Basin Relief (H)}}{\text{Maximum Basin Length (Lb)}}$$

This is a dimensionless height-length ratio and allows comparison of the relative relief of any basin regardless of difference in scale or topography. Relief ratio is equal to the right angled triangle and is identical with the tangent of the angle of slope of the hypotenuse with respect to horizontal (Strahler, 1964). This measure is the overall steepness of a drainage basin that is an indicator of intensity of erosion processes operating on the slope of the basin. Normally, it has inverse correlation with drainage area and size of drainage basin. For the present study, it is 0.01.

#### **Relative Relief (Rhp)**

The Rhp is an important morphometric variable used for the overall assessment of

morphological characteristics of terrain. Melton (1957) suggested a method to calculate Rhp by dividing the H with P. There are three categories of Rhp viz (i) low = 0 m – 1 m, (ii) moderate = 1 m – 3 m and (iii) high = above 3 m. The Rhp of the Baitarani basin is 0.19 and therefore, the basin has a low relative relief.

### **Basin Relief (H)**

The H is defined as the difference in the elevation between the highest point (Z) of a basin and the lowest point (z) on the valley floor (Strahler, 1957). The elevation at Z of the Baitarani river basin is 1165 m and the z at the basin mouth is 2 m from mean sea level. Therefore, the relief of the river basin is 1163 m.

### **Basin Slope (Sb)**

Basin Slope enables the assessment of runoff generation, direction and volume. Basin Slope (Sb) = (Basin Relief / Length of basin) The basin has a Sb of 5.35 that reflects the relatively mountainous and plateau nature of the terrain plains

### **Dissection Index (DI)**

Dissection index (DI) is a parameter that implies the degree of dissection or vertical erosion and expounds the stages of terrain or landscape development in any given physiographic region or basin.

Dissection Index (DI) = (Relative Relief / Absolute Relief)

On average, the values of DI vary between '0' (complete absence of vertical dissection/erosion and hence dominance of flat surface) and '1' (in exceptional cases, vertical

cliffs, it may be at vertical escarpment of hill slope or at seashore). DI value of Baitarani basin is 0.998 that indicates the basin is highly dissected and morphometrically the river is in young stage. But, actually this is not the state of whole basin and is found in upper reaches or mountainous areas of the basin occupied by first order streams.

### **Ruggedness Index (RI)**

The topographic ruggedness index indicates the extent of instability of land surface (Strahler, 1956). It is derivative of long-standing interaction between available sharpness of local relief and the amplitude of available drainage density and other environmental parameters such as slope, precipitation, weathering, soil texture, natural vegetation etc. Ruggedness index is measured by taking into account both relief and drainage.

Ruggedness Number (RN) = (Basin Relief \* Drainage Density) / 1000

The measured value of RI of Baitarani basin is 0.74.

### **Conclusion**

The morphometric analysis of Baitarani basin using Geographic Information System is a tool that helps the researchers to analyse the drainage basins easily and accurately in short time duration. GIS facilitates analysis of various morphometric parameters and acts as an effective tool in establishing relationship between drainage morphometry and properties of landforms. Geomorphological study of an area is the systematic study of present day landforms, related to their origin, nature, development, geologic changes recorded by the

surface features and their relationship to flood hazard. Some morphometric elements (measurement of landforms) provide valuable information for vulnerability to flood. The morphometric parameters evaluated using GIS helped to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc. Similar studies in conjunction with high resolution satellite data help in better understanding the landforms and their processes and drainage pattern demarcations for basin area planning and management (M. Bagyaraj and B. Gurugnanam, 2011). The analysis of linear aspects of drainage basin result shows that the basin has a dendritic pattern with sixth order

stream. High bifurcation ratio in the study area indicates a strong structural control on the drainage. The results of areal aspect show that the texture of drainage is high. The analysis of elongation ratio indicates the drainage basin is elongated in nature with high relief and steep slopes. The result of relief aspect shows the study area is characterized by high relief and high stream density.

#### **Acknowledgment**

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# **Integrated Approach to Study Spatial Variations in Water Resources: A Case Study of Chandraprabha Basin**

**Kavita Mishra**

An integrated approach in mapping and analysis of availability, utilization and conservation of water resources is urgently needed to fulfill the increasing demand of water for irrigation, human and livestock consumption, industries, hydro electric power generation, recreation and other consumptive uses. The approach comprehends the use of modern techniques of Remote Sensing (RS) and Geographic Information System (GIS) as well as traditional techniques and data sources for getting reliable and desired results. Revolution in the digital world has opened a new arena of mind-set in the field of geospatial mapping and analysis. As a result, the RS and GIS have provided very powerful data base and techniques of analysis for solving complex problems of resources inventory, hydrogeomorphic features, geomorphic hazards, environmental problems, geo-environmental management etc. Present paper attempts to assess the spatial variation in water resources using integrated approach taking into account a case study of Chandraprabha Basin which accounts a major portion of Karmanasha Basin (Eastern Uttar Pradesh). The interpretation of Remote Sensing (RS) data in conjunction with ancillary data and sufficient ground truth information makes it possible to identify and outline the presence of various surface and sub surface water resources. The study is largely based on the integrated use of data and techniques like RS and GIS along with the supportive information gathered from different sources.

**Key words:** Remote sensing, GIS, watershed, surface water resources, sub surface water resources, ground water recharge potential zone, watershed prioritization.

## **Introduction**

Water is vital to life, without which no living organism can survive.....It is one of the principal factors that helps to improve agricultural productivity and food security. Crops' yield response with fertilizers can be increased by applying adequate irrigation-water at the right time. The availability of sufficient

water and the avoidance of excess water are essential if the high yielding varieties of food grains are to maintain their characteristics (Whyte, 1976). Irrigation as the basis for increasing crop production was discussed in detail at the Food and Agriculture Organization (FAO) Regional Conference, Bangkok (1968). In India, the problem of water crisis is likely to

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become more severe and serious even in northern flood plain areas where some districts or their some of the Development Blocks are reported under dark zone of ground water utilization. The open lands available for natural recharges are reduced due to large scale urbanization (Raghunath,2009) and expansion of rural settlements, roads and other infrastructures. The availability and utilization patterns of both surface and sub surface water also vary in purview of time and space. Even in hard rock areas, such variations are more wider than floodplain zones. Therefore it is utmost important to identify the areas of potential ground water recharge so that the depleted ground water aquifers could be improved and could be tapped during needs. An integrated approach to study water resources' availability, utilization and conservation is urgently needed to fulfill the increasing demand of water for various purposes. Remote Sensing (RS) and Geographic Information System (GIS) have provided very powerful data base and techniques of analysis for solving complex problems of resources inventory and related aspects (Mishra and Kumra, 2007). Geospatial technology is a rapid and cost effective tool used in the delineation of groundwater potential zones by integrating various data related to geology, geomorphology, slope etc. (Samson and Elangovan,2015). These data are the sources for the preparation of thematic maps and to analyze diverse data sets for decision making and planning using GIS. There are many scholars like Saraf and Choudhary (1998), Lillesand and kiefer (2004) Girish Kumar et al., (2008), Thakur and Raghuwanshi (2008), Nagarajan and Singh (2009), Preeja et al., (2011), Suribabu et al., (2012), Selvarani et

al.,(2017) who have used remote sensing/GIS for groundwater studies. Present paper is an attempt to map out and analyze the spatial variation in the sources of water resources as well as to identify and delineate the groundwater potential zones and prioritization of watershed for future water resources development planning by combining multi-sources data and techniques in GIS environment.

#### **Study Area**

The study area, i.e., Chandraprabha basin (24° 45' N – 25° 15' N and 82° 55' E – 83° 20' E) with an area of 1355.80 km<sup>2</sup> administratively occupies major portion of southern Chandauli district, eastern most part of Mirzapur district and very small part of northern Sonbhadra district. The western boundary of the basin is at a distance of about 12 km and 2 km from Varanasi city and Mughalsarai town respectively. Physiographically, the area is divided into two parts: (i) Gangetic plain and (ii) Vindhyan plateau, which are separated by 100 m contour. The drainage pattern in the Gangetic plain may be noted dendritic while in the Vindhyan plateau region, it is marked sub dendritic to sub parallel depending on local lithologic variations. Geologically, the basin consists of Vindhyan formation (Upper Vindhyan) in the southern part and Ganga alluvium in the north. Precipitation is the ultimate source of all the water resources which occurs mainly in three months (July, August and September) of the year in the study area. Rainfall not only controls the surface water but it also determines the quantity of ground water. The study area has been divided into two sub watersheds, i.e., Chandraprabha (SWC) and Garai (SWG) and further in eleven micro sub watersheds based

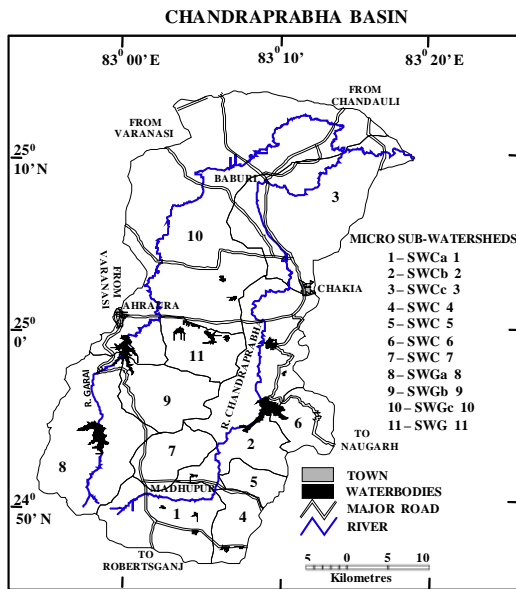


Fig.1

on morphometric parameters (Mishra et al.,2009) (Fig.1).

**Methodology and Data Base**

The present study is based on the integrated approach which comprehends the use of modern techniques of Remote Sensing (RS) and Geographic Information System (GIS) as well as traditional techniques and data sources for getting reliable and desired results. Survey of India (SOI) toposheet numbers 63 0/3, 0/4, 0/8, L/13 and P/1 (Scale 1:50,000) were used to prepare the base map, demarcation of watershed and micro sub-watersheds while relevant information related to water resources were extracted from digital data of IRS – P6, LISS – III geocoded (FCC) product. Arc GIS 10.1 software was applied for mapping and computing different aspects of water resources. The areal extent of objects/features were computed for all the eleven micro

sub-watersheds of basin by applying GIS techniques. This could facilitate a better and comparative analysis of different features of both at sub watershed and micro sub-watershed levels. Average annual reservoir statistics were collected from unpublished records of the Irrigation Division, District Chandauli while source wise irrigated area at development block levels for the years 1993-94 and 2003-04 were obtained from *Statistical Magazine of Districts Chandauli, Mirzapur, and Sonbhadra*. Micro sub-watershed level data were generated taking into account their percentage share in the concerned development blocks. Data related to Pre-Monsoon, Post-Monsoon water tables and generalized water tables were gathered from U.P. Ground Water Department, Lucknow.

**Surface Water Resources**

The RS data (satellite imagery) have fruitfully been utilized for analyzing spatial location of both surface water and ground water resources. On the basis of satellite image interpretation and SOI toposheets the surface water of study area can broadly be grouped as i) perennial stream, ii) canal, iii) reservoir, iv) *Bandhies* and v) ponds/ *Tals* (local depression). The two perennial rivers Chandraprabha and Garai are the main sources of surface water in the study area. Canal is the main source of irrigation in northern part of the study area which can be grouped in three categories: (i) main canal, (ii) distributaries and (iii) minor. The lengths (km) of these three types of canals have been obtained by personal computation in GIS environment as 125.67, 80.37 and 353.73 respectively ( total length of all three=559.77km). There are seven main canals such as Chandauli canal, Baburi canal

**Table 1.** Average Annual Reservoir Statistics

Name of Reservoir	Name of River	Catchment Area (km <sup>2</sup> ) (ham)	Year of Completion (ham)	Gross Capacity (ham)	Live Storage (ham)	Excess Runoff (ham)	Total Runoff Recorded in River (ham)	Evaporation Losses (ham)
Chandraprabha	Chandraprabha	259	1958	9339	9084	2236	11320.89	1009
Muzaffarpur	Chandraprabha	44	1918	382	283	48	1923.25	121
Bhonka	Bhonka Nala (Garai)	52	1957	792	792	92	1315.00	98
Aharaura	Garai	NA	1954	NA	NA	NA	NA	NA
Dongia	Garai	NA	NA	NA	NA	NA	NA	NA

Source: Unpublished Data Collected Personally from the Irrigation Division, District Chandauli.

Nakaiya canal, Mugalsarai-Chandauli feeder, Chandauli and Left Karmanasha canal, Mugalsarai distributary and Ghaghar canal (at southern boundary) while many distributaries and minors are taken out from these canals. Madhupur, Chankia, Rajkura, Dhanawal, Shahpur, Garai, Sota and Tiara are some of the prominent distributaries of the study area (Fig. 2).

There are five reservoirs namely Chandraprabha, Muzaffarpur, Ahraura, Dongia and Bhonka (Fig.2, Table1). *Chandraprabha reservoir* was constructed in 1958 on the Chandraprabha river. It has a catchment area of 259 km<sup>2</sup> with gross capacity of 9,339 ham. The evaporation losses from Chandraprabha reservoir has been estimated to 1009 ham. Besides controlling floods, it also serves as feeder reservoir for the Muzaffarpur reservoir situated at further downstream. *Muzaffarpur Reservoir* is a pick-up weir with a capacity of 382 ham on the Chandraprabha river. It was constructed by the princely ruler of the former 'Banaras' State in 1918. Water from the reservoir is tapped through two main canals namely, Nikaiya

and the Pathrawa canals. *Bhonka Reservoir* was constructed in 1957 under the 'First Five Year Plan' on the *Bhonka Nala*, a tributary of

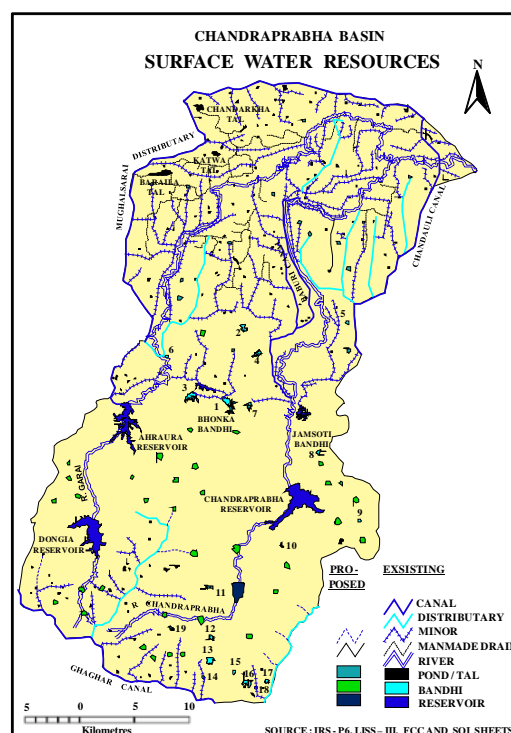


Fig 2

the Garai river. This reservoir has a capacity of 792 ham. Water is tapped through two canals, i.e., Hetampur and Bhonka feeder canals. *Ahraura Reservoir* was constructed in 1954 under the 'First Five Year Plan' on the Garai river in the western part of the study area (Mirzapur district).. Water is tapped through *Ahraura canal*. *Dongia Reservoir* is situated on the Garai river (Rajgarh block, Mirzapur district).

*Bandhies* are the earthen embankments built across a minor drainage channel or '*Nala*' for impounding the rainwater. There are 19 *Bandhies* confined mainly in plateau region which are seasonal in nature and provide water for *Kharif* crops, mainly paddy. They also help in plantation and checking the soil erosion. These *Bandhies* are generally confined to dissected plateau areas of Vindhyan upland while ponds/ *Tals* are mainly confined in the plain region. There are three most significant *Tals* in the study area, i.e., Baraila *Tal*, Katwa *Tal* and Chandarkha *Tal*. Water from these rain-fed *Tals* is tapped through small artificial channels mainly for irrigating

agricultural land (Table 2).

### Occurrence of Ground Water and Characteristics of Water Table

Ground water occurs in aquifers that may be defined as geologic formations which contain sufficient saturated permeable materials to yield significant quantities of water through wells and springs (Lohman, 1988 and Todd, 1995). As regards the area under study, ground water in the plateau region occurs under water table conditions in shallow aquifers while in alluvial plain it is under semi-confined to confined conditions in deeper aquifer. In hard rock areas, it generally occurs under water table condition in the second porosity such as cracks, fractures, joints, fissures, bedding planes etc. There are 18 observation wells in the study area as identified by UP Ground Water Division, Lucknow (Fig. 3A). The depth of water table and its fluctuation is influenced by several factors like climate, surface relief, geological structure and hydrological characteristics of the rock beds. Table 3 shows the generalized water table for 18 hydrograph stations. In flood plains

**Table 2.** Length and Command Area of Bandhies

Name of Bandhi	Length (m)	Command Area (ha)	Name of Bandhi	Length (m)	Command Area (ha)
1. Bhonka	2012	100	11. Jaimohni Posta	550	61
2. Daudpur	3657	195	12. Uditpur (Surra)	950	61
3. Mukaram	2317	110	13. Chamer	950	149
4. Dakahi	2609	257	14. Chuppepur	510	57
5. Amara	500	NA	15. Bojh	600	71
6. Mubarakpur	1100	400	16. Shamshepur	1000	127
7. Gulal	985	38	17. Bisheshwarpur	950	40
8. Jamsoti	350	24	18. Piprahi	600	71
9. Lawari	400	23	19. Mairahwa	470	32
10. Narkati	355	24	Total Basin	20865	1840

Source: Unpublished Data Collected Personally from Irrigation Department, Varanasi

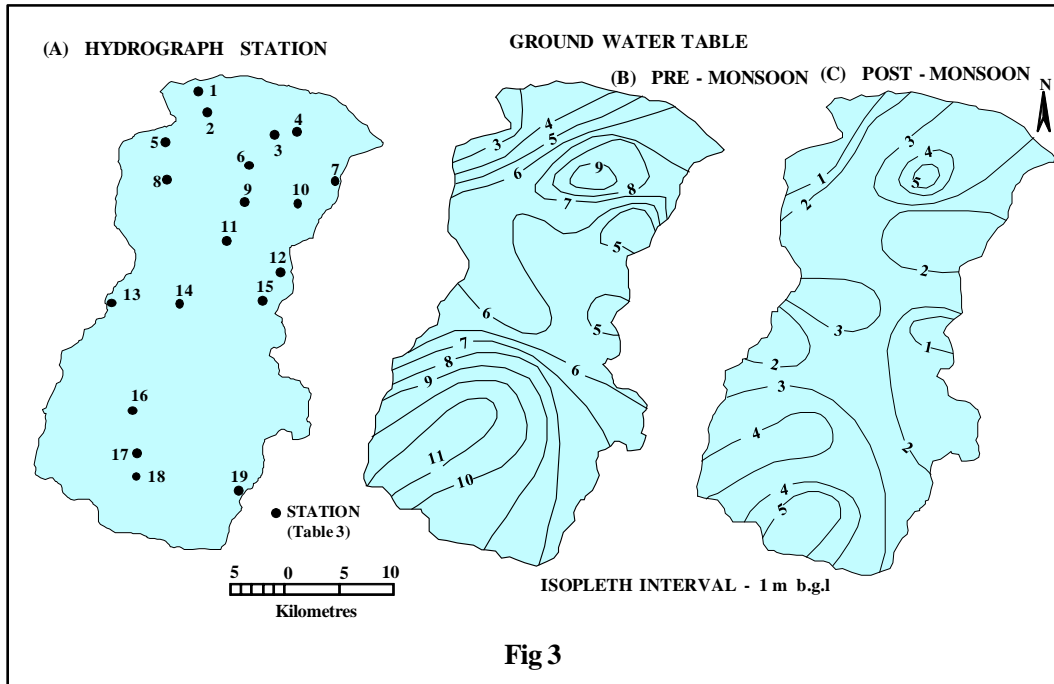


Fig 3

zones water table varies from 73.58 m above mean sea level (a.m.s.l) in Baburi to 85.96 m (a.m.s.l) in Tilauri. On the other hand, in plateau region water table varies from 92.05 m a.m.s.l. (Raghunathpur) to 275.94 m a.m.s.l. (Madhupur). The analysis of Table 3 clearly reflects the influence of topography on water table. Pre-Monsoon and Post-Monsoon water level contours of the Chandraprabha basin have been prepared at 1 m interval below ground level (b.g.l.) for the year 2003-2004. As regards the depth of water table in pre-monsoon it varies from 3.51 m b.g.l. (Niyamtabad) to 9.5 m b.g.l. (Baburi) in alluvial plain and 5.33 m b.g.l. (Ahraura) to 11.69 m b.g.l. (Sukrit) in plateau region. Some peculiar trends of water contour may be observed in the pre-monsoon water table map (Fig. 3 B) like: (i) in north of the study area water table is high and (ii) very small circle of 9 m (b.g.l.) contour is marked in this area

due to natural levee. Baburi (9.5 m b.g.l.) is situated on the natural levee of Chandraprabha river so the water table is marked as more than 9 m b.g.l. North-western part of the study area exhibits minimum contour of 3 m b.g.l. due to influence of Ganga river. On the other hand, southern portion of the study area (Vindhyan Plateau) so that the water level becomes high in this portion. Wells are built only in the buried pediment areas where the drilling process is easier due to softer lithologic materials below the surface.

