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Tectonic Geomorphology of the Veshav Basin, SW Kashmir Himalaya

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ABSTRACT

Geomorphic indices have been recognized useful tools to evaluate tectonic activity in the regions of active deformation. We used geomorphic features, drainage analysis and in particular, geomorphic indices for indications of active deformation in the Veshav basin, SW Kashmir valley. Tectonic geomorphology, drainage features and different geomorphic indices (e.g., mountain front sinuosity (smf), hypsometric integral (Hi), basin elongation ratio (Eb), basin asymmetry (AF), longitudinal profile and stream gradient index (SL) were carried out using topographic maps (1: 50, 000), SRTM DEM (90m resolution) supplemented with field data. Tectono-geomorphic and drainage anomalies such as scarp development, sudden drainage deflections, and stream captures were used to infer zones of remnant tectonic activity. The study demonstrates the usefulness of drainage, tectono-geomorphic and geomorphic indices in exploring active tectonic features and suggests that the Balapur fault extend beyond study area (Veshav basin), which however need paleoseismic investigations for firm seismic hazard assessment.

Key words: *Active Tectonics, Geomorphic indices, Drainage characteristics, Balapur fault, Pir Panjal range*

INTRODUCTION

Geomorphic indices provide basic reconnaissance tools to identify tectonically active regions (Keller, 1986), their vulnerability to tectonic deformation, and level of tectonic activity (Keller, 1986; Keller and Pinter, 1996; Demoulin, 1998). Some of these indices were developed to quantify the description of landscape (Strahler, 1952). It is possible to quantify the tectonic impact on any drainage basin by any individual geomorphic parameter. However, a group of parameters with their assessment relative to one another allows addressing the issue successfully and identifying a particular characteristic of a drainage basin, its vulnerability to tectonic deformation and level of tectonic activity (Keller, 1986; Keller and Pinter, 1996; Demoulin, 1998). In addition, classification of tectonically active zones can be known by using remote sensing data and technology e.g., DEMs, remote sensing satellite images, topo-sheets, drainage analysis, geographic information systems (GIS) and geomorphic indices. From last couple of decades remote sensing has been one of the most promising tools needed for computation of the geomorphic indices. Moreover, the satellite interpretation technique and data generation exercise is precise and less time consuming, which otherwise needs immense man power and time. The image interpretation process if collaborated with selected field observations provides valuable information. Several workers have carried out geomorphic indices / morphotectonic analysis / tectonic geomorphology using remote sensing and GIS techniques to note tectonically active zones (Rockwell *et al.,* 1985; Keller, 1986; Wells *et al.,* 1988; Keller and Pinter, 1996; Demoulin, 1998; Burbank and Anderson, 2001; El Hamdouni *et al.,* 2008; Dehbozorgi *et al.,* 2010). Hence, considering the diversity of the tectono-geomorphic features (Keller and Pinter, 1996; Burbank and Anderson, 2001), we analyzed six geomorphic indices: Mountain Front Sinuosity (Smf), Hypsometric Integral (Hi), Basin Elongation Ratio (Eb), Drainage Basin Asymmetry (AF), Longitudinal Profile and Stream Gradient Index (SL). This kind of methodology has been found useful in various tectonically active areas such as the SW USA (Rockwell *et al.,* 1985), the Pacific coast of Costa Rica (Wells *et al.,* 1988), the Mediterranean coast of Spain (Silva *et al.,* 2003), the southwestern Sierra Nevada of Spain (El Hamdouni *et al.,* 2008) and several SW parts of the Kashmir basin (Ahmad and Bhat, 2012; Ahmad, 2014; Ahmad *et al.,* 2013, 2015). Therefore, using remote sensing and GIS quantitative geomorphic approach, the present study aims to infer active tectonic signatures supplemented with field investigations in the Veshav sub-basin of the Jhelum basin (SW Kashmir Himalaya) (Fig. 1).