Post monsoon ground water levels have been marked upward in comparison to pre-monsoon period because of availability of water to recharge during monsoon period. Ground water level is observed lowest at Godhana (0.86 m b.g.l.) and maximum at Baburi (5.08 m b.g.l.) lying in the alluvial plain. On Vindhyan plateau,

**Table 3.** Pre-Monsoon and Post-Monsoon Water Table, their Fluctuation and Generalized Water Table in m (2003-2004)

Village Name	Fluctuation of Water Table (b.g.l.)			Generalized WaterTable (a.m.s.l.)
	Pre-Monsoon	Post-Monsoon	Fluctuation	
1.Godhana	3.78	0.86	2.92	76.08
2.Niyamtabad	3.51	2.48	1.03	78.98
3.Sikri	8.30	4.08	4.22	74.78
4.Khuruhuja	6.18	3.38	2.80	76.20
5.Dhara	3.71	0.89	2.82	77.18
6.Baburi	9.50	5.08	4.42	73.58
7.Fatehpur	7.31	2.62	4.69	75.31
8.Jamalpur	6.45	2.18	4.27	77.73
9.Mawaia	6.34	1.81	4.53	75.46
10.Utraunt	4.67	1.24	3.43	75.57
11.Parbatpur	5.52	2.06	3.46	79.54
12.Tilauri	5.66	2.62	3.04	85.96
13.Ahraura	5.33	1.72	3.61	92.39
14.Balia	6.37	3.70	2.67	99.33
15.Raghunathpur	4.90	0.95	3.95	92.05
16.Sukrit	11.69	4.42	7.27	274.73
17.Bat Bantara	10.13	3.88	6.25	273.75
18.Madhupur	9.65	5.59	4.06	275.94

Source: U.P. Ground Water Department, Lucknow and Self Computation

b.g.l.– below ground level, a.m.s.l. – above mean sea level

the minimum water level depth can be observed at Majhgain (2.35 m b.g.l.), situated in the south eastern part of study area and maximum at Madhupur (5.59 m b.g.l.). Two high patches of water level are seen in the post-monsoon period (Fig. 3 C) one in the north-eastern flood plain zone and another in the southern portion on buried pediment.

#### **Ground Water Recharge Potential Zone**

Ground water potential zones and related studies using remote sensing and geographical information system (GIS) have been attempted

by numerous scholars at international and national levels (Saraf, *et al.*, 1998; Reddy, *et al.*, 2000; Murthy, 2000; Sreedevi *et al.*, 2001; Singh, *et al.*, 2002; Lillesand and kiefer, 2004; Shaban *et al.*, 2006; Mishra, 2006; Vijih, 2007; Nagarajan, 2009). Ground water potential recharge zone of the area under study has been identified and analyzed through integration of different relevant layers such as hydrogeomorphic features, lineaments, soil thickness, slope and land use/land covers using techniques of image interpretation and GIS. There are as much as five categories of ground

water potential recharge zones have been identified and delineated in the study area using satellite imagery: (i) very good, (ii) good, (iii) moderate, (iv) poor and (v) very poor (Fig.4).

Very good ground water potential zones covering 15.94 per cent of total area are marked in the new flood plain, old flood plain-I, old flood plain-II and paleochannels. On imagery, it is easily visualized by dark red tone and smooth texture. Water level varies from 6.18 m b.g.l to 9.5 m b.g.l in pre-monsoon and from 2.18 m b.g.l to 5.08 m b.g.l in post monsoon periods. On the other hand, good ground water potential zone (31.35% area of basin) have been noticed in some patches of old flood plain of northern part and a very small portion of deeply buried pediment areas of central eastern part. Such areas are depicted by gray mixed red tones with coarse texture on imagery which show a promising zone for ground water extraction. Ground water table in old flood plain varies from 8.30 mbgl (Sikari) to 3.51 mbgl (Niamtabad) in pre monsoon and from 4.08 m b.g.l (Sikari) to 0.86 m b.g.l (Godhana) in post monsoon periods (Table 3).

Good ground water potential zones on plateau region are marked in intermontanne valleys and deeply buried pediment features surrounding to Madhupur. A few tube wells in the eastern part of Madhupur were seen yielding enough quantity of water (130 l/pm). Although hard sandstone was reported at the depth of 18 m to 36 m but available zone for water exploration is found in fractured hard sandstone at depth 36 m to 45 m or 50 m to 70 m. Hand pumps in deeply buried pediment zone are also running at depth of 50 m to 60 m. On satellite

imagery, good ground water potentiality zones on plateau region are easily identified by light to dark red tones with medium to coarse textures. The level of ground water in bore wells varies from 9.65 m b.g.l (Madhupur) to 4.90 m b.g.l (Raghunathpur) in pre-monsoon and 5.59 m b.g.l (Madhupur) to 0.95 m b.g.l (Raghunathpur) in post-monsoon period (Table 3). Very low depth of ground water in post monsoon period in Raghunathpur is recorded because of its location in intermontanne valley.

Moderate ground potential zones are expanded over to deeply dissected plateau and shallow buried pediment zones of central part covering 19.59 per cent area of the basin. On image, it has been identified by dark to medium gray and white mixed red tones and medium to coarse textures because of poor crop land and open forest covers. Ground water level is recorded very high with variations from 11.69 m.b.g.l. (Sukrit) to 10.13 m.b.g.l. (Bat) in pre-monsoon and 4.42 m.b.g.l.(Sukrit) to 3.88 m.b.g.l.(Bat) in post-monsoon periods. Occasionally the wells become dry in the summer season. Poor recharge zones are confined to less dissected plateau and shallow buried pediment which allow a greater amount of rainfall to overflow as runoff. Because of this fact and low permeability, such areas have been marked as poor to moderate ground water potential zone covering 27.18 per cent area in southern plateau region. These zones are visualized by light gray to white mixed red tones with coarse texture on image. Very poor to poor ground water potential zone are noticed in rocky surfaces of pediments features (Mishra, 2006). These zones are easily recognized by

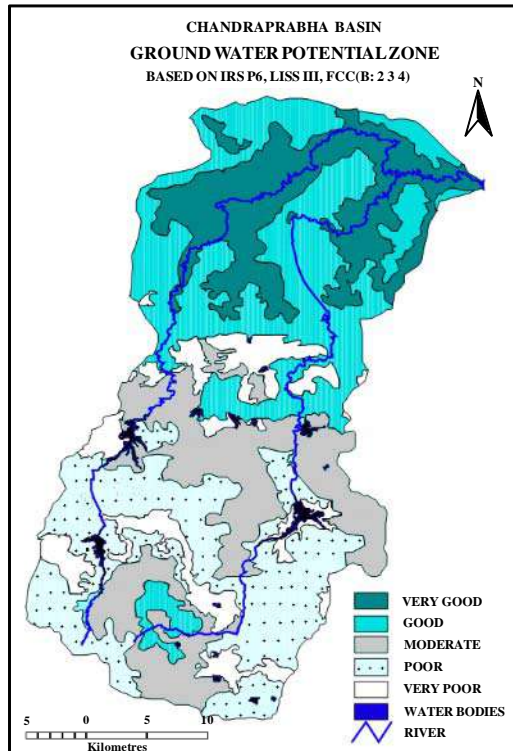


Fig 4

light gray to mixed white tones on satellite imagery and spread over 4.88 per cent area of basin.

### Water Resource Utilization for Irrigation

The controlled irrigation has become the chief factor in increasing agricultural productivity due to the adoption of high yielding varieties of seeds, chemical fertilizers and multiple cropping, (Singh and Dhillon, 1984). The means of irrigation in the study area can broadly be enlisted as canal, tube well and other sources. Canal is one of the major means of irrigation consisting of 86.29 per cent total irrigated area of basin (2003-04). The area

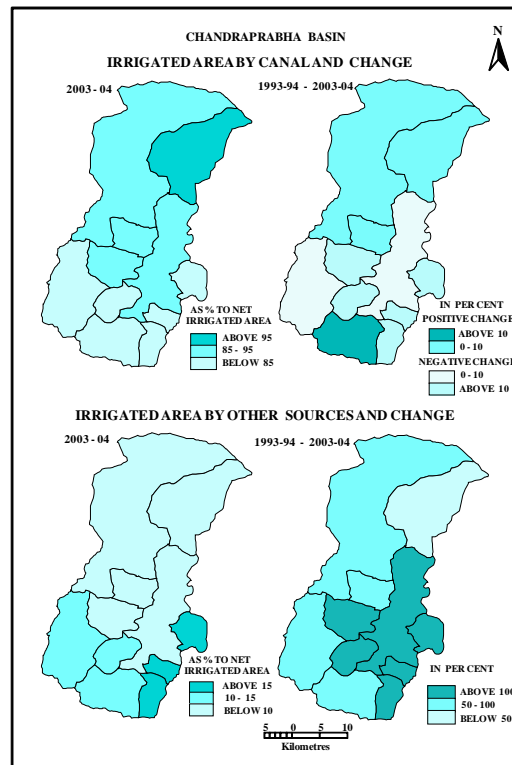


Fig 5

under canal irrigation varies from 83.06 per cent (SWC5, SWC 6) to 96.83 per cent (SWCc 3). Highest percentage share of irrigated area is observed in micro sub-watershed SWCc 3 (96.83) which is mainly attributed to the non-availability of water from their sources/reservoirs due to irregularity in rainfall (Fig 5 and Table 4).

Tube well irrigated area of the basin covers a very small proportion (2.95% of total irrigated area) and is mainly confined in the flood plain region. The highest percentage of area under irrigation by tube wells is recorded in SWGc 10 micro sub-watershed (9.38%), whereas lowest (1.34%) in SWCc 3. The

**Table 4.** Source Wise Irrigated Area (2003 – 04) and Change (1993-94 – 2003-04) in Chandraprabha Basin

Micro Sub- Watershed	2003 – 04 (%)				Weigh- tage	Change 1993-94 – 2003-04 (%)			
	Canal	Tube Well	Others	Irrigation Intensity		Canal	Tube Well	Others	Irrigation Intensity
SWCa 1	83.21 (1)	2.51 (1)	14.28 (2)	67.73 (1)	5	13.04	21.12	89.81	24.61
SWCb 2	90.08 (2)	1.45 (1)	8.47 (1)	96.42 (3)	7	-9.31	-5.6	112.25	4.86
SWCc 3	96.83 (3)	1.34 (1)	1.83 (1)	95.45 (3)	8	7.25	-26.30	28.17	11.14
SWC 4	83.73 (1)	-	16.27 (3)	70.77 (1)	5	-12.30	-	124.00	1.99
SWC 5	83.06 (1)	-	16.94 (3)	96.91 (3)	7	-13.30	-	240.40	2.11
SWC 6	83.06 (1)	-	16.94 (3)	96.91 (3)	7	-13.30	-	240.40	2.11
SWC 7	82.62 (1)	4.31 (2)	13.07 (2)	79.29 (2)	7	-15.55	21.12	125.00	1.89
SWGa 8	83.29 (1)	2.51 (1)	14.20 (2)	53.15 (1)	5	-9.42	24.35	51.19	17.51
SWGb 9	87.44 (2)	2.88 (1)	9.68 (1)	84.83 (2)	6	-13.30	16.56	126.72	2.61
SWGc 10	85.74 (2)	9.38 (3)	4.88 (1)	87.36 (2)	8	6.35	-19.19	52.35	12.12
SWG 11	90.08 (2)	1.45 (1)	8.47 (1)	96.42 (3)	7	7.25	-5.61	87.63	7.86
Total	86.29	2.95	10.76	84.11		-3.88	6.61	116.17	7.89

Source : Statistical Magazine of Districts Chandauli, Mirzapur, and Sonbhadra and Personal Computation. (Parentheses show the Weights for priority assessment).

positive change under tube well irrigation (6.61%) has been recorded during the period of study (1993-94 to 2003-04) in the basin although some micro sub-watersheds of the basin have shown a negative change of above 20 per cent. *Bandhies*, ponds, tanks etc. are other sources of irrigation specially used in plateau region. There are mainly dependent on the quantum of rain water put for storage. The average irrigated area by such sources is recorded as 10.76 per cent ranging from 1.83 per cent in SWCc 3 to 16.94 per cent in SWC 5. Lower percentage share is marked mainly in plain region and higher in plateau region of the basin. Higher positive change in irrigated area by other sources has been observed in Chandraprabha basin. Very high change is

marked in micro sub-watersheds SWC 5 (240.40%) and SWC 6 (240.40%), while lower percentage is recorded only in SWCc 3 (28.17%) (Table 4 & Fig 5).

#### **Prioritization of Micro Sub-Watershed for Water Resources Development**

The weighted score method has been applied to assess the priority status of micro sub-watersheds for water resources development under which weights of 3, 2 and 1 are assigned for high, moderate and low categories of water resource utilization respectively (Table 4). The sum of weighted score values has been accounted to group the micro sub-watersheds into three categories of priority status for future water resources

**Table 5.** *Prioritization of Micro Sub-Watersheds Based on Water Resource Utilization*

Weighted Score	Priority	Micro Sub-Watershed	
		No.	Name
Below 6	I	3	SWCa 1, SWC 4, SWGa 8
6 - 8	II	6	SWCb 2, SWC 5, SWC 6, SWC 7, SWGb 9, SWG 11
Above 8	III	2	SWCc 3, SWGc 10

development such as I, II and III denoting their number as 3, 6 and 2 respectively (Table 5). The first level watersheds are those areas where condition for water resources development is poor and they need special attention to meet the future demand. The higher number of micro sub-watersheds in moderate priority indicates that the availability and utilization pattern of water resources in the basin are moderate condition. The high priority areas like SWCa 1, SWC 4 and SWGa 8 are those areas where canal and tube well irrigation as well as intensity of irrigation are found in moderate to poor conditions hence the emphasis should be given in these areas to upgrade the facilities for water resources utilisation.

The results obtained from the analysis indicate that the micro sub-watersheds of SWCc 3 and SWGc 10 have shown higher weighted scores because they occupy good to very good position regarding both surface and ground water resources. Ground water recharge due to influent seepage and infiltration from irrigated fields are also higher in these areas because of their specific hydrogeomorphological characteristics consisting of flood plain features. Both, the good quality and sufficient quantity of ground water

resources are marked in such areas. On the other hand, the micro watersheds coming under moderate priority level have witnessed by moderate to poor ground water conditions. Ground water in these areas is found under secondary porosity which requires a detailed geophysical survey for exploration and future utilization.

**Conclusion**

The scarcity of water is the biggest problem in the Vindhyan plateau region where both the surface as well as ground water are largely dependent on the rainfall. The irrigated area is shrinking due to non-availability and timely supply of water through canals. Canal water supply should be arranged as per the need of the area especially in SWCa 1, SWCb 2, SWCc 3, SWC 4 and SWGc 10 micro sub-watersheds. Installation of private tube wells for irrigation is increasing by rich farmers in the flood plain zones. The poor farmers are deprived of such facilities, so, financial support for small/marginal farmers may be given to fulfill their irrigational demand. The priority status of micro sub-watersheds based on water resource utilization indicates that the south and south-western parts of the area under study covering SWCa 1, SWC 4 and SWGa 8 micro sub

watersheds have poor potentiality of water and requires special attention at first priority level of water resources development and planning. Renovation and de-siltation of existing ponds and creation of new ponds in entire Chandraprabha basin are necessarily required to meet the demand of water. It may also contribute enough to increase the ground water recharge. Some *Bandhies* and reservoirs have been proposed in plateau region taking into

account the morphometric characteristics, contour arrangements, and suitability of sites. Some of the rain water harvesting techniques adopted in other parts of the country like contour bunds, mini-earthen check dams on gullies and *Nalas*, concrete dams/check dams on streams, flood water harvesting and renovation of existing traditional pond/*Tals* may also be practiced in Chandraprabha basin.

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# Sensitivity Analysis through SWAT model for Sirsa River Basin in Western Himalaya

**Narender Verma and Pratik Dash**

In this paper an attempt has been made to perform sensitivity analysis of various hydrological variables through SWAT model for Sirsa river basin, an ungauged basin, in Western Himalayas. The study used remote sensing data derived evapo-transpiration(ET) to parameterize SWAT model through manual calibration. For this study twelve sub-basins using fifth order stream as threshold were delineated from Aster Dem. These were further subdivided into 179 HRUs by overlaying land use landcover(LULC), soil and slope layers. Climate input parameters were loaded to run the model for the period of 2001-2008, considering first three years as warm-up period. After initial SWAT run, sensitivity analysis was performed based on Latin LH-OAT method. From sensitivity analysis groundwater related parameters (GWQMN, REVAPMN, GW\_REVAP and RCHR\_DP), soil related parameters (SOL\_Z, SOL\_AWC and SOL\_K) and HRU related parameters (EPCO, ESCO and CANMX) were found to be most sensitive.

**Keywords :** Evapotranspiration, hydrological model, hydrological response units, sensitivity, SWAT

## Introduction

Quantitative information of hydrological components not only helps to understand governing processes, but is also essential to manage water resources under changing environmental conditions. Among all hydrological components, runoff is commonly measured at several points on main stream. Though, data is readily available in developed countries, but is poorly maintained in developing countries. Hence, for sustainable water resources management, quantification of rainfall-runoff relation and other hydrological components is essential, but a challenging task.

To overcome this challenge hydrological modelling has emerged as a potent tool. Several hydrological and environmental models have been developed recently to quantify hydrological components and probe the hydrologic response to human activity (Wu and Xu, 2006; Wu and Liu 2012).

Hydrologic models, especially rainfall-runoff models are 'simplifications of the real-world system under investigation' (Gupta et al., 2005). Based on the hydrological process description, hydrological models can be either lumped (conceptual) or fully distributed or semi-distributed. Since last two decades, integrating

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with geospatial tools and remotely sensed data, ample distributed and semi-distributed models has been developed to estimate water quality and quantity (Manguerra and Engel 1998). Among various models, Soil and Water Assessment Tool (SWAT) model has been popularly applied worldwide for various ranges of watersheds varying topography, climate, soil and management conditions over long periods of time (Zhang et al. 2007; Gassman et al. 2007; Krysanova and White 2015). SWAT model (Arnold et al., 1998) is a physically based semi-distributed, basin-scale and continuous-time model. It is suitably used for estimating water balance components (Manguerra and Engel 1998; VanLiew and Garbrecht 2003), sediment and nutrition loss (Chu et al 2004; Behera and Panda 2006), impact of nonpoint-source pollution and water management (Santhi et al. 2006), land use change (Nie et al. 2011, Li et al 2013, Yan et al. 2013) and climate change (Wu and Johnston 2007; Githui et al., 2009; Jha et al., 2014) on water quality and quantity. In this study SWAT model is opted as it offers: (a) detail surface and sub-surface hydrologic processes, (b) spatial heterogeneity in the model input-output, (c) long-term hydrologic simulation with limited data, even for ungauged basin also, (d) simple and user-friendly platform, good documentation and solution feedback from large number of user community etc.

Physically-based models, like SWAT, incorporate huge number of parameters, of which most are not physically measurable. It is obtained through a process of adjustment with field data (observed), known as calibration. But, adjustment of such huge parameters is cumbersome and labour-intensive (Immerzeel and Droogers, 2008). Hence, identification of

key parameters and the parameter precision is required for calibration (Ma et al., 2000, Arnold et al., 2012). Sensitivity analysis helps to identify most influential parameters that have significant influence on model output (Saltelli et al., 2000). A combined method of Latin Hypercube (LH) sampling and One-Factor-At-a-Time (OAT) is popularly used for sensitivity analysis in which each model parameter is changed at predefined interval, while others are kept constant at their nominal value (Turanyi and Rabitz, 2000; Holvoet et al., 2005; Van Griensven et al. 2006; Cibin et al., 2010). This LH-OAT approach embedded in SWAT interface is used in this study. However, understanding of variation in model output with change in sensitive parameter value is utmost important for manual calibration. Few studies experimented model accuracy by manually varying SWAT parameters. For example, Wu and Johnston (2007) evaluated the effect of plant uptake compensation factor (EPCO) and soil evaporation compensation coefficient (ESCO) on deviation of discharge values under dry and average climate condition. Kannan et al (2007) tested the effect of four most sensitive parameters on stream flow components by varying OAT at low, medium and high parameter values. Mosbahi et al (2015) compared Nash-Sutcliffe coefficients of simulated runoff at various points in a range of sensitive parameter values by varying OAT.

In gauged basins, availability of observed data makes it easier for realistic simulation. But, for the ungauged basin accurate estimation of hydrologic variables is difficult and challenging task (Cibin et al. 2013). The studies that simulated hydrologic behavior of ungauged basins are either based on physical considerations or other theories, like Grey

information theory, fuzzy theory etc. (Nayak et al., 2005; Wang et al., 2013). Several studies found regionalization approach as most suitable method for estimation of runoff in ungauged basin (Parajka et al., 2005; Göttinger and Bárdossy, 2007; Zhang et al., 2008; Gitau and Chaubey, 2010; Samuel et al., 2011, Cibir et al., 2013). In this approach, hydrologic information, i.e., model parameters or model structure are transferred from gauged (donor) to ungauged (target) catchment based on similarity in catchment characteristics or spatial proximity (Samuel et al. 2011, Razavi et al. 2013). But, this approach is not applicable for an ungauged basin, if a donor basin is not available. Hence, hydrological parameters measured using satellite data could provide a viable solution to calibrate hydrological model for data scarce region (Immerzeel and Droogers, 2008).

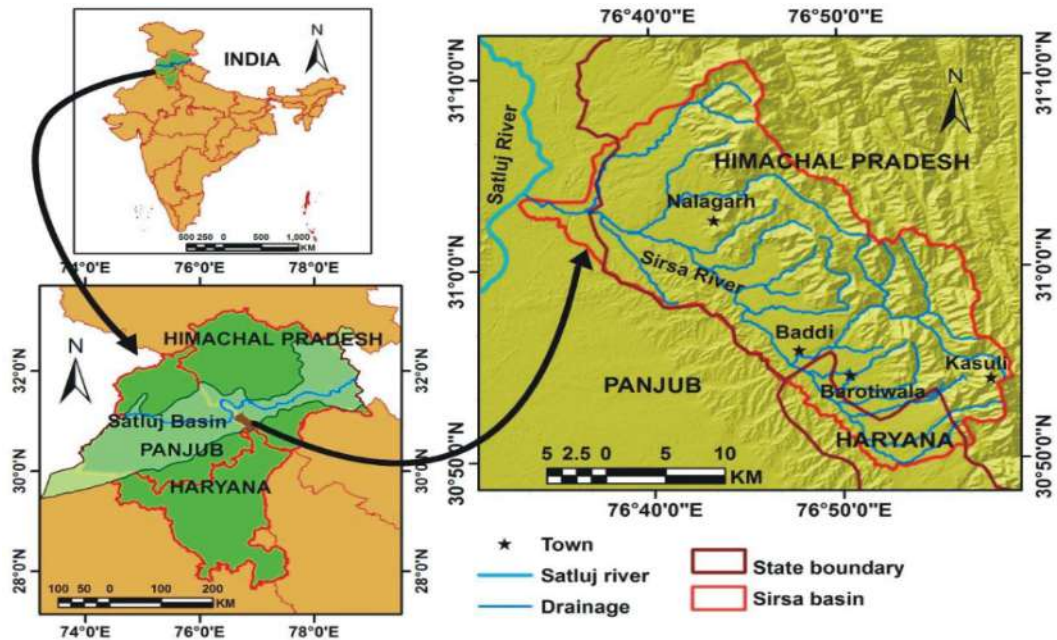
Application of remote sensing data derived hydrological components like, evapotranspiration and soil moisture for parameterization of hydrological models in ungauged basin is recently getting momentum in hydrological engineering (Boegh et al. 2004; Immerzeel and Droogers, 2008; Stehr et al. 2009; Zhang et al. 2009; Jhorar et al., 2011; Githui et al., 2012). Most of these studies, used Moderate Resolution Imaging Spectroradiometer (MODIS) product of land cover and vegetation cover (NDVI, LAI) to estimate evapotranspiration (ET) based on the Surface Energy Balance Algorithm (SEBAL) for calibration of SWAT model or other hydrological model (Immerzeel and Droogers, 2008; Zhang et al. 2009; Jhorar et al., 2011; Githui et al., 2012).

Hydrological information in developing countries, like India are limitedly available.

Additionally, alteration of land use practice, climate change, industrialization and high rate of water consumption has raised big question on water quality and its availability for future. Hence, hydrological modeling for data scarce basins is required by planners and managers for sustainable management of water resources. In the present study, sensitivity analysis using SWAT model for Sirsa river basin, an ungauged tributary basin of Satluj river in the western Himalaya, India is performed to understand the most sensitive parameters affecting the hydrological regime of this river basin.

### Study area

The Sirsa river basin, a downstream tributary channel of Satluj river, flows through Himachal Pradesh, Haryana and Punjab states in India. The study site covers approximately 670 km<sup>2</sup> area of which 75% lies in Solan district of Himachal Pradesh. The basin extends from 30°49'22.3" N to 31°11'2.003" N latitudes and 76°32'22.483" E to 76°59'2.223" E longitudes in western Himalaya at the fringe of Ganga plain. The basin is an intermontane river system, bounded by outer Siwalik range in the southwest and Kasauli–Ramshahr Tertiary ranges in the north-east (Figure 1). Elevation of the basin varies between 250 and 1900 m, almost half of which is characterized by intermontane valley (Nalagarh valley). The basin landscape is characterized by ridge and valley topography, eroded undulating surface, flat alluvial fan etc. The tributaries of Sirsa river that originate from Kasauli–Ramshahr ranges are long; while rivulets developed in the outer Siwalik are too short. The drainage morphometry indicates that the basin is elongated and well drained with an average drainage density of 3 km/km<sup>2</sup> (Dash et al. 2013).



**Figure-1** Extent of Sirsa River Basin

The basin is located in sub-tropical monsoon climate with a mean annual temperature of 23.5°C and an annual mean rainfall of 900mm. About 80% of annual precipitation is received during summer monsoon (June - September). The dominant land use land cover (LULC) classes in the basin are dense forest, open forest and agricultural land. The major soil type of the study basin is sandy loam (Central Ground Water Board 2007). The valley region (Dun) is dominantly covered by sandy loam soil, while loamy skeletal soil is found in Kasauli–Ramshahr ranges. Soil layers are quite thick in the intermontane valley and outer Himalaya than Kasauli–Ramshahr ranges. Soils are characterized by low to moderate permeability. Major industrial hub of Himachal Pradesh, *i.e.*

Baddi-Barotiwala-Nalagarh corridor is located in the study basin. Rapid industrialization and urbanization has increased water demand, and intervening hydrologic process of the basin.

### Material and methods

#### SWAT model

The Soil and Water Assessment Tool (SWAT) model has been used in this study (SWAT version 2005). SWAT is a continuous time, physically based semi-distributed hydrologic model that simulates hydrologic components on daily basis. The model accounts for large-scale spatial variability of hydrologic processes partitioning a basin into a numbers of land parcels in two phases. Initially, based on topography, the basin is divided into numerous sub-basins, considering drainage area

threshold. Then, sub-basins are further segregated into numerous conceptual homogeneous land parcels, known as hydrologic response units (HRUs) combining slope, soil and land use layers.

Water budget of surface, sub-surface and deep aquifer is calculated for each HRU, basin and sub-basins. SWAT model simulates various hydrological components, like evapotranspiration, surface runoff, lateral flow, baseflow, deep aquifer recharge etc. based on water balance equation expressed as follows:

$$SW_t = SW_0 + \sum_{i=1}^t (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

Where,  $SW_t$  is the final soil water content (mm),  $SW_0$  is the initial soil water content on day  $i$  (mm),  $R_{day}$ ,  $Q_{surf}$ ,  $E_a$ ,  $w_{seep}$  and  $Q_{gw}$  are precipitation (mm), surface runoff (mm), evapotranspiration (mm), seepage flow (mm) and return flow (mm) on day  $i$ , respectively.

SWAT model offers two methods for surface runoff simulation, of which SCS Curve Number method (Arnold et al. 1998) was opted in this study. Potential evapotranspiration (PET) is calculated using Penman–Monteith method (Monteith, 1965) and Hargreaves method (Hargreaves and Samani, 1985), though Priestley-Taylor method is also offered by the model. Percolation is estimated by storage routing method, while muskingum method is used for channel routing. Most importantly, SWAT system embedded within GIS interface is more helpful to integrate several spatial information, including topography, soil, land cover, climate etc (Yan et al. 2013). A more detailed description of the model is found in Neitsch et al. (2005a) and online documentation (<http://swatmodel.tamu.edu/>).

## Data preparation

Topographic data, land use and soil data, meteorological data are essentially required for SWAT model setup. To input topographic information, Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) of 1 arc-second resolution was used. A soil map of 1:125,000 scale was acquired from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). Soil classes were reclassified according to SWAT soil database. Land use land cover (LULC) information was acquired from Landsat TM image. A LULC map of 2009 was prepared from Landsat data based on supervised classification. In absence of long term in-situ meteorological data, gridded raster climatic data of NCEP/NCAR Global Reanalysis Products of Global Meteorological Forcing Dataset for Land Surface Modelling (ds314) was used in this study. Global gridded datasets of 1o spatial resolution was collected from Computational and Information Systems Laboratory (CISL) archive (<http://rda.ucar.edu/datasets/ds314.0/>). The meteorological data, that included minimum and maximum temperature, precipitation, solar radiation, wind speed and relative humidity, were collected for two grid locations with the help of python programming for the period of 2003–2008. Climate data was prepared in suitable format for SWAT2005 as guided by Neitsch et al. (2005b).

## Parameter sensitivity and adjustment

For this study, twelve sub-basins were delineated from DEM, considering 2000 ha minimum drainage area and fifth order stream as threshold. Overlaying LULC, soil and slope layers sub-basins were further divided into 179

**Table 1.** *Statistics of parameters used for calibration*

Parameter	Sensitivity report		final value
	Rank	Mean value	Calibrated
GWQMN	1	0.26	46.44
ALPHA_BF	2	0.22	0.2
REVAPMN	3	0.19	46.5
GW_REVAP	4	0.06	0.03
RCHR_DP	5	0.056	0.36
CN2	6	0.041	*
CANMX	7	0.035	5
EPCO	8	0.022	0.6
SOL_AWC	9	0.01	0.09
SOL_Z	10	0.009	480
SOL_K	11	0.006	10
ESCO	12	0.005	0.3
GW_DELAY	13	0.005	18

\* *Varies with LULC and soil types*

HRUs. Afterwards, climate input parameters were loaded to run the model for the period of 2001-2008, considering first three years as warm-up period. After initial SWAT run, sensitivity analysis was performed based on Latin LH-OAT method. To make calibration process easier, most sensitive parameters were manually varied once-at-a-time (OAT) within the range as suggested in the SWAT user's manual (Neitsch et al., 2001). The analysis was carried out for 20 model parameters with 10 intervals in Latin hypercube (LH) sampling. The rate of change in selected hydrological components (model output) with respect to change in each parameter values was tested to identify suitable parameter values.

## Model performance

## Results and discussions

### Sensitivity analysis

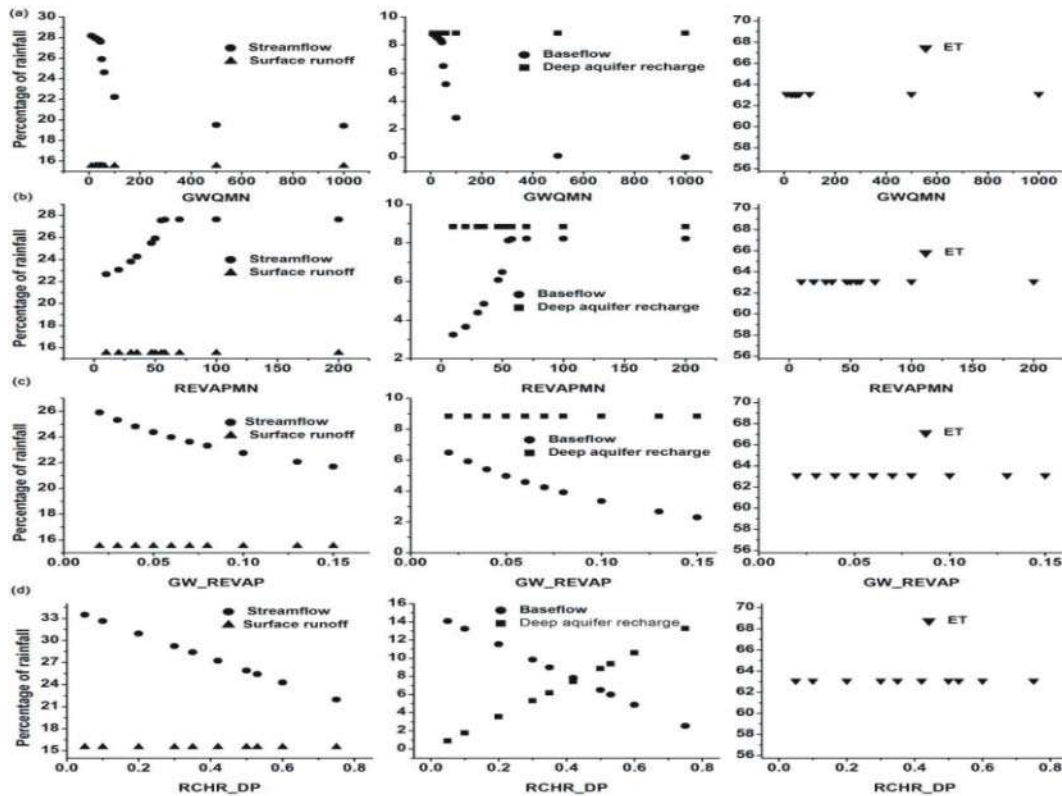
LH-OAT based sensitivity analysis was performed to identify and choose influential parameters by ignoring redundant parameters. The most sensitive parameters found in this study are: curve number (CN), soil available water capacity (SOL\_AWC), soil depth (SOL\_Z), soil evaporation compensation factor (ESCO), saturated hydraulic conductivity (SOL\_K), threshold depth of water in the shallow aquifer required for return flow (GWQMN), groundwater 'revap' coefficient (GW\_REVAP), groundwater recession factor (ALPHA\_BF) etc. Table 1 lists rank of sensitive parameters and their final values. The sensitivity of groundwater parameter (.gw), soil parameter (.sol) and HRU parameter (.hru) to surface runoff, stream flow, baseflow, deep aquifer recharge and evapotranspiration are discussed in this section. During this process, one parameter was changed randomly, while others were kept constant.

### Groundwater parameters (.gw)

The sensitivity of groundwater parameters, particularly GWQMN, REVAPMN, GW\_REVAP and RCHR.DP on hydrological components are presented in Figure-2. Parameters are found sensitive to baseflow, and consequently to stream flow.

### GWQMN

Variations in water balance components for changes in GWQMN values are presented in Figure -2a. It is clear that with the increase of GWQMN, water yield and baseflow decreased. For high values of GWQMN a



**Fig.2 : Sensitivity of groundwater parameters to different water balance components**

considerable portion of infiltrated water is stored in soil; while, at a low value of GWQMN, SWAT produces more baseflow that, in turn, increases stream flow also (Kannan et al., 2007). Noticeably, at initial value of GWQMN (up to 60) the rate of decrease in baseflow and stream flow is low to moderate. But, afterwards rate of decrease increases abruptly up to GWQMN value of 175. Baseflow and stream flow remain constant while GWQMN value exceeds 500. Kannan et al., (2007) recommended low GWQMN for realistic prediction of daily stream flow.

**REVAPMN**

REVAPMN is the threshold depth of

water in shallow aquifer that controls water movement to unsaturated zone for re-evaporation to occur. With the increase of REVAPMN, baseflow as well as stream flow increased (Figure-2b). But after a certain value (REVAPMN=60), both remain constant. Because at this certain threshold value no ‘revap’ will occur for the basin. At low REVAPMN, as ‘revap’ from the soil is high, the contribution of baseflow to stream flow is very low. In this study, the REVAPN value was finally adjusted close to GWQMN.

**GW\_REVAP**

Groundwater ‘revap’ coefficient (GW\_REVAP) controls the amount of water

that will 'revap' to upper soil layer. GW\_REVAP value ranges from 0.02 to 0.2. For a high value of the parameter, the model returns water to root zone for 'revap', hence, baseflow contribution to stream flow decreased. This parameter moderately controlled baseflow and stream flow in this study (Figure-2c). However, GW\_REVAP value was finally set to 0.03 for this study.

#### **RCHR\_DP**

RCHR\_DP controls the amount of water that will move from shallow aquifer to deep aquifer. It was found fifth-rank sensitive parameters in this study. With the increase of parameter value amount of baseflow, as well as stream flow decreases and deep aquifer recharge increases linearly (Figure 2d). This parameter is most significant for separation between shallow and deep aquifer recharge.

#### **Soil parameters (.sol)**

Soil parameters, mainly SOL\_Z, SOL\_AWC and SOL\_K showed significant control on each water balance components (Figure -3). The sensitivity results of these three parameters are discussed below.

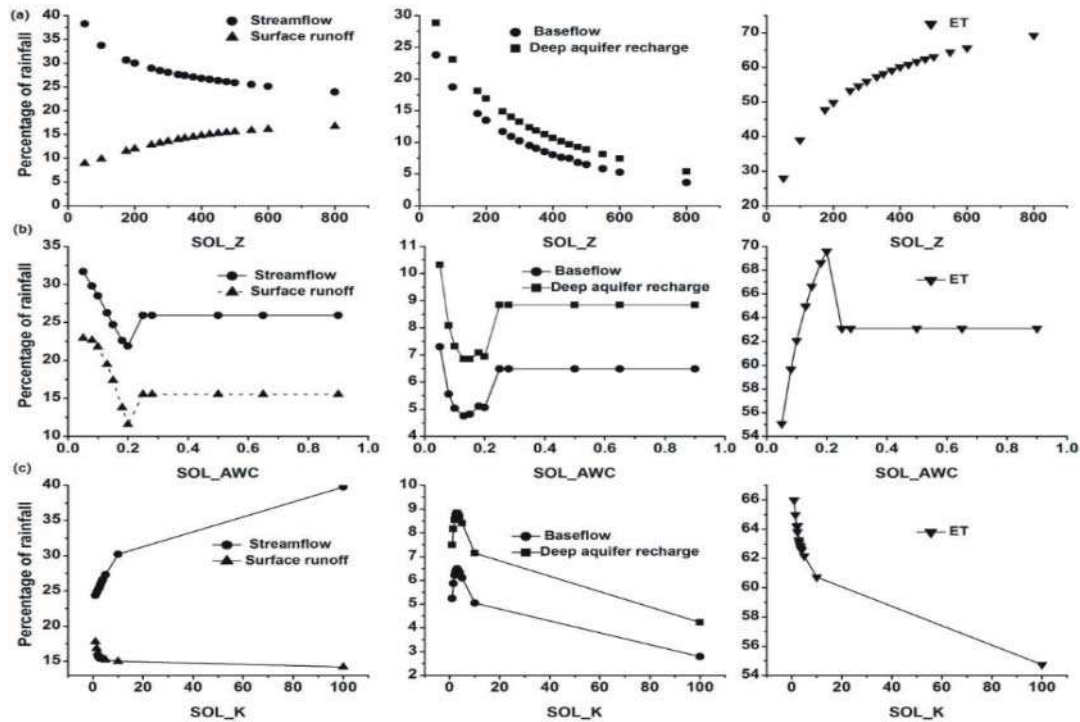
#### **SOL\_Z**

Hydrologic components showed curvilinear relation with SOL\_Z values (depth of soil layer). An increase in SOL\_Z value increased surface runoff and evapotranspiration, and decreased total stream flow, baseflow and deep aquifer recharge (Figure -3a). As soil depth increases, root zone depth and soil profile depth increases. It increases water holding capacity, as well as, water availability in the soil profile that, in turn, increased evaporation from soil profile and transpiration from plants. Thus, increase of

vadose zone depth caused decrease in shallow and deep aquifer recharge and increase in evapotranspiration (ET). In the SWAT model, less depth of soil profile helps in quick downward movement of water from lowest soil layer to shallow aquifer. With increase of soil depth, delay in water movement to shallow aquifer will increase. Thus, groundwater recharge decrease and ET will increase. From the Figure -3a it is assumed that with the increase of soil water content due to increase of soil depth, surface runoff increased. But, as the rate of decrease of baseflow was higher than increase of surface runoff, stream flow trimmed down. However, interaction of this parameter with other soil and groundwater parameters can change its influence to hydrologic components.

#### **SOL\_AWC**

SOL\_AWC (available water capacity in soil) is one of crucial parameters that determine field capacity of soil, ranges between 0-1. In this study, SOL\_AWC was found sensitive to various water balance components in a similar pattern. Initially, surface runoff, stream flow, baseflow and deep aquifer recharge was decreased and evapotranspiration increased with the increase of SOL\_AWC value up to 0.2. But, in between SOL\_AWC value of 0.2 and 0.3, response of each component is reversed. Finally, beyond SOL\_AWC value 0.3, the parameters show no sensitivity to the water balance components. It can be concluded that with a fractional increase in SOL\_AWC, evapotranspiration from soil and canopy increases as soil moisture increases. But, after a critical point (here 0.2), with the increase of SOL\_AWC percolation to shallow and deep aquifer increased.



**Fig. 3 : Sensitivity of soil parameters to different water balance components**

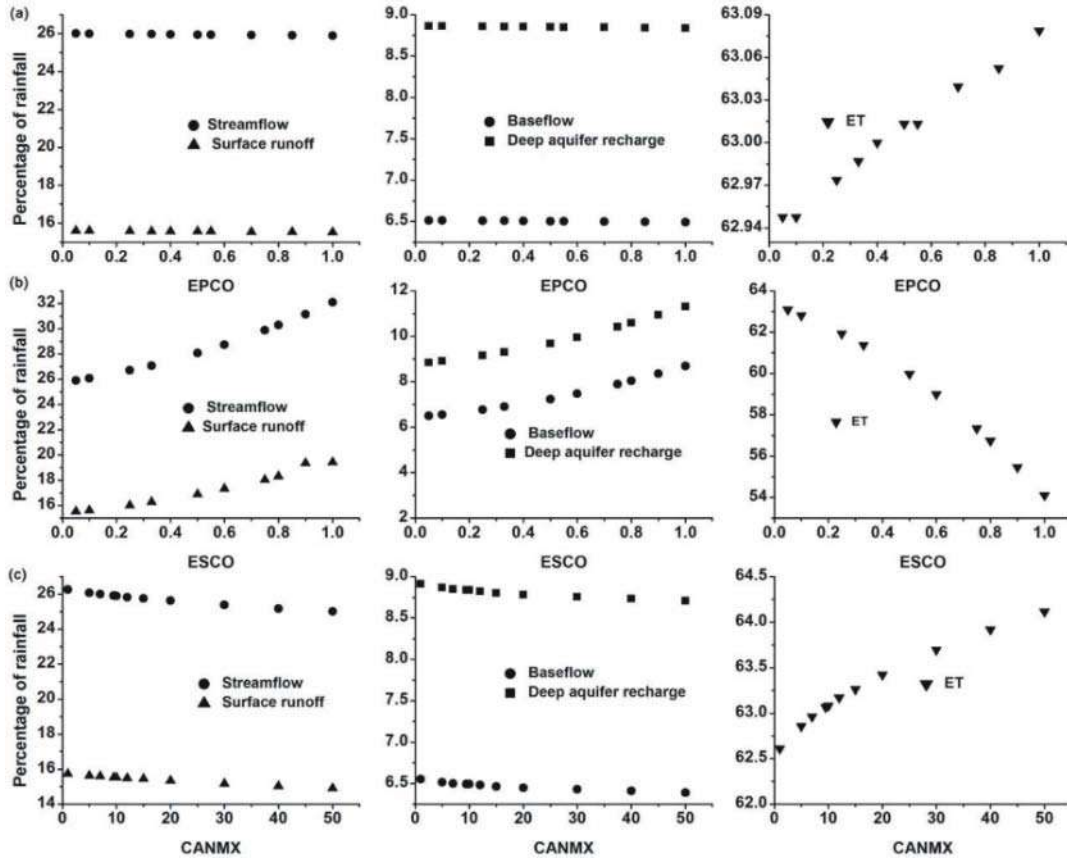
**SOL\_K**

Saturated hydraulic conductivity of soil (SOL\_K) plays a significant role in hydrologic processes. The infiltration and percolation capacity of soil is directly proportional to the soil saturated hydraulic conductivity (Neitsch et al., 2005a). At low value range (0-10) SOL\_K was found very sensitive to all hydrological components. When SOL\_K approached 0 to 10, stream flow, baseflow and deep aquifer recharge increased, though, surface flow and ET decreased (Figure 3c). But, when the value increased from moderate to high, value of these components decreased, except stream flow. The results are quite similar with the findings of Kannan et al.

(2007). Till SOL\_K value approaches 10, baseflow, stream flow and groundwater recharge increased significantly as infiltration and percolation capacity increased. But beyond SOL\_K value 10, most part of infiltrated water converted as lateral flow, rather than groundwater recharge. Albeit, the contribution of surface flow and baseflow to stream flow is reduced, but substantial increase in lateral flow hiked stream flow (Figure 3c).

**HRU parameters (.hru)**

EPCO, ESCO and CANMX were found most sensitive HRU configuration parameters in this study. These parameters were found comparatively less sensitive for water balance components (Figure 4).



**Fig. 4: Sensitivity of HRU parameters to different water balance components**

**EPCO**

The plant uptake compensation function (EPCO) controls ET through allowing plant to uptake water from layers within rooting zone (Wu and Johnston, 2007). The value of EPCO ranges between 0 and 1. At low EPCO value, model allows plant to uptake water from top soil layer; but, as EPCO approaches 1.0, plant water uptake demand will be met from deep soil layer also. In this study, with the increase in EPCO value ET increased linearly, though the rate of increase is less (Figure 4a). As for higher EPCO value, model allows to meet the

more water uptake demand of plant from lower soil layer, ET increased marginally.

**ESCO**

The soil evaporation compensation factor (ESCO) controls evaporation from soil by modifying depth distribution in soil profile. ESCO is found sensitive to all water balance components(Figure 4b). ET decreased in curvilinear shape with the increase of parameter value and rest components increased with moderate rate (Figure 4b). As the value of ESCO is reduced, the model is able to extract more of the evaporative demand from

lower level (Neitsch et al., 2005b), resulting an increase in ET. For high ESCO values, ET decreased and consequently surface runoff, baseflow and other components increased. The sensitivity of this parameter is quite similar to previous studies (Kannan et al., 2007; Wu and Johnston, 2007).

### CANMX

A change in the value of the maximum canopy storage (CANMX) affects ET and other water balance components. Figure 4c shows that CANMX is less to moderately sensitive to all components. With the increase in CANMAX, ET has increased slightly; whereas other components have decreased but at a low rate. As maximum canopy storage is increased, interception is increased. As a result, surface runoff, baseflow and deep aquifer recharge have decreased, and concomitantly the amount of evaporation of intercepted water is increased. However, CANMX found less sensitive to all components as compared to

other parameters.

### Conclusions

Hydrologic modelling in mountainous regions is challenging because of scarcity of climatic data, extreme elevation gradients, and orographic effects. In this study SWAT model has been used to perform sensitivity analysis in Sirsa River Basin. The most sensitive parameters for this study basin are groundwater related parameters (GWQMN, REVAPMN, GW\_REVAP and RCHR\_DP), soil related parameters (SOL\_Z, SOL\_AWC and SOL\_K) and HRU related parameters (EPCO, ESCO and CANMX). Overall it is an efficient and simple approach for identification of sensitive parameters. However, there might be some uncertainty in model simulation raised from error in input data, calibration approach etc. due to unavailability of observed meteorological data, the study used gridded reanalysis data that was coarse in resolution for this study.

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## **Spatio-Temporal changes in wheat cultivation in Himachal Pradesh: 1990 to 2010**

**Shivjeet Kaur, Anuja Thakur and Kuljeet Singh Sohal**

Wheat is a crop of tropical and temperate regions. It is the leading crop in Himachal Pradesh. The main objective of this paper is to reveal the spatio-temporal changes in wheat cultivation in Himachal Pradesh during 1990 to 2010. For this purpose, the present study is divided into three parts. First part reveals the patterns of wheat cultivation for 1990 and 2010. While the second part highlights the changes in wheat cultivation and factors responsible for them. Whereas conclusions are drawn and suggestions are made in part third. From the study, it is found that areas with low altitude, comparatively high temperature, high rainfall, fertile soils comfortable irrigation facilities, etc. have experienced high share of wheat cultivation. In upper Himalayas owing to the popularity of horticulture crops like apple and vegetables, wheat cultivation has suffered. The present paper is based on secondary sources of data. The unit of study is tehsil. Statistical methods are used for deriving the results and cartographic techniques are applied for mapping the results.

**Keywords:** Temporal, cultivation, infrastructure, altitude, irrigation.

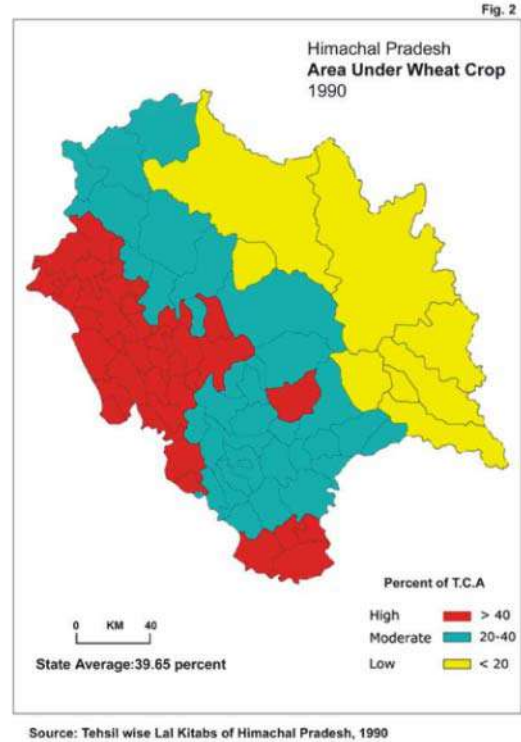
### **Introduction**

Scientific research regarding the origin of wheat on the globe reveals that first of all this plant was domesticated and cultivated in south-west Asia between 9000 to 1000 B.P. It is believed that from here, it has spread to the rest of the world (Vavilov, 1949). It is also considered that Aryans had brought wheat grains to India, and since then it is being grown (www.Farmers Portal). Wheat is counted among the big three cereal crops (corn, rice and wheat) and is the dominant crop in temperate as well as tropical countries (Shewry, 2009). India is the second largest producer of wheat in the world (Kaur, 2003;

Sharma, 2014; Ranjana, 2012). It is the major Rabi crop in terms of value, volume and area which shows its importance in respect of area and production. Wheat is a staple crop, grown as a primary food product and for other uses of primary as well secondary ones and also provides a large fraction of the dietary protein (Tiller, 2007). It is rich in proteins, vitamins and carbohydrates which provides balanced food. Its vegetative plant parts make valuable livestock feed (www.wikipedia.com). The production and productivity of wheat was very low before independence in India but with the ushering of green revolution during mid sixties, there had been bumper increase in its

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production and productivity, which help to make our country self, sufficient in food grains productions. From wheat growing areas point of view Himachal Pradesh falls under northern hill zone (www.Farmers Portal).

### Growing Conditions

Wheat crop has its own set of environmental conditions under which it grows most effectively. Three groups of factors that largely determine whether it can be economically produced in a given area, and therefore control its distributional pattern, are agronomic, social, and economic (Singh, 1976). Wheat is sown in the months of October-November, when temperature ranges between 15° C to 25° C and for growing period cool winters are ideal. Whereas, crop is harvested

in April-May, when temperature ranges between 28°C to 32°C. The average days required for wheat cultivation are 140 to 160 (Hussain, 2009). Soils with clay - loamy or loamy texture and of crumb structure are ideal for wheat cultivation. It requires well distributed rainfall ranges between 40 to 110 centimeters which is congenial for its growth (Sarker, Itohara, Hoque and Sardar, 2011).

### Objectives:

The present study has the following objectives:

- 1) To analyze the spatial pattern of wheat cultivation during: 1990 to 2010.
- 2) To find out the changes in Wheat cultivation during the study period.
- 3) To identify the factors responsible for

changes in wheat cropping.

4) To draw conclusion and make suggestions.

### Study area

Himachal Pradesh is lying between 30°22'40" N to 33°12'40" N latitudes and from 75°45'55" East to 79°04'20" East longitudes. It occupies an area of 55673 sq. kms. Himachal Pradesh is a mountainous state. Its topography varies enormously. There are Shiwalik hills, high peak mountain with steep slope, steep gradient, valleys, snow covered areas, glaciers, alpine areas, etc. Broadly, its climate varies from hot and sub-humid tropical in south and south-west, whereas in northern and eastern parts have cold, alpine and glacial. Average temperature during summers varies between 28°C to 32°C and during winters, it comes down to freezing point. There are three broad seasons, summer, winter and rainy. Soils vary between silty clay, clay, loamy, sandy loam, sandy pebbles, glacial soils, etc. From administrative point, there are 81 tehsils and 12 districts. Average density of population is 109 persons per sq.km according to census 2001.

### Sources of Data and methodology

The present paper is empirical in nature and is based on secondary sources of data. Tehsil is taken as unit of study. Two time periods *i.e* 1990 average of 1988-89, 89-90 and 90-91 and 2010 average of 1998-99, 99-2010, 10-11 are taken for revealing the spatio-temporal changes in wheat cultivation in Himachal Pradesh. The data is collected from Lal kitabs of all the tehsils of the state, various state offices, libraries, books, reports and journals. Simple statistical techniques are used for deriving the results and cartographic methods are applied for mapping the results.

## Discussion

### (A) Spatial Patterns of Wheat Cultivation: 1990

During 1990, Himachal Pradesh had 3,84,806 hectares area under wheat crop which comprised of 39.65 percent of the total cropped area. The Sangla tehsil of Kinnaur district recorded highest area (48.74 %), whereas Nirmand tehsil of Kullu district has lowest area (1.85 %) under wheat crop. It shows that the spatial distribution of wheat cultivation was not uniform in the state. This uneven spatial pattern of wheat cultivation was owing to many factors like physical, socio-economic, cultural, organizational etc. Fig. 2 shows the spatial distribution of wheat crop which is depicting the following three categories.

- (i) Areas of High proportion of wheat cultivation : (> 40 percent)
- (ii) Areas of Moderate proportion of wheat cultivation: (20-40 percent)
- (iii) Areas of Low proportion of wheat cultivation: (<20 percent)

#### (i) Areas of High Proportion (>40 percent)

This category comprised of thirty eight tehsils covering 46.91 percent of the total occurrences. The highest share of 48.74 percent of area under wheat crop was recorded in Nirmand tehsil and lowest (40.02 %) in Shahpur tehsil. This category includes the tehsils of area Sh.Naina Devi ji, Ghumarwin, Jhanduta, Shahpur, Bhattiyat, Hamirpur, Sujanpur, Bhoranj, Barsar, Nadaun, Kangra, Baroh, Nurpur, Indora, Fatehpur, Dehra, Khundian, Jaswan Kotla, Rakkar, Jawali, Jaisinghpur, Nirmand, Mandi, Lad Bharol, Paddar, Sarkaghat, Baldwara, Renuka ji, Paonta Sahib,

Shillai, Una, Bangana, Amb, Haroli, Jawala mukhi, Nahan, Baddi and Nalagarh. All these tehsils except Nirmand, Mandi and Paddar, are lying in the lower Himalayas. Extreme western parts of this category has piedmont plains with undulating and dissected topography, comparatively fertile soils, moderate rainfall, developed infrastructure than eastern and middle parts of the state. All these factors had led to high percent share of wheat cultivation in this category.

#### **(ii) Areas of Moderate Proportion (20-40 percent)**

Category of moderate share of wheat cultivation included thirty five tehsils of the state and comprised of 43.20 percent of the total occurrences. It was mainly lying between the categories of high and low percent share of wheat crop. The tehsils lying in this category were namely, Chamba, Churah, Salooni, Bharmaur, Palampur, Dharamshala, Baijnath, Kullu, Banjar, Shimla (urban), Shimla (rural), Suni, Theog, Rampur, Kumarsain, Chopal, Rohru, Jubbal, Chirgaon, Dodra kwar, Chachiot, Thunag, Jogindernagar, Sundernagar, Karsog, Pachhad, Rajgarh, Solan, Kasauli, Arki, Kotkhai, Kandaghat, Bilaspur Sadar, Pangi and Dalhausie. This category mainly confined to lesser Himalayas or middle Himalayas. Here, valleys and gentle slopes were used by farmers for wheat cultivation during winters. Though majority of the tehsils received snowfall during winters, yet snow melt with augment of summer except on high peak areas. In some parts, there were irrigation facilities but not as much as it was in case of high category. These factors were responsible for moderate concentration of wheat cultivation in this category.

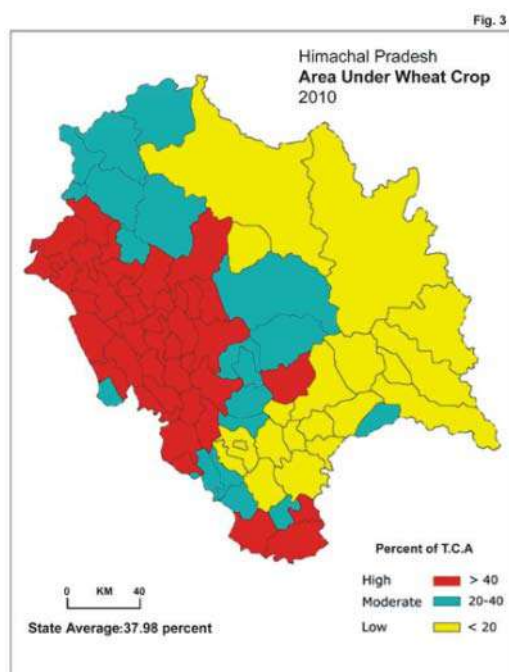
#### **(iii) Areas of Low Proportion (<20 percent)**

This category covered areas of eight tehsils which contained 9.87 percent of the total occurrences. Tehsils lying in this category were Nichar, Kalpa, Sangla, Pooch, Moorang, Lahaul, Spiti, and Manali. These were the areas with high mountains and snow covered peaks. During winters, these areas had experienced heavy snowfall. Here steep slopes, thin layer of soil, harsh climatic conditions, were hindrances in the successful cultivation of wheat. But with the augmenting of summers, snow started melting in lower parts and consequently wheat plants flourished. Leaving aside the above factors, socio-economic, cultural and agricultural infrastructure were also less developed. Therefore, all these conditions had led to the low share of wheat cultivation in this category.

From the preceding discussion, it is concluded that areas with low altitude, comparatively high temperature, fertile soils, comfortable irrigation facilities, occasionally snowfall etc were having high percent share of wheat cultivation. Whereas, areas with heavy snowfall, high mountain peaks, non friendly geo-climatic conditions and poor agricultural infrastructure were having low share of wheat cultivation. While areas lying in middle Himalayas below snowline or in Shiwaliks with less favorable geo-climatic conditions had experienced moderate proportion of wheat cultivation.

#### **(B) Spatial Patterns of Wheat Cultivation: 2010**

In Himachal Pradesh, wheat crop occupies 3, 57,737 hectares of land under its cultivation in 2010 which accounts for 37.98



percent of the total cropped area. Its share varies between 0.01 percent in Shimla (urban) and Kotkhai tehsils of Shimla district and 51.00 percent in Una tehsil of Una district. This uneven distributional pattern of wheat crop in the state is owing to variations in topography, altitude, slope, gradient, soils, climatic conditions, socio-economic environment, development of agricultural infrastructure, availability of agricultural research and extension services, organizational factors etc. Fig. 3 shows the spatial patterns of wheat cultivation in the state during 2010. It is categorized into three categories.

(i) Category of High share of Wheat cultivation: (>40 percent)

(ii) Category of Moderate share of Wheat cultivation: (20-40 percent)

(iii) Category of Low share of Wheat cultivation: (<20 percent)

### (i) Areas of High Share (>40 percent)

This category is largely confined to the western parts of the state and form a compact belt. Beside this belt, there is a small patch under the category in Sirmaur district including tehsils of Nahan, Paonta Sahib and Shillai. Wheat share in this category ranges between 40.18 percent in Nurpur tehsil to 51.00 percent in Una tehsil. It comprises forty two tehsils namely, Bilaspur Sadar, Sh. Naina Devi ji, Ghumarwin, Jhanduta, Bhattiyat, Hamirpur, Sujampur, Bhoranj, Barsar, Nadaun, Kangra, Baroh, Palampur, Shahpur, Fatehpur, Dehra, Khundian, Jaswan kotla, Jawala mukhi, Rakkar, Baijnath, Jawali, Jaisinghpur, Mandi, Jogindernagar, Lad Bharol, Paddar, Sarkaghat, Baldwara, Nahan, Paonta Sahib, Shillai, Nalagarh, Arki, Baddi, Una, Bangana, Amb, Nurpur, Indora, Sundernagar and Haroli. The main reasons for high percent share of wheat cultivation in this category are mild temperature, cool winters, comfortable rainfall, traditional wheat growing areas, undulating and dissected topography, moderate slope, presence of valleys, wheat as main staple food of the people, comparatively higher and assured economic returns than other crops of the winter season etc. Owing to all these factors, people prefer to grow wheat crop than other crops of the winter season.

### (ii) Areas of Moderate Share (20-40 percent)

Nineteen tehsils come under the category of moderate proportion of wheat cultivation which contains 23.45 percent of the total occurrences. Here, the proportion of wheat crop ranges between (20.46 %) in Solan tehsil of Solan district to (38.07 %) in suni tehsil of Shimla District. Tehsils of Chamba, Churah,

Salooni, Pangi, Bharmaur, Dalhausie, Dharamshala, Kullu, Nirmand, Banjar, Suni, Dodra kwar, Chachiot, Thunag, Karsog, Renuka ji, Pachhad, Solan and Kasauli are included in this category. These areas are mountainous with interlocked hills. On the hill tops, the cultivation of wheat is not feasible, but on moderate slopes and in valleys, wheat is grown. These areas have also experienced snowfall but generally snow melt with the start of summers. In valleys, soils are comparatively deep and fertile than on the slopes. Moreover, the southern slopes receive more sunshine and precipitation as compared to northern slopes. At the time of wheat sowing in October and at the harvesting time, *i.e.* April-May, the temperature is favorable for its cultivation but during growing period temperature is low. Therefore, owing to the above mentioned factors, these tehsils have recorded moderate proportion of wheat crop.

### **(iii) Areas of Low Share of Wheat (<20 percent)**

Here, low share of wheat cultivation ranges between 0.01 percent in Shimla (urban) and Kotkhai tehsil and 19.72 percent in Shimla (rural) tehsil. It comprises the tehsils of Kandaghat, Rajgarh, Chirgaon, Jubbal, Rohru, Kumarsain, Rampur, Kotkhai, Theog, Shimla (rural), Shimla (urban), Lahaul, Spiti, Manali, Moorang, Pooh, Sangla, Kalpa, Nichar and Chopal. In this area physical environment is not highly suitable for crop farming especially for wheat crop, because during winters all these areas have experienced moderate to heavy snowfall. Moreover, the amount of snowfall starts increasing from south-west to north-east. This area has very low temperature during winters, thin and immature soils. Besides all

this, geo-climatic conditions are more favorable for cultivation of vegetables and Apple than wheat cultivation. All these above mentioned reasons, have led to low share of wheat cultivation in this category.

Above discussion reveals that the percent share of wheat cultivation declines from west to east. Secondly, areas with harsh geo-climatic conditions like Greater Himalayan areas are not suitable for wheat crop, but these areas grow fruits especially apple and vegetables (potatoes). In lower Himalayas, the percentage of wheat is high, while in most parts of middle Himalayas, wheat cultivation is recorded of moderate proportion.

### **(C) Spatial Temporal Changes in Wheat Cultivation: 1990-2010**

During study period in Himachal Pradesh, certain developments in agriculture sector have occurred. These are introduction of modern inputs like agro-chemicals, machinery, spray pumps etc, road density, mechanization, development in transportation, emergence of fruits and vegetables cultivation, leveling of land in valleys and an undulating topography, government policy, marketing facilities especially for vegetables and apple etc. All these development have affected the wheat cultivation. Overall area under its cultivation has declined from 3,84,806 hectares to 3,57,737 hectares which has registered an absolute negative change of 27,069 hectares. But, it has decreased from 39.65 percent to 37.98 which recorded -1.67 percent volume of change during 1990 to 2010. While tehsil wise, the volume of change is not uniform. In some tehsils particularly in western parts, wheat cultivation has recorded decline as well as increase in area under its cultivation. Whereas in major parts

**Table 1.** Changes in Wheat Cultivation in Himachal Pradesh during 1990-2010.

Sr. No.	Tehsils	1990	2010	Volume of change
1.	Bilaspur Sadar	37.85	45.45	7.6
2.	Sh.Naina Devi ji	43.87	44.82	0.95
3.	Ghumarwin	46.20	47.26	1.06
4.	Jhanduta	47.40	46.97	-0.43
5.	Chamba	33.53	31.15	-2.38
6.	Churah	29.10	22.62	-6.48
7.	Salooni	24.03	28.02	3.99
8.	Pangi	39.12	31.50	-7.62
9.	Bharmaur	27.71	22.48	-5.23
10.	Dalhausie	35.20	36.49	1.29
11.	Bhattiyat	46.53	40.37	-6.16
12.	Hamirpur	47.22	48.66	1.44
13.	Sujanpur	48.47	49.88	1.41
14.	Bhoranj	48.74	50.00	1.26
15.	Barsar	48.47	49.56	1.09
16.	Nadaun	48.00	49.48	1.48
17.	Dharamshala	37.80	37.91	0.11
18.	Shahpur	40.02	44.68	4.66
19.	Kangra	41.31	43.83	2.52
20.	Baroh	45.14	45.05	-0.09
21.	Baijnath	38.10	41.55	3.45
22.	Jaisinghpur	47.11	49.66	2.55
23.	Palampur	37.49	41.82	4.33
24.	Dehra	47.87	47.54	-0.33
25.	Khundian	45.87	48.24	2.37
26.	Rakkar	48.47	47.16	-1.31
27.	Jaswan Kotla	48.30	47.15	-1.15
28.	Jwala mukhi	47.11	48.48	1.37
29.	Jawali	43.81	43.71	-0.10
30.	Fatehpur	45.15	44.86	-0.29
31.	Nurpur	42.50	40.18	-2.32
32.	Indora	42.27	40.23	-2.04
33.	Nichar	14.24	6.76	-7.48
34.	Sangla	1.85	0.46	-1.39
35.	Kalpa	5.78	0.69	-5.09
36.	Moorang	7.49	0.06	-7.43
37.	Pooh	4.80	0.26	-4.54
38.	Kullu	33.46	31.87	-1.59
39.	Manali	7.10	6.94	-0.16
40.	Nirmand	48.84	35.93	-12.91
41.	Banjar	39.05	33.25	-5.80
42.	Lahaul	8.35	0.30	-8.05
43.	Spiti	8.71	3.15	-5.56
44.	Mandi	40.42	47.47	7.05
45.	Chachiot	37.40	31.52	-5.88
46.	Sarkaghat	47.40	48.11	0.71
47.	Sundernagar	39.47	40.46	0.99
48.	Thunag	39.38	20.87	-18.51
49.	Jogindernagar	39.30	41.03	1.73
50.	Lad Bharol	45.07	46.89	1.82
51.	Paddar	40.71	40.97	0.26
52.	Baldwara	40.09	47.27	7.18
53.	Karsog	35.14	37.22	2.08
54.	Shimla(rural)	33.30	19.72	-13.58
55.	Rampur	36.85	15.85	-21.00
56.	Chopal	23.73	19.77	-3.96
57.	Rohru	29.98	1.78	-28.20
58.	Shimla(urban)	29.25	0.01	-29.24
59.	Suni	29.90	38.07	8.17
60.	Theog	23.01	1.21	-21.80
61.	Kotkhai	20.02	0.01	-20.01
62.	Kumarsain	24.53	15.34	-9.19
63.	Jubbal	23.11	0.98	-22.13
64.	Chirgaon	21.31	14.14	-7.17
65.	Dodrakwar	32.51	31.57	-0.94
66.	Nahan	40.10	41.45	1.35
67.	Renuka ji	40.34	35.37	-4.97
68.	Paonta Sahib	42.99	42.66	-0.33
69.	Shillai	47.06	45.05	-2.01
70.	Rajgarh	21.89	9.88	-12.01
71.	Pachhad	32.03	25.71	-6.32
72.	Solan	35.27	20.46	-14.81
73.	Baddi	42.00	45.97	3.97
74.	Arki	36.20	41.50	5.30

75.	Kandaghat	23.52	16.28	-7.24
76.	Kasauli	36.67	35.13	-1.54
77.	Nalagarh	40.30	44.87	4.57
78.	Una	42.81	51.00	8.19
79.	Bangana	45.88	47.69	1.81
80.	Amb	47.18	47.00	-0.81
81.	Haroli	44.14	39.80	-3.94

**Source:** Tehsil wise Lal Kitabs, Himachal Pradesh.

of the state especially eastern and southern, wheat cultivation has significantly declined, owing to the Plantation of apple orchard and more area under vegetable cultivation especially potatoes (Table 1). Fig.4 reveals three categories of negative volume of change and two categories of positive volume of change which are discussed in the proceeding paragraphs.

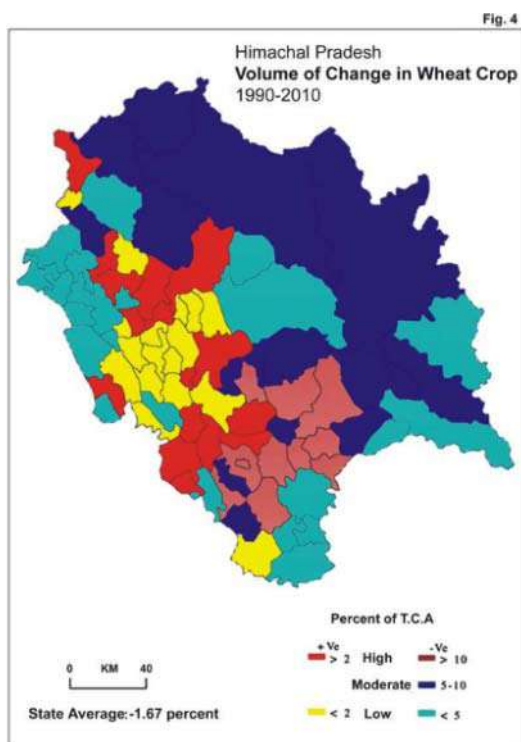
Positive change in wheat cultivation is noted in thirty three tehsils which are mostly lying in the category of high proportion of wheat cultivation during 1990 as well as in 2010. Out of 33 tehsils, 16 tehsils have registered positive change over 2 percent. These tehsils are Bilaspur Sadar, Salooni, Shahpur, Kangra, Baijnath, Jaisinghpur, Palampur, Khundian, Mandi, Baldwara, Karsog, Suni, Baddi, Arki, Nalagarh and Una . While seventeen tehsils have noted less than 2 percent positive volume of change. These are Sh.Naina Devi Ji, Ghumarwin, Dalhausie, Hamirpur, Sujanpur, Bhoranj, Barsar, Nadaun, Dharamshala, Jawala mukhi, Sarkaghat, Sundernagar, Jogindernagar, Lad Bharol, Paddar, Nahan and Bangana . The main reasons for positive volume of change in wheat cultivation in these areas are rugged topography, low rainfall, traditional wheat growing areas, main staple food, development of agricultural infrastructure, existence of

Himachal Pradesh Agricultural University at Palampur, various centre's of agriculture research and extension services, in these areas, etc.

With respect to negative change in wheat cultivation, it is also found low in some of the tehsils which have high percent share of wheat cultivation in 1990 as well as in 2010. These tehsils are lying in the extreme western parts largely confined to the major parts of Una and Kangra district, some tehsils of low negative change are of Sirmaur, Kinnaur and Kullu districts. In all these areas, the change was recorded less than 5 percent.

While high negative change of over 10 percent is registered especially in Shimla district which is due to the fact that is more area is brought under apple and vegetables from wheat. It has led to high negative volume of change in wheat cultivation. Except these tehsils, there are three more tehsils namely, Solan, Nirmand and Thunag which experienced high negative change. In case of Solan tehsil, vegetable cultivation is responsible, while in Nirmand and Thunag both vegetables and fruits are preferred than wheat by farmers and consequently these tehsils have noted high negative change.

The areas with moderate negative change are lying in the districts of Chamba , Lahaul and Spiti and major parts of Kinnaur and tehsils of Chirgaon, Banjar and Chachiot. In this category, the area under wheat cultivation was less than 10.00 percent in 1990, whereas in 2010 it has come down to less than 1.00 percent. The main reasons of moderate change were the popularity of apple orchards and cultivation of vegetables which yield higher economic returns to farmers, less favorable geo-climatic conditions for wheat cultivation, heavy snowfall



(except the tehsils of Chachiot, Banjar) etc. All these factors have created ideal conditions for apple orchards and as a result, farmers have left wheat cultivation. Thus, these areas have experienced moderate volume of negative change in wheat cultivation.

Thus, it is concluded that wheat cultivation suffered mainly owing to the popularity of fruits and vegetables in the state, because the higher reaches are highly suitable for apple orchards and vegetable cultivation. In major parts of the state which are lying below the snowline, vegetables are grown throughout the year. Even in lower and middle Himalaya, the trend of the farmers is turning towards vegetable cultivation owing to setting up of Horticultural University at Solan, development of road network, easy and rising marketing of winter vegetables in

the state as well as in plain areas of Punjab, Haryana and Delhi.

### Conclusion and Suggestions

It is concluded that in 1990, area under wheat cultivation was 39.65 percent which was highly variable throughout the state. It was lowest (1.80 %) in Sangla tehsil and highest (48.74%) in Nirmand tehsil which was largely the result of highly variations in geo climatic, socio-economic, cultural and organizational factors etc. As a result, western parts of the state had registered more than 40 percent area under wheat cultivation whereas eastern parts which are lying in greater Himalayas has less than 20 percent area under its cultivation and the remaining parts of the state has noted moderate proportion between 20 to 40 percent. It is further deduced that the picture has almost remained the same in 2010 with 37.98 percent of the total cropped area under wheat cultivation. Though some areas have noted under wheat cultivation yet wheat has remained as a first ranking crop in Himachal Pradesh in the overall cropping pattern. The category of high share of wheat cultivation has expanded in size in 2010 as compared to 1990, but the moderate category varying between 20 to 40 percent has shrunked in its size. Whereas low category has experienced expansion in its size because it has snatched area from moderate category particularly in Shimla district. The main reason is the increase in area under Apple and vegetables.

Overall decrease of -1.67 percent in wheat cultivation during study period was recorded. But it has registered more declines in Lahaul and Spiti, Kinnaur and Shimla districts. Whereas, area under wheat has increased in the districts of Kangra, Una,

Mandi, Bilaspur and Hamirpur. It is concluded that wheat cultivation is still preferred by farmers in major parts of the state. It is suggested that more agricultural infrastructure should be developed in the state so that area under wheat cultivation can be increased.

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## **Status of Educational Attainments Among Female Population in Haryana, India**

**Mohammad Ishtiyaque, Anita, Md. Israil Khan, Mussarat Jahan**

Social indicators like religion, caste and creed become stronger indices when these are coupled with literacy and education to distinguish between inter and intra social groups. A social group with higher level of educational attainment is considered more active, productive and dynamic than those having low level of education. Higher education is regarded as an important factor to bring about socio-economic changes. Studies show that there exists a significant gap between male and female with regard to the level of education in the developing countries in which female literacy is found very low. The present case study of Haryana, a State adjacent to Delhi confirms the above statement. As per the census of India 1981, female literacy in the State was 22% against 48% for male population. The share of female literacy increased to 33% in 1991, 55% in 2001 and 67% in 2011; still lagging behind by 20% against the male population. It is also to be noted that Mewat District of Haryana registered only 38% female literacy against 73% among males. A general view about low literacy among female population in Haryana is due to cultural taboos. The society is divided into many *Khaps* – small cultural groups, which control social and cultural activities of the society. The *Khaps* do not allow much freedom to women acquire modern education and participate in development programmes. The paper highlights the status of educational attainment among women population in Haryana. In spite of the economically progressive State, the level of higher education among the female population is far behind the expectations or national average. Thus the objective of the paper is also to investigate the reasons behind such a low level of educational attainments among female population in Haryana. The study is based on secondary data derived from the census of India ranging from 1971 to 2011. Education index has been found out for each district separately to understand the district wise differences in educational level among the female population and to highlight the main reasons behind low level of education among them. The study may go a long way to the upliftment of higher education among Haryanavi women and help planners to achieve their goal in educational planning in the State.

**Keywords:** *Social indicator, khap panchayat, educational index, education attainment, honour killing*

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### **Introduction**

Educational attainments may simply be defined as to acquire various levels of formal education such as primary, secondary, and higher education: medical, technical and vocational education and training etc. Countries like ours, in which literacy and education are divided by drawing a hairline between them. Invariably primary educated persons in India who form a larger segment of population may be considered just literate because most of them can only read but unable to express their feelings in writing. The Government has also defined literacy loosely to accommodate larger number of population who can read and write with understandings at the seven years of age group. Because of change in the definition of literacy in the previous censuses, the percentage share of literate persons increased to a satisfactory level in the country. However, primary educated people of India may not be comparable to any of the advanced country's primary educated people.

The government of India is trying to improve the country's education status in order to enhance the standard of living, overcome the problems of poverty and unemployment, achieve social equality and equal income distribution, etc. (Kothari Commission Report 1964-65). Education is believed to facilitate individuals well being and overall socio-economic and other development of the country. It is considered not only an instrument of enhancing efficiency but also an effective tool of widening and augmenting democratic participation and upgrading the overall quality of social life (Goel, 2008).

In spite of all efforts gender inequality in education tends to be more in developing countries which directly or indirectly put

hindrance in economic development and growth (Klasen – 2002; Knowles – 2002). On the other hand gender equality, be it in education or any other social aspects perpetuates economic growth, promotes harmony and basic dignity of human life (Goel and Makhija 2011). The Human Development Report – 1994 highlighted that for all developing countries taken together, the female literacy rate is 29 per cent lower than that of male literacy which may be because of rural-urban disparity, difference in economy, degree of concentration of educational institutions and status granted to female, etc. Because of these reasons the girls in our country are discouraged and not allowed to go for higher, or technical education. As a result, the presence of women in these sectors are insignificant or very low.

The Indian Census data for the last few decades registered such a large difference in literacy between male and female population. A close examination of Census Data reveals that the difference between male and female literacy was higher during the earlier decades especially during 60s and 70s while the gap was reduced gradually during the later part of the 20<sup>th</sup> century. The studies highlight that male-female differentiation in literacy has been narrowing down largely due to opening of schools in the countryside and also due to increasing socio-economic development of rural masses. (U-DISE report 2014).

With regards to the attainment of higher and technical education, it is said that both accessibility to education as well as socio-economic background of individuals held responsible. It is the family/society's vision to allow children to go either for religious education, technical education or higher education. Low socio-economic status of

parent's affects their attitude towards their children's education (Mor, Sethia 2015). India is one of those countries in which a large difference also exists between boys and girls education.

Like many other States in India, Haryana although being a progressive State, also suffers from such a social evil and discrimination between boys and girls education. Girls have many restrictions while boys are given more freedom. Female participation in public domain, such as material control, participation in politics, authority of power in domestic affairs is very much limited in Haryana. This is perhaps due to illiteracy, rigid adherence of conservative cultural values, lack of awareness, poverty, etc. Contrary to the above, proper education and training provide systematic knowledge, develop skills, abilities, character and mental power – all that become tools of empowerment for both men and women. As such quality education is likely to enhance female's economic independence by getting paid employment. The World Bank in its 2001 Report mentioned that "Educating female results in improved productivity, rising income and economic development with a better quality of life-notably at healthier and better nourished population." (world bank report- 2001)

### **Objectives**

The main objective of the study is to find out the educational status of women in the districts of Hayrana. The paper is also trying to highlight the educational differentials between male and female population in the State. The present study has been carried out for both the above objectives under five decades, *i.e.* 1971, 1981, 1991, 2001 and 2011. In the absence of published data, the study did not include 2011 data for the discussion of

women's educational status. Attempt has been made to classify educational status into four groups for the purpose of easy understanding. These categories are: up to middle; senior secondary; graduation and above; technical and professional. The paper also tries to understand the role of *Khaps* with regard to educational attainments among the women in the State of Haryana.

### **Database and Methodology**

The paper is based on secondary data derived from the Census of India for the periods mentioned above. Percentage of literacy and educational attainment for each category was calculated for each district. Finally educational index was worked out by applying a suitable technique which has been discussed in the seventh section of the paper. The values of educational attainments have been classified into three groups (*i.e.* high, medium and low) to show the spatial pattern over the state.

### **Literacy in Haryana**

A general picture of Haryana reveals that 25.71 per cent of its population was literate with 17.77 per cent female and 38.9 per cent male according to 1971 census. It increased to 76.64 per cent in 2011 with 85.38 per cent male and 66.77 per cent female literacy.

As has been already been pointed out that Hayrana had a very low female literacy rate during 1971 as compared to male, but with the economic growth in the State, a significant progress has been made with regard to female literacy. This can be seen from Table - 1 which reveals that female literacy rates in Haryana has made a quantum jump from 1971 to an impressive 66.77 per cent in 2011 (almost 4 times increase). While the male literacy rate too has registered an improvement from 38.90

**Table 1.** District wise Literacy Rate of Women in Haryana (1971 - 2011)

State/ District	1971		1981		1991		2001		2011	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Haryana	38.9	17.77	48.20	22.27	56.08	32.72	78.5	55.73	85.4	66.77
Ambala		30.76	53.03	34.97	62.67	47.23	82.3	67.39	88.5	76.64
Bhiwani		NA	48.13	16.30	57.26	28.29	80.3	53.00	87.4	64.80
Faridabad		NA	52.14	22.93	59.55	33.24	85.1	56.31	89.9	75.17
Fatehabad		NA	NA	NA	NA	NA	68.2	46.53	78.1	59.29
Gurgaon		17.26	48.61	20.02	53.09	27.12	88.0	47.78	90.3	77.64
Hisar		14.02	41.46	16.71	49.83	26.02	76.6	51.08	82.8	62.31
Jhajjar		NA	NA	NA	NA	NA	83.3	59.65	89.4	70.96
Jind		9.17	38.08	12.24	49.47	24.27	73.8	48.51	82.5	61.58
Kaithal		NA	NA	NA	44.40	23.01	69.2	47.31	79.3	60.69
Karnal		17.81	47.27	24.49	54.39	35.24	76.3	57.97	83.7	68.29
Kurukshetra		NA	41.75	21.56	56.89	38.69	78.1	60.61	83.5	69.18
Mahendragarh		11.19	55.52	20.44	61.88	29.61	84.7	54.08	91.3	65.25
Mewat		NA	NA	NA	NA	NA	61.2	NA	73.0	37.58
Palwal		NA	NA	NA	NA	NA	75.1	NA	82.6	56.40
Panchkula		NA	NA	NA	NA	NA	80.9	65.65	88.6	77.48
Panipat		NA	NA	NA	53.90	32.85	75.1	57.97	40.8	68.23
Rewari		NA	NA	NA	66.52	37.70	88.4	60.83	92.9	70.54
Rohtak		20.13	56.44	26.82	62.56	37.32	83.2	62.59	88.4	71.19
Sirsa		NA	39.52	18.88	46.70	27.79	70.1	49.93	78.6	61.16
Sonipat		NA	54.28	25.34	62.87	38.90	83.1	60.68	89.4	70.88
Yamunanagar		NA	NA	NA	57.56	41.26	78.8	63.39	85.1	71.99

Source: Census Reports 1971, 1981, 1991, 2001 and 2011

per cent to 85.38 per cent during the same period, but it was only little more than double.

It is also noteworthy that the increase in the female literacy rate during the decade of 1971-81 was about 10 per cent points. While the growth rate was continued to increase by more than 10 per cent points in every subsequent decade and reached to 55.73 per cent in 2001 and 66.77 per cent in 2011.

However, comparing Haryana's female literacy rates with those of other States, the

picture becomes quite dismal. Despite its immense improvement over the last four decades, Haryana remains among the lower category States as far as the female literacy rate is concerned. At an all-India level, Haryana ranks at 16th place in respect of overall literacy, 20th in male literacy and a lowly 23rd in female literacy. While its literacy rate is higher than the national average, it is significant to note that it is much worse than its immediate neighbours viz. Punjab, Himachal Pradesh and

the Union Territory of Chandigarh.

### **District wise female literacy rate**

Out of seven districts in the State during 1971, the highest literacy rate (30.76 %) was recorded in district Ambala which was considerably higher than the State average (17.77%) whereas the lowest female literacy rate was found in district Jind (9.17%). The female literacy rate in the remaining five districts varied from 11.19 per cent to 20.13 per cent. In 1981, district Ambala once again had the highest percentage (42.80%) literate women whereas the lowest percentage of female literacy was recorded in district Jind (15.23%). The literacy rate of women in other districts varied from 20 to 33 per cent.

A considerable hike of 12.68 per cent in the literacy rate of women was registered during 1991. Ambala again registered the highest female literacy rate (56.62%) while Kaithal district the lowest (28.37%). In the remaining 14 districts women literacy rate ranged from 50.07 per cent to 30.12 per cent in Jind district.

According to the Census of 2001, the female literacy in Haryana increased to 55.73 per cent. Within a span of 10 years an increase of 15.26 per cent was recorded. Out of 19 districts, seven had above 60 per cent female literacy. Ambala district was again placed on the top with regard to female literacy (67.39%), while in the remaining districts, the literacy rate was less than 59.65 per cent.

During the decade of 2011 literacy rate of women in Haryana increased from 55.73 per cent to 66.77 per cent, a rise of 11.04 points. At the district level there has been a remarkable increase in the literacy rate as nine districts of the state had registered above 70 per cent. This time district Gurgaon (77.64 %) took the lead,

followed by district Panchkula (77.48 %) and district Ambala (76.64%). The remaining districts registered less than 75 per cent female literacy. The lowest female literacy rate was registered in the newly created district Mewat with only 37.58 per cent.

### **Educational attainment of Women in Haryana**

Education is an important medium of acquiring knowledge and information. The level of education, especially higher level of education provides dynamism to society and helps in social upliftment. Hence, access to education has been recognized as a fundamental right to both males and females. The role of female education is multipronged. It has the potential of empowering females in several different ways: by equipping them with the awareness and knowledge required to make beneficial life choices, by increasing their ability to access resources and services, by enabling them to become informed consumers and citizens, by inculcating a feeling of self-worth and by increasing their ability to accept challenges among other things.

The educational attainments have been grouped into four categories: (a) up to Middle, (b) up to Senior Secondary, (c) Graduation and above, (d) Technical and Professional Education. Up to the Middle level includes Primary and Middle education, while up to the Senior Secondary level includes Matriculation / Secondary / Higher Secondary / Intermediate / Pre-University. Graduation and above includes graduation, post graduation and research (Ph.D.). The technical and professional education includes Engineering, Medical, Management, etc. The educational levels of women in Haryana have been shown in the following Table-2. It is to be noted that about

Table 2. District wise Women's Educational Attainment in Haryana

State/District	1971			1981			1991			2001						
	Primary and Middle	Matriculation and Higher secondary above	Technical/Professional	Primary and Middle	Matriculation and Higher secondary above	Technical/Professional	Primary and Middle	Matriculation and Higher secondary above	Technical/Professional	Primary and Middle	Matriculation and Higher secondary above	Technical/Professional				
Haryana	9.77	1.41	0.42	0.21	12.51	3.60	1.04	0.4	18.77	6.68	1.93	0.44	25.56	11.54	3.41	0.44
Ambala	16.82	3.24	1.07	0.37	20.11	6.57	2.13	0.73	26.86	11.07	4.67	0.81	31.91	16.16	6.00	0.73
Bhiwani	NA	NA	NA	NA	9.01	1.63	0.45	0.26	15.91	4.53	0.64	0.29	25.39	9.78	1.47	0.41
Faridabad	NA	NA	NA	NA	11.47	5.18	2.01	0.31	17.40	8.65	3.61	0.40	22.59	12.27	5.87	0.37
Fatehabad	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21.80	7.45	1.45	0.26
Gurgaon	9.71	1.40	0.42	0.21	11.11	3.13	0.99	0.32	15.85	6.09	2.24	0.42	19.73	9.78	4.73	0.38
Hisar	7.27	0.83	0.24	0.15	9.45	2.63	0.71	0.29	14.36	4.82	1.25	0.35	22.95	9.73	2.54	0.41
Jhajjar	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	28.59	14.27	2.00	0.58
Jind	4.58	0.43	0.11	0.08	6.85	1.49	0.38	0.19	14.10	4.02	0.78	0.29	22.67	8.37	1.34	0.33
Kaithal	NA	NA	NA	NA	NA	NA	NA	NA	13.47	3.62	0.75	0.24	22.93	7.63	1.52	0.22
Karnal	10	1.54	0.48	0.19	14.10	4.42	1.35	0.42	20.48	6.76	2.59	0.54	27.58	11.60	3.52	0.41
Kurukshetra	NA	NA	NA	NA	13.13	2.89	0.73	0.31	24.25	6.72	2.09	0.44	29.61	12.54	3.56	0.41
Mahendragarh	5.95	0.37	0.08	0.07	11.65	1.72	0.37	0.22	17.88	3.66	0.43	0.23	28.57	8.62	1.07	0.25
Mewat	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Palwal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Panchkula	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	24.71	15.86	11.36	0.95
Panipat	NA	NA	NA	NA	NA	NA	NA	NA	18.75	6.97	1.98	0.43	25.99	12.90	3.74	0.37
Rewari	NA	NA	NA	NA	NA	NA	NA	NA	23.14	6.10	1.08	0.26	31.03	12.49	2.18	0.38
Rohatak	11.42	1.55	0.38	0.33	14.35	4.52	1.21	0.63	20.97	8.79	1.73	0.60	26.68	15.89	4.73	0.85
Sirsa	NA	NA	NA	NA	10.71	2.58	0.53	0.29	15.65	4.80	1.11	0.39	23.46	8.65	2.04	0.33
Sonapat	NA	NA	NA	NA	13.87	4.57	0.99	0.6	21.29	10.44	2.43	0.63	26.92	14.97	3.03	0.65
Yamunanagar	NA	NA	NA	NA	NA	NA	NA	NA	25.4	7.87	2.43	0.55	31.17	13.90	4.12	0.41

Source: Census Report 1971, 1981, 1991 and 2001.6.2 Senior Secondary Education

10 per cent female were found educated up to the Middle level in 1971 which has been increased to about 26 per cent during 2001. Technical education remained very low while the trend of increase under senior secondary and graduation levels were found around 10 per cent points only.

The educational attainment of women at different levels for each district has been presented in the following paragraphs:

### **Middle School Education**

The trend of women's educational attainment up to middle level remained the highest in district Ambala for all the three decades. While the lowest percentage was found in the districts of Jind (during 1971-81), Kaithal (during 1991) and Fatehabad (during 2001) respectively. It is to be noted that in no case the percentage of female educational level crossed the limit of 31 per cent under this category.

The trend of educational level of women under this category varied from 1.41 per cent in 1971 to 11.54 per cent in 2001 in Haryana. The district-wise trend shows that district Ambala recorded the highest percentage in all the four decades while Mahendragh was found the lowest followed by Jind, Kaithal and Fatehabad during 1971-2001.

### **Graduation and above Education**

At Graduation and higher level of educational attainment among the women population in the State was 0.42 per cent during 1971. The table reveals that the highest percentage under this category was found in district Ambala during all the four decades while the lowest percentage was found in district Mahendragargh in all the four decades. In the remaining districts, it ranged from 0.11 per cent

to 5.87 per cent.

### **Technical and Professional Education**

Technical and professional level of educational attainment among women in Haryana during 1971, 1981, 1991 and 2001 were found disappointing. The table reveals that during 1971, the total percentage of women in the State who had some kind of technical and professional educational qualification was only 0.21 per cent. In all the districts of the State the level of technical and professional education remained less than one per cent during all the four decades. District Panchkula, Rohtak and Ambala acquired the higher position under this category (Fig. 1).

### **Index of Educational Status of Women**

As has already been pointed out that the female literacy rate in our country lagging far behind than the male literacy rate because of a variety of historical, social and economic factors. Due to the prevalence of prejudices and social milieu against women's education, they are not allowed much mobility and granted relatively low status in the society. Economically, the appalling poverty and low degree of occupational participation among women are the factors for wide disparity in the male-female literacy rates. The increasing social awakening and male literacy have stimulated female literacy directly as well as indirectly. The efforts through National Policy for Empowerment of women has also created an environment for all round development of women and enable them to realize their full potential (Godyal and Makhija, 2011). Haryana has shown increasing trend of literacy among female population but seems lagging behind in educational attainments as compared to surrounding states. To assess the various levels

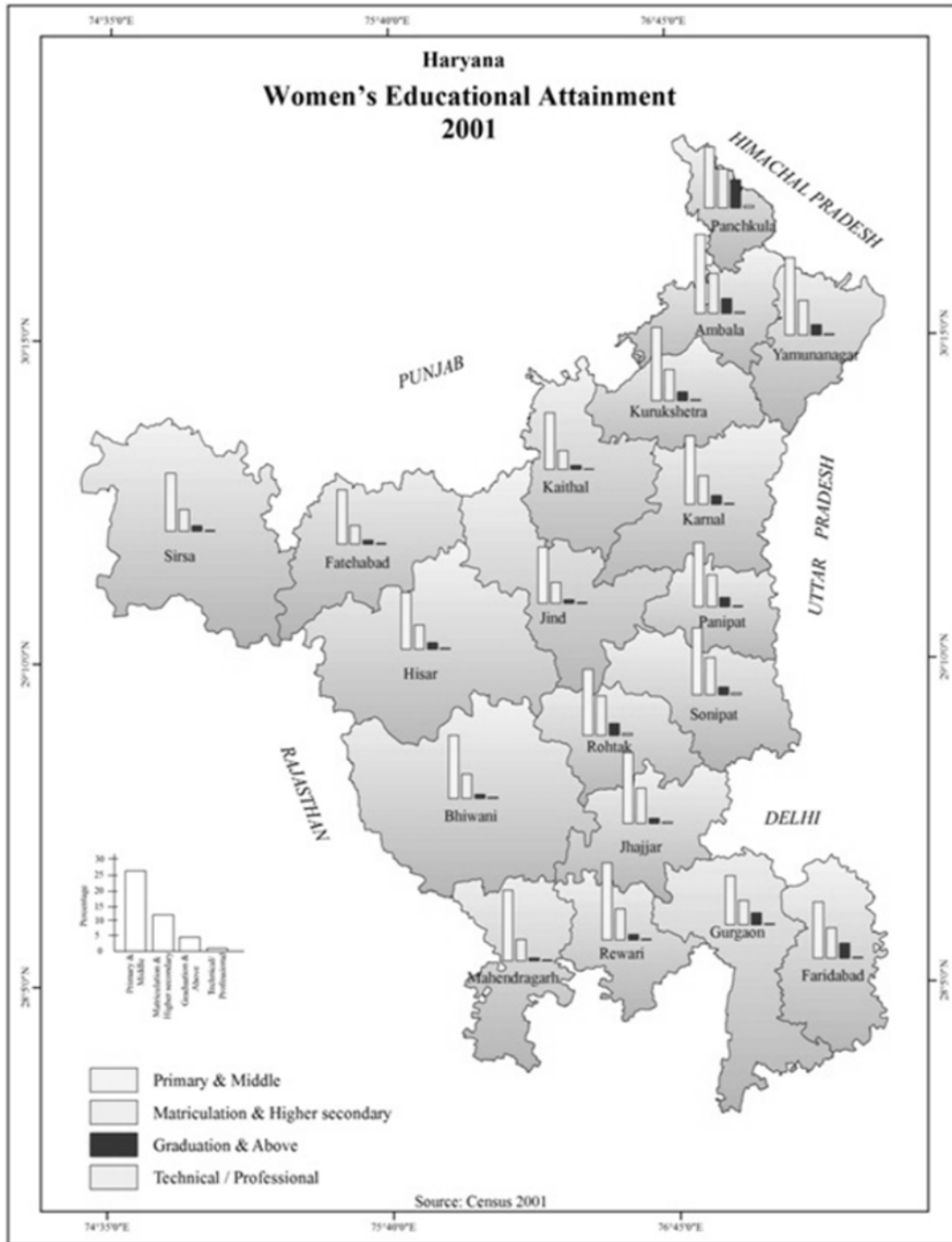


Fig. 1.

of educational attainments among the women, an index of educational attainment for each district has been calculated by using the following formula.

Education index for each district has been calculated as  $\frac{x_i}{\bar{x}}$ ,  $i > 1, 2, 3, \dots, n$

$$\text{where } \bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

$n$  is number of districts

$x_i > a, 2b, 3c, 4d$

where:

$a$  represents percentage of women up to

**Table 3.** District wise Index of Education among Women in Haryana (1971- 2001)

District	1971	1981	1991	2001
Ambala	1.99	1.81	1.68	1.38
Bhiwani	NA	0.62	0.71	0.83
Faridabad	NA	1.24	1.19	1.07
Fatehabad	NA	NA	NA	0.68
Gurgaon	1.04	0.92	0.92	0.89
Hisar	0.73	0.77	0.74	0.84
Jhajjar	NA	NA	NA	1.06
Jind	0.43	0.5	0.65	0.72
Kaithal	NA	NA	0.61	0.71
Karnal	1.09	1.22	1.11	1.02
Kurukshetra	NA	0.95	1.16	1.08
Mahendragarh	0.51	0.73	0.69	0.81
Panchkula	NA	NA	NA	1.53
Panipat	NA	NA	1.02	1.04
Rewari	NA	NA	1.00	1.04
Rohtak	1.21	1.26	1.17	1.23
Sirsa	NA	0.79	0.76	0.78
Sonipat	NA	1.21	1.32	1.11
Yamunanagar	NA	NA	1.28	1.18

Source: These calculated values have been derived by using the given formulae.

Middle level of education,

$b$  represents percentage of women up to Senior Secondary level of education,

$c$  represents percentage of women in Graduation and higher level of education,

$d$  represents percentage of women in technical and professional education.

Table 3 shows district wise education index of women in Haryana during the decades of 1971, 1981, 1991 and 2001. During 1971, the index of educational status of women in the State varied from the highest 1.99 in district Ambala to the lowest in district Jind 0.43. The districts of Rohtak (1.21), Karnal (1.09), Gurgaon (1.04), Hisar (0.73) and Mahendragarh (0.51) had been at 2nd, 3rd, 4th and 5th places, respectively in the index of the educational status of women in Haryana.

In 1981, the highest education index of women in the State was found in district Ambala (1.81) and the lowest in district Jind (0.50). In the districts of Faridabad, Rohtak, Karnal and Sonipat, the education index varied between 1.26 and 1.21 which were comparatively higher than the other districts in the State. It was interesting to note that districts of Kurukshetra and Gurgaon with higher economic level fell under the group of Sirsa, Mahendragarh, Hisar and Bhiwani districts in which the education index varied between 0.62 and 0.95 (Fig. 2). In the districts of Ambala and Gurgaon, the education index point of women decreased while in the districts of Hisar, Mahendragarh, Jind, Karnal and Rohtak the education index of women slightly increased.

During 1991, the highest education index was again recorded in district Ambala (1.68). The lowest education index of women was found in district Kaithal (0.61). In the districts of Sonipat, Faridabad, Yamunanagar, Karnal,

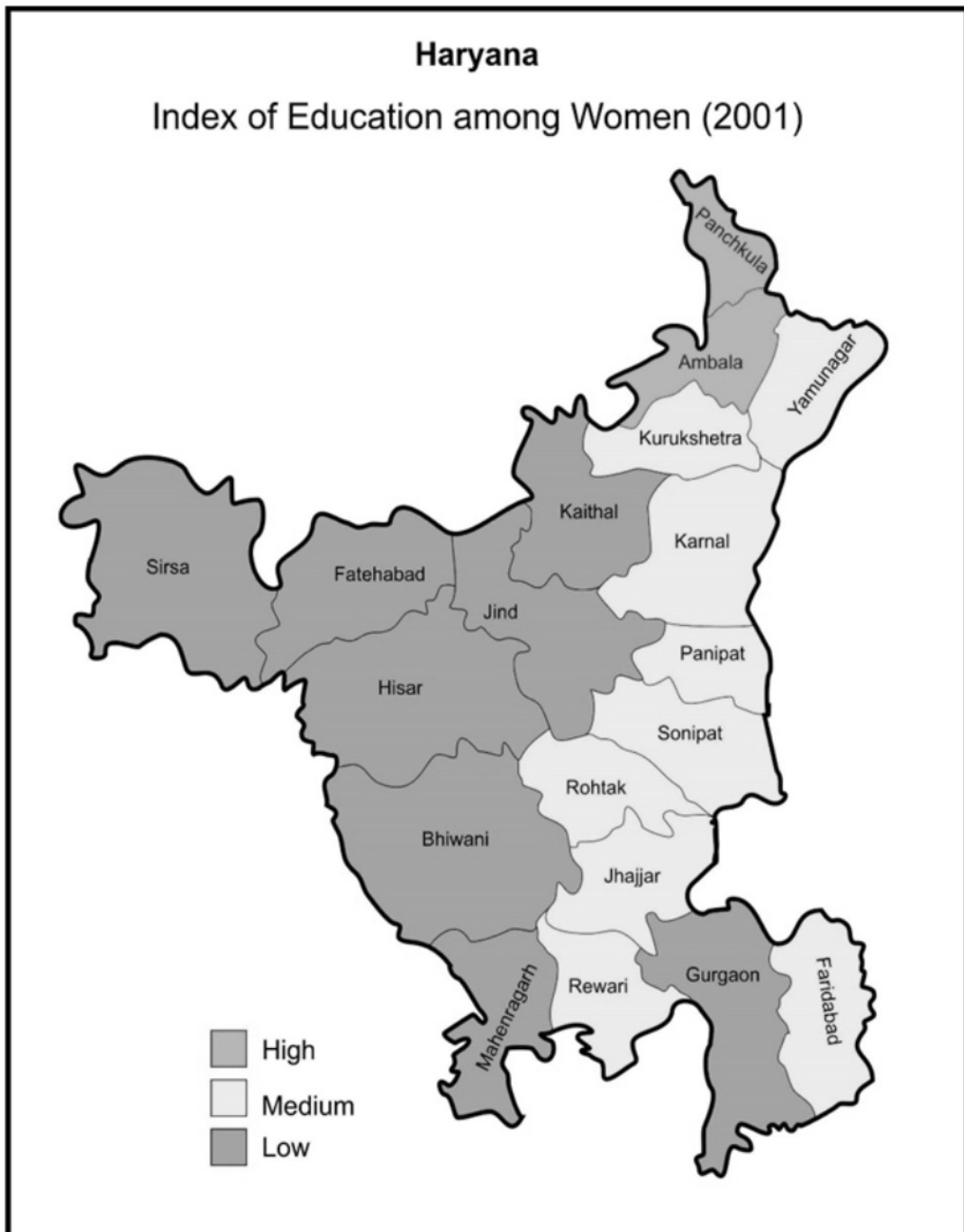


Fig. 2.

Kurukshetra, Panipat, Rohtak and Rewari the education index of women ranged between 1.00 and 1.32. In the districts of Gurgaon, Hisar, Sirsa, Mahendragarh, Jind, Kaithal, Bhiwani the education index of female varied from 0.61 to 0.92. The education index of women declined in the districts of Ambala, Faridabad, Hisar, Karnal, Mahendragarh, Rohtak and Sirsa marginally. In the districts of Bhiwani, Jind, Kurukshetra and Sonipat, the education index of women improved slightly.

During the decade of 2001, district Panchkula (1.53) registered the highest education index of women in the State followed by district Ambala (1.38) at the second place. In the districts of Yamunanagar, Sonipat, Rohtak, Rewari, Panipat, Kurukshetra, Karnal, Jhajjar and Faridabad the female education index varied from 1.02 to 1.23 while in the districts of Sirsa, Bhiwani, Gurgaon, Fatehabad, Mahendragarh, Kaithal and Jind the education index of women remained below 1.00.

It is also to be noted that in the districts of Yamunanagar, Sonipat, Karnal, Kurukshetra, Faridabad, Gurgaon and Ambala the female education index declined in comparison to the last decade whereas in the districts of Bhiwani, Hisar, Mahendragarh, Panipat, Rewari, Jind, Rohtak and Kaithal some gain in the education index was registered during 2001.

It is noted that in spite of the forceful intervention by the government and several NGOs and above all, the United Nation's enormous pressure with regard to the upliftment of women education, both the country and many States including Haryana could not come up to the expected results. As has already been mentioned, that a number of reasons are responsible for slow progress in the development of higher education in the

country in general and Haryana in particular. Among others, *Khap diktat* is considered a major factor for poor show with regard to educational status in the State.

### Role of Khaps

*Khap* is a community organization which has no government recognition, but can exert significant social influence within their community. Although the *Khap Panchayats* have no constitutional right, they enjoy full legitimacy and authority among the segments of their caste and consider themselves as the custodian of honour. The *Khaps* are self proclaimed courts. (Rajpurohit, Prakash 2015).

The main role of the *Khap* is to maintain peace and harmony between various *Khaps* by settling disputes and passing resolutions related to the social welfare and reinforcing traditional value system. *Khap panchayat* imposes its order through social boycotts and imposing fines or forcing the victims to commit suicide (Chowdhary, 2004). In some Haryana villages, the young girls are routinely threatened, abused and killed all under *Khap* verdicts. In an adverse situation the families had to feed pesticide pills to the teenage girls and then dispose off their bodies in order to avoid *Khap* verdicts. Honour killing of young couples is common on defying *Khap* rules. Sangwan believes that this is a land in which the rule of men prevails rather than the rule of law. (Sangwan, 2010). As such the question of rights for women does not exist anywhere in the territories ruled by *Khap panchayats*. Even the government could not do much to control their power.

Randhir Singh, member of *sarv Khap Panchayats* of Meham Chaubisi has on record stated that, "our predecessors have laid down rules, the lines along which life ought to be lived.

Women, if they overstep and if they are driven by their desire may end up being murdered. 1984. He has further stated that co education is ruining the lives of girl. It is due to education that the society is witnessing the transgression of *maryada* by women which is ultimately leading to chaos. Another member of *sarv khap*, Sri O.P. Dhankar has even went a step ahead and said that women are bound by certain boundaries of society. No one can overstep it (Sawhney, 2012). On the other hand males are allowed some relaxation while women are never allowed to bend the rule. Sometimes rules are bend for the boys but for the girl rules are never allowed to bend . Some schools are also forced to have separate timings for the boys and girls. Fearing their daughters would go astray, many parents marry them off at an early age, which ultimately affect the status of their educational attainments.

### Conclusions

The study highlights decadal variations in the female literacy, educational status and the index of educational attainments of women in Haryana. The above indicators are important to determine the overall status of women with regard to women empowerment emphasizing their role in the family, society and work place. They have been living under conditions of social and economic inequality despite the fact that they constitute half of the work force in the rural areas and participate actively in household and other socio-economic spheres in urban areas. Still women are not able to achieve equal status and not perceived as equal partners in social and economic activities both at the national and state level in India.

The study reveals that women literacy was very low in Haryana during the early 20<sup>th</sup> century but a significant change was recorded

during the recent decades. A jump of six fold increase was registered as against the male literacy which was registered to two folds only.

The people of the state are aware of the importance of education of girls but they are not in favour of sending their girls for higher education as most of them are expected to help in the household chores and look after the siblings. The custom of getting the girls married at an early age still prevails due to social pressure especially due to honour killing, dowry and illiteracy. Most of the girls do not complete their education and drop out from the schools after primary education. As such the attainment of higher education in the state is quite low. Ambala and Faridabad districts took the lead in higher education while in technical education, Ambala and Panchkula recorded the highest share.

It is unfortunate that the state has got very low level of education index for women. Half of the total districts of Haryana have got less than one point of the index value. Ambala and Panchkula scored fairly good points as compared to other districts.

It also needs to mention with much surprise that in spite of economic development, the state of Haryana suffered with a very low sex ratio. Although a little increase was observed during 2011, the state recorded only 877 females per 1000 males. It clearly indicates biased and hostile attitude against female child in the state. The *Khap panchayats* are highly patriarchal in nature and can mobilize a large number of people on the basis of family, *gotra* / community and villages to exert political pressure on the government to get their demands fulfill. For example the *Jat* quota agitation during February 2015 has exposed the government and the law and order machinery

of the State got simply collapsed during the agitation. It clearly shows the dictate of the *khaps* in the state. The cases like Murthal incident and various episodes of such violence against women specially belonging to lower sections witnessed the failure of Haryana administration (Gurtoo, 2016).

### Suggestions

It is essential that the educational status of women in Haryana should be allowed to improve so that women are guaranteed equal rights with their counterpart. The Government should take strong decisions and implement the laws strictly in favour of women's cause and safeguard of their interest. The strict administrative action against culprits will bring attitudinal change in the society. It will also change the patriarchal mind-set of people and

recognize women as equal partners which will promote their status in the society.

Finally, it may be concluded that without improvement and achieving the higher educational status of women in Haryana the concept of gender equality, freedom, participation in social, political and economic activities will remain a dream in the society. Therefore, there is an urgent need to release the burden of dictate of *Khaps* and provide all kinds of opportunities and protection for the safeguard of the women to participate in the nation building process in the country.

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# **Spatial Inequality in Health Care Infrastructure in Allahabad District: A Geographical Study**

**Amit Kumar Singh and V. K. Kumra**

Health is a fundamental human right and central to the concept of quality of life. Due to various socio-economic and political factors, there exists a widespread inequality in the distribution of health care facilities in India. The present study attempts to highlight the existing health care infrastructure and also tries to analyse the inter-block disparities regarding health care facilities in Allahabad district. To identify the regional disparities of health care infrastructure three broad categories have been identified i.e. availability of health care infrastructure, performance of public health care centres and accessibility to healthcare services. There is found considerable shortfall in the existing and required number of Primary Health Centres and manpower under the public health system in Allahabad district. Nearly 80 per cent of the total area of Allahabad district is suffering due to very poor health care infrastructure. Only four development blocks viz. Shankargarh, Phulpur, Chaka and Meja have relatively better health care facilities than the rest of the district. Analysis of block level disparities in health care infrastructures would help to identify specific deficiencies and suggest corrective measures to improve the healthcare system in the district for achieving the goal of 'Health for all'. The state government needs to adopt viable policies and programmes and take some immediate actions to improve the health care infrastructure in Allahabad district.

**Keyword:** Disparities, healthcare infrastructure.

## **Introduction**

Health is not just the absence of disease. It represents both physical and mental capability for healthy living. Health is an important dimension of well-being and essential factor of development. Knowledge and understanding of healthcare services are necessary for health resource allocation and planning (Joseph and Phillips, 1984). Health care is a social determinant as it is influenced by social policies. One of the basic objectives of Eleventh Five Year Plan was to achieve good health for

people, especially the poor and the underprivileged. In view of this, the department of Health and Family Welfare has focused its attention on improving the state of primary health services by channelizing adequate financial and manpower resources to make healthcare services more accessible and affordable particularly to the poor people.

The regional inequality in India exists at all levels. It is now a matter of great concern amongst researchers and policy makers even though the basic goal of our economic planning

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has been to identify undernourished sector and eliminating regional imbalances for balanced development of the country. The variation in different indicators of development in various regions may be attributed to the variation in policy perspectives, historical background, and uneven distribution of the resources (Dadibhavi *et al.*, 2006). A number of studies have been conducted dealing with regional disparities and level of development at micro and macro levels using a number of development indicators. Debapriya and Mohanthy, (2000), analysed variation in level of development and found glaring disparities in socio-economic sector at inter and intra-regions. Wang (2007) used composite index and various social and economic indicators to measure the level of development for different provinces of China. Shaban and Bhole (1999) used **Principle Component Method** (PCM) to assess the level of development in different districts of Maharashtra, using different indicators and variables. In fact, after independence of the country, the health infrastructure of Allahabad district has expanded manifold, still the physical health infrastructures are inadequate to extend quality health services to all the people. The present paper attempts to investigate micro level (block) disparities in availability of healthcare facilities in Allahabad district. The study is likely to be helpful for administrators, policy makers and planners to curb the existing problem and promote the balanced development particularly at micro level.

### **Review of Literatures**

Health is an essential input for the development of human resource and the quality of life and in turn the social and economic development of the nation (WHO, 1978). The health care as a constitutive element of well-

being and yet it has been one of the most neglected aspects of development in India (Dreze and Sen, 2005). Just as health status is influenced by the socio-economic factors, similarly health services are shaped by the socio-economic and political factors of any region (Baru *et. al.*, 2010). Inequality in the distribution of health care facility is a common manifestation of these factors and a general feature of health care system in India. According to Rajeshwari and Sinha (2004), the distribution of health care institutions in India is influenced by locational preference. Public health is nothing but, the practice of preventing disease and promoting good health within groups of people, from small communities to entire country (Pradad, 2013). Gill (2009) in his study concluded that the National Rural Health Mission (NRHM) is on the right track of addressing the rural health care with the institutional changes it has brought within the health system. But there are problems in implementation, so that delivery is far from what it ought to be with respect to physical infrastructure, medicines and funding. Lewando Hundt *et. al.* (2012) in their study observed that there are issues of accessibility in terms of distance, and of acceptability in relation to lack of local and female staff, lack of cultural competencies and poor communication. Also they found that provision of accessible and acceptable health care in rural areas poses a challenge to health care providers and these providers of health care have a developing partnership that could potentially address the challenge of provision to this rural area. In this context, an attempt is made to examine the spatial distribution of health care infrastructure in Allahabad district. It is not surprising that there is a tremendous pressure on existing health care system to meet the need of vast

population. Hence an assessment of available resources is imperative for proper allocation and efficient utilization of health care services.

### Study Area

The district of Allahabad ( 24°47' N to 25°47' N latitudes and 81°19' E to 82°30' E longitudes) covers an area of 5,246 km<sup>2</sup>. It is located in the southern part of Uttar Pradesh. The northern part of the district lies in the Gangetic Plain whereas southern part comes under the Vindhyan Plateau. To its south and south-east is the Bagelkhand region, to its north and north-east is the Awadh region, and to its west along with Kaushambi it forms the part of Doab i.e. the lower Doab region. Allahabad district is surrounded by the districts of Bhadohi and Mirzapur in the east, Kaushambi and Banda in the west, Pratapgarh and Jaunpur in the north and Banda and Madhya Pradesh in the south. The River Ganga and Yamuna flow through the district. The mainstay of economy is primarily agriculture. The region is characterized by fast growing population, lack of appropriate transportation, adequate health care delivery and education.

### Objectives

The main objectives of the present study are as follow:

- i. To evaluate the existing infrastructure for health care services in Allahabad district.
- ii. To assess the inter-block variations in health care facilities in the study area.
- iii. To find out the regional pattern in the distribution of health care infrastructure of Allahabad district.

### Data base and Methodology

The present research work is entirely based on secondary sources of data collected from Census of India, 2011 and Bureau of

Applied Economics and Statistics, Government of Uttar Pradesh, for the year 2011. Studies conducted for the measurement of regional disparities have used different indicators for classifying reasons for assessing relative level of development. The indicators are different and heterogeneous across the community development blocks of the district. Infrastructure can be measured either in terms of investment towards a particular service or in terms of physical quantity of the services available to the end users. In the present study twelve indicators of physical infrastructure services have been considered to find out the Healthcare Infrastructure Index (HII) for Allahabad district. Table 1 shows the selected indicators of health care infrastructure. These are grouped in three categories under different heads: i. Availability of health care facilities, ii. Performances of public health care centres, and iii. Accessibility to health care facilities.

In the present work community development blocks have been taken as the unit for study. The detailed methodology for preparing Healthcare Infrastructure Index (HII) is described below:

$$I_{ij} = \frac{(X_{ij} - \text{Min}X_{ij})}{(\text{Max}X_i - \text{Min}X_{ij})}$$

$I_{ij}$  is the infrastructure indicator for the  $j^{\text{th}}$  block with respect to  $i^{\text{th}}$  variable and  $X_{ij}$  represents the value of the  $i^{\text{th}}$  infrastructural development indicator in  $j^{\text{th}}$  block,  $\text{min} X_{ij}$  and  $\text{max} X_{ij}$  are the minimum and maximum values of  $X_{ij}$  respectively. However, if  $X_{ij}$  is negatively associated with the status of infrastructural development,  $I_{ij}$  can be defined as:

$$I_{ij} = \frac{(\text{Max}X_{ij} - X_{ij})}{(\text{Max}X_i - \text{Min}X_{ij})}$$

To find out the level of development of

**Table 1.** Selected indicators of Health care Infrastructure of Allahabad district

<b>Availability of Healthcare Infrastructure</b>	X <sup>1</sup>	Doctor-population Ratio
	X <sup>2</sup>	Population served per Primary Health Centre (PHC)
	X <sup>3</sup>	Population served per sub-centre
	X <sup>4</sup>	Number of Medical institutions per 1,00,000 population
	X <sup>5</sup>	Number of beds per 1,00,000 population
<b>Performances of public health care centres</b>	X <sup>6</sup>	Percentage of indoor patients to total indoor patients of Allahabad district
	X <sup>7</sup>	Percentage of outdoor patients to total outdoor patients in Allahabad district
	X <sup>8</sup>	Percentage of immunization to total immunization of Allahabad district
	X <sup>9</sup>	Percentage of institutional delivery to total institutional delivery of Allahabad district
<b>Accessibility to Healthcare infrastructure</b>	X <sup>10</sup>	Number of Medical institutions per 100 sq. km.
	X <sup>11</sup>	Number of sub-centres per 100 square kilometres.
	X <sup>12</sup>	Percentage of villages with nearest PHC within 5 km ( If not available within the village)

Source: Computed by Author

health care infrastructure, Healthcare Infrastructure Index (HII) has been computed. It is calculated by taking a simple average of the chosen indicators. It may be algebraically expressed as:

$$HII_{ij} = \frac{\sum_{i=1}^n I_{ij}}{N}$$

Where, N represents total number of selected indicators for healthcare infrastructure and HII<sub>j</sub> denotes the Health Care Infrastructure Index for j<sup>th</sup> block. The high values of HII<sub>j</sub> indicate high level of development and vice versa.

### Results and Discussion

Sound health infrastructure ensures efficient and effective utilization of essential public healthcare services. The totality of the public healthcare infrastructure includes all governmental and non-governmental entities that provide public healthcare services to the

people.

#### Availability of health care facilities:

The doctor-population ratio is perhaps the most important factor affecting the healthcare facility in a particular area. Allahabad district has acute shortage of doctors and also there is huge variation in population served per doctor. In 2015-16, population served per doctor in Siadabad block was 42,194 while for Kaudhiyara it was 1,59,700. Table 4 depicts the overall scenario regarding doctor-population ratio in the study area which is quite frustrating. Since independence India initiated planning process for overall development of the country including raising the standard of living of the people. In such programmes, one of the initiative was establishment of Primary Health Centres (PHC) with three sub-centres and four to six beds per Primary Health Centre in community development block (Reddy *et.al*, 2013). PHCs are the most important peripheral

**Table 2.** *Population-PHC Ratio in the Blocks of Allahabad District (2015-16)*

Size of population served per PHC	Name of the development blocks
Below 30,000	—
30,000-50,000	Bahadurpur, Pratappur, Saidabad, Handia
50,000-70,000	Mauaima, Soraon, Jasra, Shankargarh, Dhanupur, Meja, Uruwan, Manda, and Koraon
70,000-90,000	Kaurihar, Karchhana
90,000 and Above	Holagarh, Bahria, Phulpur, Chaka and Kaudhiyara

Source: Computed by the Author

**Table 3.** *Population-Sub-centres Ratio in the Blocks of Allahabad District (2015-16)*

Size of population served per Sub-centres	Name of the development blocks
Below 5,000	—
5,000-7,000	Jasra, Shankargarh, Holagarh and Kaudhiyara
7,000-9,000	Meja, Uruwan, Manda, Pratappur, Karchhana, Chaka, Mauaima, Soraon, Bahria, Phulpur and Bahadurpur
9,000 and Above	Kaurihar, Dhanupur, Saidabad, Handia and Koraon

Source: Computed by Author

health service institutions. Unfortunately, not a single block has been found where less than 30,000 persons are served by one PHC. In contrary to this, there are five blocks namely, Kaudhiyara, Phulpur, Chaka, Holagarh, Bahria where population served per PHC is more than three times than the existing norm. Out of the twenty development blocks there are sixteen blocks where the average number of people served by one PHC is more than 50,000. Table 2 reflects very poor condition of health care system in the Allahabad district.

The average population served by one sub-centre in Allahabad district is 7,932. In Jasra, Shankargarh, Holagarh, Kaudhiyara block on an average one sub-centre provides services to 5,000 to 7,000 persons which is much

higher than the existing norm of 3,000 persons per Sub-centres. However it is evident from the Table 3 that not a single development block in the study area fulfill the norms.

In the present analysis medical institutions include district and sub-divisional hospitals, rural hospitals, PHCs etc. It does not include sub-centres as they provide only minor health care facilities. The availability of medical institutions is measured in terms of number of medical institutions per 1,00,000 population. It is highest in Mauima block (3.77) followed by Handia (3.76) development block. Chaka (1.36) is the most poorly served block where 1,00,000 persons are served by less than one medical institution.

Population served per bed is also an

important indicator of health. Total number of beds available in Allahabad district in medical institutions is measured in terms of beds per one lakh population. It is highest in Jasra (20.97) and lowest in Holagarh block (3.28). Table 4 highlights that there are three blocks where number of beds per 1,00,000 persons is less than just ten. It reflects that as far as beds availability in the district is concerned, the condition is miserable.

**Performance of hospitals, PHCs and Sub-centres:** To measure the performances of public healthcare system, four indicators have been identified (Table 1). The performance of a healthcare unit can be expressed in terms of relative population pressure in the concerned unit. The numerical figures regarding performances of public healthcare centres are defined in terms of percentage. The clinical attendance of patients and the use of medical facilities is another important indicator which reflects the utilization of public healthcare services. The clinical attendance of patients has been analysed in terms of indoor and outdoor patients. In case of the treatment of indoor and outdoor patients, Bahadurpur and Kaudhiyara blocks performed very well. Both the blocks have served more than 10 per cent of the total indoor patients of Allahabad district. Meja block has also served a significant number of patients. In respect of indoor and outdoor admission of patients Mauima and Soraon blocks stands at lowest position.

Throughout the world women play significant role in economic growth and development and their contribution have an impact on households, communities and national economies (Aich et.al, 2014). A woman with poor health is more likely to give birth to low weight infant. Also they are less likely to be able to provide healthy food and adequate care

for their children (Reddy, 2013). One of the most important indicators of safe motherhood is the extent of institutional delivery. In respect of institutional delivery Shankargarh, Jasra, Bahadurpur, Kaurihar, Dhanupur and Meja development blocks have achieved a considerable success in recent years. The overall performance of Allahabad district is far behind the target of 100 per cent institutional delivery. Moreover, there are substantial variations in the extent of institutional delivery across the blocks. Shankargarh block ranked first with 8 per cent of the total institutional delivery in the district, while Soraon is at the lowest position with only 2.9 per cent of the total institutional delivery of the study area.

Immunization programme aims to reduce mortality and morbidity. Since time of independence emphasis has been given to preventive aspect of health care and it is well known that the prevention is better than cure (Trivedi, 2014). Universal Immunization Programme (UIP) was launched for the first time in India in the year 1985 to control diseases like Measles, Diphtheria, Tetanus and childhood Tuberculosis. The analysis reveals that there is found wide differences in level and distribution of childhood immunization within development blocks of the Allahabad district. As far as, immunization of children is concerned favourable achievement has been observed in Kaudhiyara and Saidabad blocks. Other good performing blocks are Bahadurpur, Manda and Bahria block is found to be worst performing blocks.

**Accessibility of health care infrastructure:** Accessibility to healthcare facility can ensure better health condition for the people living in rural areas. Table 5 reveals that Mauima block ranks first with relatively higher number of medical institutions per 100

sq.km. Here one medical institution serves 21.60 sq.km. Handia and Soraon blocks occupy second and third positions respectively where one medical institution serves 24.57sq.km and 27.16sq.km of area respectively. In all other blocks the number of medical institutions per 100sq.km is less than three and in Meja and Koraon the number is reduced to 0.92 per 100 sq.km and 0.99 per 100 sq.km. respectively. Though sub centres provide only minor health care facilities but it is very important for the rural poor. Soraon has higher accessibility to sub-centre as it is located at a distance of 5.43 sq.km from each other, while 20.79sq.km is recorded highest spacing in Koraon block.

Out of the total 2809 villages of the Allahabad district, only 93 villages are directly enjoying the facilities of PHCs/Sub-centres as they are located in their villages. Only 50 per cent villages lie within 1 km, 1-3 km and 3-5 km from health centres. But most of the villages (1225) lie far away from PHCs. Thus to increase the accessibility of these villages the connecting roads to PHCs should be made pucca. Availability of telephones and ambulances at PHCs/CHCs must be provided. These facilities should be in operational so that the needy person may take the benefits of these available facilities more easily. In case of accessibility of healthcare facilities within a distance of 5 km from village, the situation is satisfactory in blocks like Kaudhiyara, Uruwan, Manda, Bahadurpur, Kaurihar, etc. where more than 70 per cent villages have greater accessibility to healthcare facilities.

**Kendall's coefficient of concordance (W) to study the degree of association among parameters:** Kendall's coefficient of concordance (W) has been used to determine the degree of association between various parameters (k), for the 20 development blocks

(N) of Allahabad district. Value of Kendall's coefficient of concordance (W) is 0.2479. As, N (i.e. number of objects) is larger than 7, value of chi-square ( $\chi^2$ ) has been procured to determine the significance of W. Table value of  $\chi^2$  at 5% level of significance for (N-1= 20-1=19) 19 degrees of freedom is 28.869 but the calculated value of  $\chi^2$  is 53.546 which is considerably higher than the tabulated value. Twelve sets of ranking of selected parameters are calculated which is elaborated in Table 5. This rejects the null hypothesis that twelve sets of ranking of selected parameters are independent and accepts the alternative hypothesis of significance agreement of twelve sets of ranking.

**Overall scenario of health care infrastructure in Allahabad district:** After a detailed analysis of the aforesaid parameters, Health care Infrastructure Index (HII) for each community development blocks have been worked out to assess the status of health care facilities in different blocks of Allahabad district. Table-6 represents the Health care Infrastructure Index (HII) for Allahabad district. It will enable to identify the gaps in infrastructure development in health care facilities at the inter-block level in Allahabad district and also helps to make suggestions for appropriate policy interventions for achieving balanced infrastructure development in the area. There is found a wide range of regional variations in levels of health care development among the blocks of Allahabad district. So far, Shankargarh block with a Composite Index of 0.69 is at the top most position in providing health care services to its common people. It is followed by Phulpur, Chaka and Koraon having the rank of 2nd, 3rd and 4th respectively. On the contrary, the conditions of Bahadurpur, Kaudhiyara and Handia blocks are very poor

**Table 4.** Health care infrastructures and Health care Infrastructure Index (HII) of Allahabad District

Name of Blocks	Availability of Healthcare Infrastructure					Performances of public health care centres				Accessibility to healthcare infrastructure		
	X <sup>1</sup>	X <sup>2</sup>	X <sup>3</sup>	X <sup>4</sup>	X <sup>5</sup>	X <sup>6</sup>	X <sup>7</sup>	X <sup>8</sup>	X <sup>9</sup>	X <sup>10</sup>	X <sup>11</sup>	X <sup>12</sup>
Kaurihar	1:98388	78710	10932	1.78	11.18	5	4.7	6.8	4.9	1.85	9.49	73.66
Holagarh	1:91352	91352	6525	1.64	3.28	3	4.9	4.5	4.4	1.93	18.02	56.67
Mauaima	1:37170	61950	7148	3.77	20.45	1.9	0.9	1.2	3.8	4.63	17.20	70.00
Soraon	1:17562	64394	7727	2.59	18.64	1.7	1.1	3.6	2.9	3.68	18.41	58.65
Bahria	1:90926	90926	8023	1.47	13.93	2.2	5.5	7.4	3.5	1.60	13.60	31.00
Phulpur	1:28128	112511	8036	2.22	15.11	1.6	1.5	2.7	3.3	2.24	12.55	45.89
Bahadur-pur	1:49250	49250	7776	2.37	4.74	17	12.1	8.2	6.9	2.68	14.57	84.71
Jasra	1:21463	57234	5723	2.91	20.97	2.2	4.5	1.6	7.1	1.90	11.41	49.53
Shankar-garh	1:54503	54503	5450	3.06	20.79	2.3	2.3	2.2	8	1.09	6.55	16.04
Chaka	1:20041	110224	8479	1.36	15.42	2.1	4.6	2.7	4.3	1.96	17.00	38.24
Kaudhi-yara	1:31940	159700	6654	1.88	20.04	10.7	6.4	9.4	4.8	1.51	12.05	96.30
Karchhana	1:39271	78542	8125	2.97	15.28	5.1	1.1	3.6	3.8	2.73	11.32	35.83
Pratappur	1:44946	44946	8026	2.67	18.69	6.7	6.2	6.7	4.5	2.68	12.50	56.92
Dhanupur	1:58115	58115	9686	2.15	17.21	3.4	6	5.4	6.7	2.84	13.64	73.96
Saidabad	1:50633	42194	9737	2.76	4.74	5.3	6.2	8.5	5.6	2.81	10.44	56.33
Handia	1:21257	42513	9242	3.76	18.82	4.7	8.8	3.8	6.4	4.07	11.70	56.59
Meja	1:65695	65695	7039	2.03	18.27	5.2	9.2	3.6	4.7	0.92	6.41	50.00
Uruwan	1:33938	67876	7542	2.46	17.68	6.7	6.9	5.7	4.1	2.66	14.39	95.51
Manda	1:65806	65806	7051	2.53	18.24	7.9	2.7	7.5	4.6	1.45	8.10	89.88
Koraon	1:79184	63347	9316	2.21	12	5.3	4.4	4.9	5.7	0.99	4.81	31.37

Source: Computed by the Author.

with respect to health care services. Table 7 portrays the overall scenario regarding health care infrastructure of Allahabad district.

#### Level of Development of Healthcare Infrastructure

This level of variation in health care infrastructure may be arranged into three grades i.e. high (above 0.65), medium (0.49-0.65) and low (<0.49). Table 7 and Fig. 2 depict

the imbalances in the level of health care infrastructural development in Allahabad district. In this area, three blocks (15%) have achieved relatively advantageous position and thirteen blocks (65%) have performed at medium level with respect to health care infrastructure. Out of twenty blocks of Allahabad district, four blocks (20%) reflect low level of health care infrastructure. Poor

**Table 5.** Block wise Rank for Health care Infrastructure in Allahabad district

Name of Blocks	Availability of Healthcare Infrastructure					Performances of public health care centres				Accessibility to healthcare infrastructure		
	X <sup>1</sup>	X <sup>2</sup>	X <sup>3</sup>	X <sup>4</sup>	X <sup>5</sup>	X <sup>6</sup>	X <sup>7</sup>	X <sup>8</sup>	X <sup>9</sup>	X <sup>10</sup>	X <sup>11</sup>	X <sup>12</sup>
Kaurihar	20	15	20	4	4	11	10	15	13	7	5	15
Holagarh	19	17	3	3	1	8	11	10	8	9	19	11
Mauaima	8	8	7	20	18	3	1	1	4	20	18	14
Soraon	1	10	9	13	14	2	2	6	1	18	20	13
Bahria	18	16	11	2	6	5	12	16	3	6	13	2
Phulpur	5	19	13	9	7	1	4	4	2	11	12	6
Bahadurpur	11	4	10	10	2	20	20	18	18	13	16	17
Jasra	4	6	2	16	20	6	8	2	19	8	8	7
Shankargarh	13	5	1	18	19	7	5	3	20	3	3	1
Chaka	2	18	15	1	9	4	9	5	7	10	17	5
Kaudhiyara	6	20	4	5	17	19	16	20	12	5	10	20
Karchhana	9	14	14	17	8	12	3	7	5	15	7	4
Pratappur	10	3	12	14	15	16	14	14	9	14	11	12
Dhanupur	14	7	18	7	10	9	13	12	17	17	14	16
Saidabad	12	1	19	15	3	14	15	19	14	16	6	9
Handia	3	2	16	19	16	10	18	9	16	19	9	10
Meja	15	11	5	6	13	13	19	8	11	1	2	8
Uruwan	7	13	8	11	11	17	17	13	6	12	15	19
Manda	16	12	6	12	12	18	6	17	10	4	4	18
Koraon	17	9	17	8	5	15	7	11	15	2	1	3

Source: Computed by the Author.

transport and communication network, lack of conventional electricity supply and scarcity of potable water are major problems of this region. Apart from indifferent attitude of the government, the above mentioned problems are associated with poor development of health care infrastructure in the district.

### Conclusion

Health and nutrition are intimately and intricately connected. It must be noted that only institutions do not constitute a compressive health care system but it includes certain other

elements, like the system of nutrition, provision of safe drinking water and healthy living environment. The present study only focuses on the infrastructural facilities of health care system of Allahabad district. Nevertheless, this study provides valuable information about present state of health care in Allahabad district. It focuses on extreme shortages of health care institutions and manpower in the public health system. As majority of the people in Allahabad district depend on public health care system, the most important thing is to recruit the required number of doctors and staffs for the public

**Table 6.** *Health care Infrastructure Index (HII) in Allahabad District*

Sl. No.	Name of Development Blocks	Healthcare Infrastructure Index (HII)	Rank
1	Kaurihar	0.51	15
2	Holagarh	0.62	8
3	Mauaima	0.54	13
4	Soraon	0.62	9
5	Bahria	0.60	10
6	Phulpur	0.68	2
7	Bahadurpur	0.41	20
8	Jasra	0.64	5
9	Shankargarh	0.69	1
10	Chaka	0.66	3
11	Kaudhiyara	0.44	19
12	Karchhana	0.64	6
13	Pratappur	0.53	14
14	Dhanupur	0.48	17
15	Saidabad	0.55	12
16	Handia	0.47	18
17	Meja	0.64	7
18	Uruwan	0.51	16
19	Manda	0.55	11
20	Koraon	0.65	4

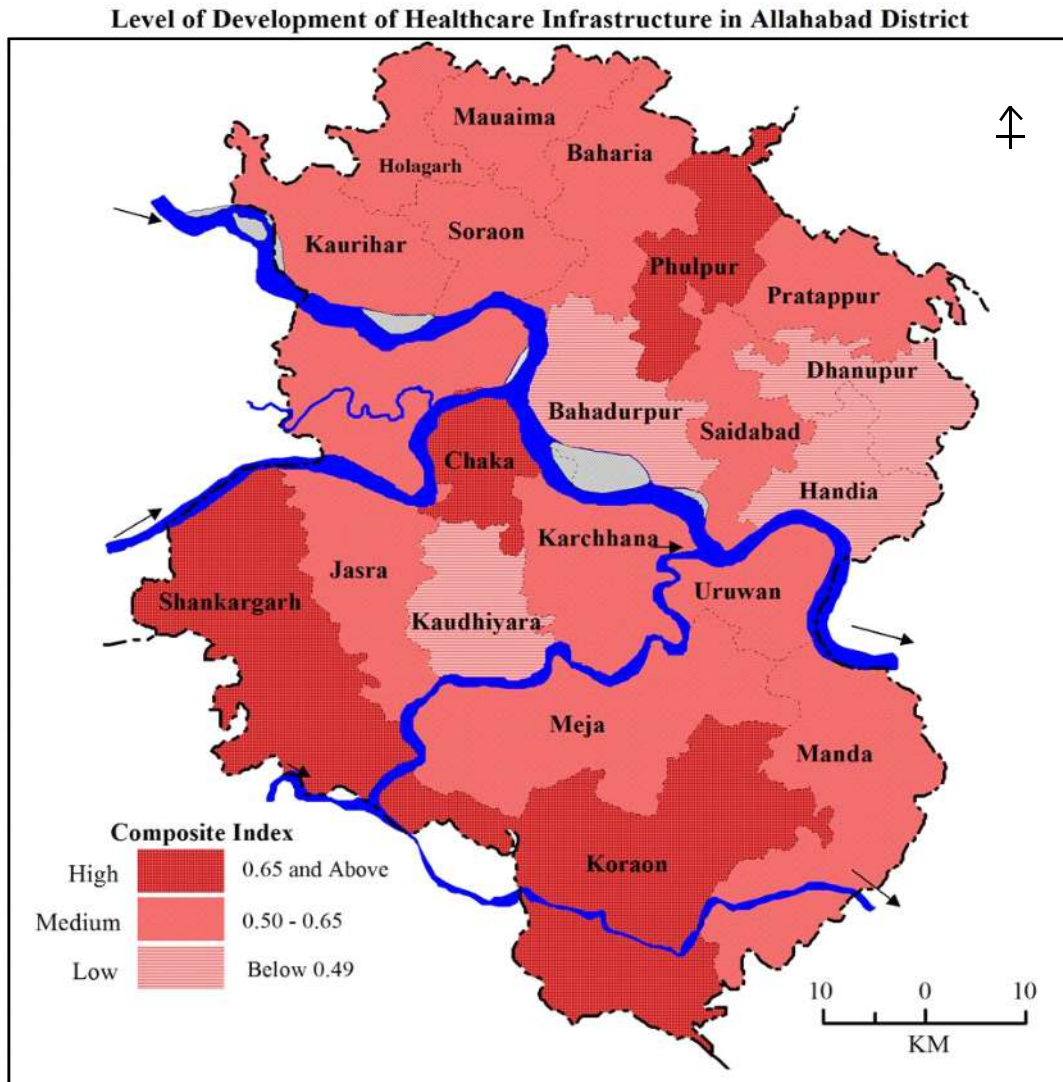
Source: Computed by the Author

health institutions. Access to services is an important determinant in meeting the healthcare needs of the people, especially living in remote areas. Ambulance service to transport serious patients to referral centres is very important. Irregular and infrequent availability of public transportation system from remote areas to healthcare facilities are generally not found in the area. Besides, private transport facilities are very expensive. Telephones or wireless communications system is not operational in many CHCs/PHCs. Local transports should be leased and attached to each PHC for transporting referred patients to the nearest accessible BPHCs/CHCs. There is urgent need to strongly emphasize the process of strengthening the infrastructural facilities at CHCs/PHCs level to utilize their full potential. Additional 19 CHC, 81 PHCs and 335 Sub-centres should be established in the Allahabad district to reduce the gap between existing and required facilities. All the PHCs should be renovated and equipped according to their need. It is also proposed that the BPHCs of seven priority blocks (Holagarh, Mauaima, Bahariya, Pratappur, Dhanupur, Saidabad and Kotwan) should be upgraded to provide basic EMOc and neo-natal services with an aim to make them full-fledged FRU in the long run.

**Table 7.** *Levels of Development in Health care Infrastructure in Allahabad District*

Level of Development	Indices	Number of Blocks	Name of Development Blocks
High	0.65 and Above	3(15)	Chaka, Phulpur, Shankargarh
Medium	0.50-0.65	13(65)	Pratappur, Saidabad, Jasra, Bahria, Mauaima, Soraon, Uruwan, Meja, Manda, Koraon, Karchhana, Kaurihar, Holagarh
Low	Below 0.49	4(20)	Bhadurpur, Kaudhiyara, Handia, Dhanupur

Note: Figures in parenthesis indicate % to total number of blocks. Source: Compiled by the author.



**Fig. 1**

Availability of doctors (including lady doctor) and para medical staff at Sub- centres, Primary Health Centres and Community Health Centre must be ensured by making adequate number of postings and constructing residential quarters for them. A vigorous attempt should be made to meet the shortage of doctors and allied manpower at the PHCs, especially those which

are deemed to serve people living in least accessible region. The ongoing efforts of the government to build up private-public partnership (PPP) and involve the panchayats more effectively in the participatory management of healthcare services are expected to ensure better health care services.

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# Spatial Pattern of Rural Settlement System in Eastern Uttar Pradesh

**Shamsul H. Siddiqui, Tariq M. Usmani and Nasim Aktar**

Settlements, which are concrete expression of human occupation of the earth surface, have always engaged the attention of geographers. The accounts of early travelers and explorers as well as the ancient books of religion and philosophy contain myriads of such references where settlements have occupied prominent place along with features of physical landscape. An attempt has been made here to analyze the spatial distribution of rural settlements according to their size. The size of settlements helps to identify the population threshold of social amenity, which is an important aspect of locations studies as human settlements produce a certain degree of order in their distributional pattern over the space and this in some way reflects the functional relations among centers.

**Key Words:** Rural settlements, size, spacing, village system.

## Introduction

There are many organisms on this planet. In them, human is the most powerful animal on the basis of his brain. There are three basic needs of man, *i.e.* Food, Cloth and Shelter. In the primitive stage, he used tree branches, caves or rock-cut for shelter.

After that, there was a change in man's work with respect to space and time and that influenced his settlement. That is why his shelter was converted into hamlet, village, town and finally into city and this hierarchy was mostly influenced by physical, social, economical and cultural factors. These factors also influenced the distribution, spacing and morphology of settlement.

The term "settlement" refers to man made habitats on the earth surface. In other words,

settlement is organized colony of human beings consisting of buildings in which they live or work or store various things and streets on which their movements take place.

The study of settlement has been one of the most significant themes of human geography. The term "settlement geography" is derived from the German "siedlung geographisch" (R. L. Singh, 1978) which involves the study of visual imprints made by man upon cultural landscape in the process of occupation. In the beginning various settlement features bore simpler forms and relationship with the environment, with the growth of civilization and technical knowledge, the degree of variability in their size, form and complexity of their relationship became overwhelming greater. This needs for the perfection of any study and

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for the understanding of the concerned surrounding environment as a whole.

The study of rural settlements has great significance, especially in the field of analytical study of distributional pattern of population, with special reference to size and spacing of rural settlements (Mukharjee, 1970).

A rural settlement, as the point of origin and primary residence of human society, is the linking thread and life blood of all geographical studies. Therefore, the consideration of settlement runs like a thread through almost the whole fabric of geographic thought (Kohn, 1959).

Rural settlement is the mainstay of human society throughout the world. It is the topographic expression of houses and highways as the home of man for safeguarding against environmental hazards (Mandal, 1981).

There are many factors like physical, social, economical and cultural which affect distribution, size, spacing and morphology of different settlements. Rural settlement as a pioneer habitat of human being is a living functional space. Rural settlement means a rural space occupied by rural community with their economic, social and cultural environment. This environment influences the entire rural way of life and their dynamic structure. Geographers look at the rural settlements as agglomeration of manmade habitat on the earth which is dependent mostly on primary occupation.

Here an attempt is made to analyze population size of rural settlements, average population size, and spacing of rural settlements.

### Objectives

The main objectives of the study are as follows :

1. To study the type and pattern of settlements
2. To explain size and spacing of settlements.
3. To understand the hierarchy of rural service centre.
4. To analyze the demographic characteristics of settlements.
5. To understand the impacts of physical, social, economical and human determinants that command the spatial character of settlements in different areas in Eastern Uttar Pradesh.

### Sources of Data

This work is based mainly on secondary sources of data. It includes both published and unpublished sources of data. Basic data has been collected through district census handbooks, socio-economic review and statistical abstracts, Uttar Pradesh census tables and gazetteers.

### Methodology

The present work has been accomplished with the help of different scientific methods. The descriptive part of this work is mainly based upon the secondary data. The data has been tabulated and calculated by using various cartographic techniques to enhance the quality of the work. Factors like average spacing, distance and density of rural settlements are considered in present work. Apart from this average population size of rural settlements, spacing of rural settlements, regional levels of development etc. are also considered for this study.

Walter Winide's formula-

$$D = A/N$$

Where,

**D** = Average distance between settlements.

A = Total area of District.

N = No. of settlements.

Walenty Winide's method is also applied for size of rural settlements is as under-

$$S = \sqrt{P/N}$$

Where,

S = Average size of population of village in a district.

P = Total population within district.

N = No. of settlements.

In the present study data has been compiled and calculated for all 27 districts of the study region and presented in table3. The five categories have been made to analyze the data on spacing of rural settlements (villages).

**Study Area**

Eastern Uttar Pradesh is situated in the northern part of the the state It spreads from 23° 45' North to 28° 20' North latitudes and 81° 5' East to 84° 36' East longitudes (Fig.1). Physically and geologically the state can be divided into two distinct regions, namely, the Ganga plain and the tarai region (piedmont region). The greatest length from north to south



**Fig. 1**

is about 550 kilometers and maximum width from east to west 375 kilometers. About two-third of the total population is engaged in primary

**Table 1.** Rural settlements and rural population by population size in Eastern Uttar Pradesh (2011)

	Population size	No. of Rural settlements	Total Rural population
A.	Small Size Villages		
1.	Less than 200	5,443 (10.74)	491,769 (0.70)
2.	200-499	8,578 (16.93)	3,030,601 (4.32)
B.	Medium Size Villages		
3.	500-999	12,528 (24.72)	9,181,232 (13.09)
4.	1000-1999	13,319 (26.28)	18,937,396 (27.00)
C.	Large Size Villages		
5.	2000-4999	9,280 (18.31)	27,436,537 (39.11)
6.	5000 and Above	1,533 (03.02)	11,071,624 (15.78)

Source: Statistical Handbook of Uttar Pradesh, 2013

**Table 2.** Average population size of rural settlements (2011)

Districts	Spacing in Km.	Total Rural population	No of villages	Settlement density/ 100 km <sup>2</sup>	Average population size
Partapgarh	1.29	3,033,899	2217	59.64	1368
Allahabad	1.34	4,481,518	3053	55.69	1468
Bahraich	1.94	3,203,687	1390	26.54	2305
Gonda	1.48	3,208,890	1817	45.39	1766
Faizabad	1.36	2,130,743	1264	53.99	1686
Ambedkar Nagar	1.16	2,117,158	1750	74.47	1210
Sultanpur	1.32	3,597,201	2527	56.97	1424
Siddharth Nagar	1.08	2,398,606	2505	86.53	958
Maharajganj	1.53	2,549,973	1262	42.75	2021
Basti	0.90	2,326,367	3348	124.55	695
Gorakhpur	1.00	3,604,766	3319	99.94	1086
Kushi Nagar	1.33	3,396,437	1639	56.42	2072
Deoria	1.08	2,784,143	2162	85.12	1288
Mau	1.03	1,706,760	1610	93.99	1060
Azamgarh	0.99	4,220,512	4101	101.16	1029
Jaunpur	1.09	4,147,624	3381	83.73	1227
Ballia	1.12	2,935,665	2361	79.20	1243
Sant Ravidas Nagar	0.91	1,586,652	1217	119.90	1304
Varanasi	1.09	2,079,790	1295	84.36	1606
Ghazipur	1.00	3,345,908	3367	99.70	994
Mirzapur	1.50	2,149,403	1961	44.52	1096
Sonbhadra	2.20	1,548,217	1429	20.70	1083
Kaushambi	1.43	1,475,140	868	48.79	1699
Saravasti	1.74	1,078,712	541	32.99	1994
Balrampur	1.82	1,982,274	1015	30.31	1953
Sant Kabir Nagar	0.98	1,348,911	1726	104.86	782
Chandauli	1.25	1,710,203	1629	64.11	1050
Eastern Uttar Pradesh	1.25	70,149,159	54754	63.78	1281

**Source:** Statistical Handbook of Uttar Pradesh, 2013

activities and three-fourth of the total population live in rural areas.

### Spacing of Rural Settlements in Eastern Uttar Pradesh

Geography is a discipline in distances. The

spacing of settlements is basically governed by the physical environment. Large rural settlements would be widely spaced, while smaller settlements would be closely spaced. These spatial patterns are constantly changing in time and space due to growth of population

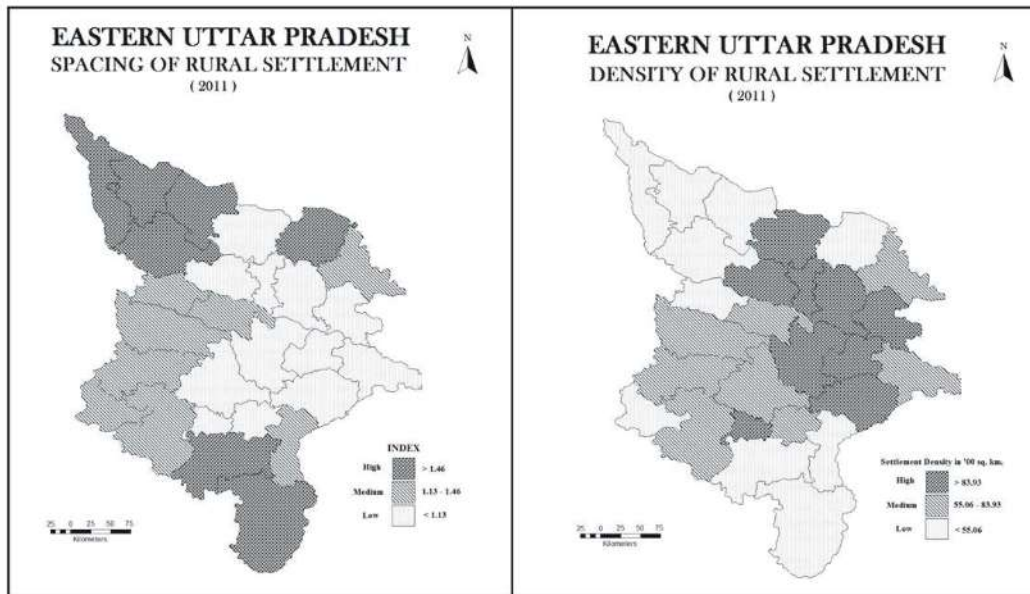


Fig. 2

Fig. 3

that has resulted in the increase in the number and size of centres and reduction in their spacing. In the present study data has been compiled and calculated for all 27 districts of the study region and presented in table no.2. The three categories have been made to analyze the data on spacing of rural settlements (villages).

#### **Areas of High Spacing (Above 1.46 km.)**

This category of high spacing of villages in the study area includes the districts of Gonda, Bahraich, Maharajganj, Mirzapur, Sonbhadra, Saravasti and Balrampur. The widely spaced villages are related with the relative absence of transport, communication, infrastructure and other facilities.

#### **Areas of Moderate Spacing (1.13 – 1.46 km.)**

The districts which fall in the moderate

spacing of rural settlements in the study area are the districts of Pratapgarh, Allahabad, Faizabad, Ambedkar Nagar, Sultanpur, Kushinagar, Kaushambi and Chandauli.

#### **Areas of Close Spacing (Below 1.13 km)**

Low or close spacing of villages in the Eastern Uttar Pradesh includes the districts of Siddharthnagar, Basti, Gorakhpur, Deoria, Mau, Azamgarh, Ballia, Sant Ravidas Nagar, Jaunpur, Sant Kabir Nagar, Ghazipur and Varanasi.

#### **Density of Rural Settlements**

The high density of rural settlement is found in 9 districts of Eastern Uttar Pradesh. These districts are Siddharth nagar, Basti, Gorakhpur, Sant Kabir Nagar, Deoria, Mau, Azamgarh, Sant Ravidas Nagar and Ghazipur. The medium density of rural settlement spreads over 8 districts namely, Pratapgarh, Allahabad,

Ambedkar Nagar, Sultanpur, Kushinagar, Jaunpur, Ballia and Varanasi. The low density of rural settlements found in remaining 10 districts. These districts are Sonbhadra, Balrampur, Faizabad, Gonda, Bahraich, Saravasti, Kaushambi, Mirzapur, and Maharajnagar.

### Conclusion

The overall analysis of the study reveals the facts that physical factors are not so strong, though important. Influence on the pattern of settlements proximity to urban settlements has exerted a stronger influence on the distribution pattern of settlement. Physical factors in combination with a set of cultural factors like irrigation and agricultural practices, land tenure and size of land holdings, infrastructural facilities and cultural practices are some of the factors impinging the distribution of rural settlements. The following findings are also derived from the above analysis

1. Growth of industries, development of

infrastructure and other facilities are the most significant factors for both larger size and lowest spacing of settlements in the region.

2. The average population size of rural settlements depends upon productivity of land, adequate amount of rainfall, irrigation facilities and development of other amenities. Such areas can support larger villages, having high population with closer spacing.

3. The number of large size villages is small and the number of small and medium size of villages is large in the study area

4. The areas which are economically backward, do not have basic amenities and infrastructure, such areas are generally far away from each other (greater spacing).

5. Social amenities (schools, colleges, hospitals, bus stop, railway station etc) play an important role in size and spacing of the villages.

6. Small size rural settlements are closely spaced while large size rural settlements are widely spaced.

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## Book Review

**Dr. K. L. Narasimha Murthy** (2014). *Research Method in Geography: A Textbook* (New Delhi: Concept Publishing Company Private Limited); pp. xi+226; price: Rs. 180; ISBN: 978-93-5125-022-7; Paperback copy.

The issue of research in geography may be considered unique because of the very nature of this discipline. Geography is generally considered as a kind of bridge between natural and social sciences. As a spatial science, it aims to describe, explain and understand the nature of occurrence of natural as well as human phenomena on the earth's surface and the meaning these phenomena accord to it. Geography is also an inclusive subject. It incorporates subject matters from vast array of academic disciplines. Therefore, the subject matter of geographical investigation is unimaginably vast. In view of these facts, writing a textbook of research methodology for geography students can be quite tricky task. There is always a challenge before the author to provide a balanced account of both physical and human geography. At the same time, a good book of geography research methodology must provide adequate understanding of quantitative as well as qualitative techniques. In view of these challenges, not many good books on research methodology written by Indian geographers are found in stacks of Indian libraries. It is in this context that the book under review, written by Dr. Kalluri Lakshmi Narasimha Murthy, is a welcome addition. Dr. Murthy has long years of teaching and research experience in geography. The book is written mainly for postgraduate and research students of geography.

The book is organized into nine chapters. The brief introductory chapter deals with the nature of geography and geographical problems. The second chapter deals with research methodology in geography. The author is of the view that the sub-disciplines of geography are different not only because of differences in the focus of their studies but also their varied historical evolution. This necessitates application of different methods for different sub-branches of geography. Third chapter is on the nature of geographical research including major steps in geographical research. This chapter also contains a section on the meaning of research hypothesis and its role in geographical research.

Fourth chapter is on the importance and types of research design for geographical research. It also contains discussion on the issue of objectivity in geographical research. In chapter five, author discusses various sampling techniques for geographical research. It also contains a section on the utility of experimental method in conducting geographical research. Chapter sixth is on various data collection techniques, their merits and demerits. Chapter seventh is a big chapter. It provides detailed information on the nature and types of research inputs for various branches and sub-branches of geography. It also contains a case study of multi-temporal satellite data for the study of water resource problems in Udaipur basin. Chapter eight is on the application of statistical techniques in geographical research. The chapter also contains a co-authored research paper by the author titled: *Population of India: A Geographical Appraisal and a Statistical*

*Account.* It is quite a lengthy where materials and issues of diverse nature are jumbled together. Chapter nine contains step-by-step guidelines for project report writing. It contains a co-authored research proposal titled '*Nutritional Deficiency Diseases and their Prevalence: A Case Study of Urban Pondicherry*'. The book contains a brief bibliography and index of authors and subject.

The book has many shortcomings. While the idea to produce a reader friendly textbook on research methodology for the students of geography is highly appreciable, but unfortunately the execution of this book is quite poor. It is not a well structured and envisaged book. There are many cases of repetitions. Many research works which are cited in the book do not appear in the bibliography. Despite these limitations, the book may be considered as useful for postgraduate geography students.

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