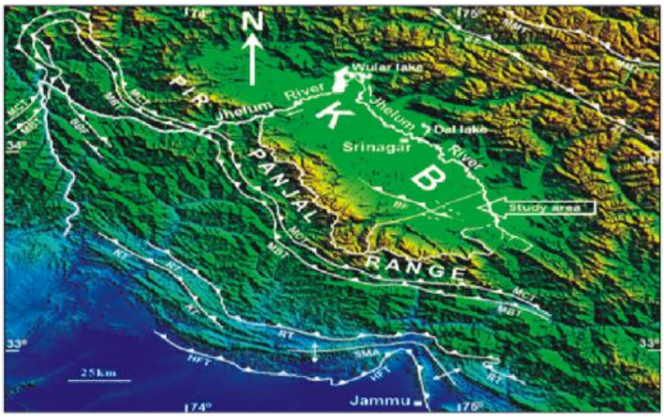

Fig. 1. Geological structures in and around Kashmir Himalaya. The base is SRTM DEM with overlapped faults adapted from Agarwal and Agrawal (2005); Hussain *et al*. (2009); Thakur *et al*. (2010); Ahmad and Bhat (2012); Ahmad *et al*. (2013, 2015) Ahmad, 2014. KB = Kashmir basin; MCT = Main Central thrust; MBT = Main Boundary thrust; HFT = Himalayan Frontal thrust; MMT = Main Mantle thrust; ZT = Zanskar thrust; BBF = BalakotBagh fault; RT = Riasi thrust; KT = Kotli thrust; SMA = Surin-Mustgarh anticline; BF = Balapur fault; dashed lines are inferred faults.

Geology and tectonic setting

The Kashmir basin has diverse geological record ranging from Precambrian to Recent (Middlemiss, 1911; Wadia 1975; Bhatt, 1989) (Fig. 2). With Salkhala Series (Precambrian) and Dogra Slates (lower Cambrian) as oldest stratigraphic basement floor (Wadia, 1975), the basin has a more or less full sequence of fossiliferous Paleozoic such as Panjal Volcanic Series (Panjal Trap and Agglomeratic Slate), Gneissose granite, Gondwana Shale, Fenestella Shale, Syringothyris Limestone, Permo - Triassic rocks and Conglomerate Beds in various parts of Kashmir (Middlemiss, 1910; Wadia, 1975). The exposed bedrock units of the study area consist of Panjal Volcanic Series (Panjal Trap and Agglomeratic Slate), gneiss or gneissose granite and metamorphic schists, and Triassic limestone. The stratigraphic succession is given in Table 1. Most of the area is covered by fluvio-glacial sediments, collectively known as the Karewa (Plio-Pleistocene), which has been assigned Group status (Farooqi and Desai, 1974; Bhatt, 1989). These consist of 1300m thick sequence of unconsolidated clays, sands, and conglomerates with lignite beds unconformably lying on the bedrock and are overlain by the recent river alluvium (Bhatt, 1976; Wadia, 1975; Burbank and Johnson, 1982; Singh 1982). The Karewa Group has been subdivided into Hirpur and Nagum Formations (Singh, 1982), whereas Bhatt (1989) divided them progressively younger Hirpur, Nagum, and Dilpur Formations, respectively.

The Kashmir basin is believed to have evolved in the late Miocene by shifting of the NE thrust complex from the base of the Great Himalayan side to the southwest forefront of the Pir Panjal range (Burbank, 1983; Burbank and Johnson, 1983); as a result, the NE thrust complex was replaced by the existing structural system (basement complex: MBT/MCT). This was followed by accumulation of low energy fluviolacustrine sediments (Karewa) that constrain initial timing of basin formation to ~5 Ma (Burbank and Johnson, 1983). Bhat (1982) proposed a rift-reactivation model to explain the formation of the Kashmir basin along two deep-seated faults, i.e., the Panjal thrust from the west and Zanskar thrust from the east. However, recent work suggests that the Kashmir basin evolved as a result of active dextral strike-slip fault accompanied by pull-apart character in NW Himalaya (Alam et al., 2015a,b). It is bounded on the northeast by the Great Himalayan and southwest by the Pir Panjal Ranges. Several thrust faults have been delineated in southwest of the Pir Panjal Range including the MCT/Panjal, MBT/Murree, Riasi, and Kotli thrusts (Thakur et al., 2010); as a result, the zone has a complex pattern of faulting. All these faults are considered to be imbrications of the northward rooted basal décollement known as Main Himalayan thrust (Schelling and Arita, 1991; Brown et al., 1996; DeCelles et al., 2001). In addition, several out-of-sequence faults have been identified and delineated between Himalayan Frontal thrust (HFT) and Main Boundary thrust (MBT). These include the Riasi thrust (RT), the Kotli thrust (KT) and the Bagh-Balakot fault (BBF). The latter was the source fault of Oct-2005 Mw 7.6 Muzzafarabad earthquake (Kaneda et al., 2008; Hussain et al., 2009; Thakur et al., 2010) which claimed more than 80,000 lives. No faulting was known north of the MCT/Panjal thrust or MBT/Murree thrust except a few speculated faults were mapped on the basis of satellite data (Nakata et al., 1991; Yeats et al., 1992). However, the identification of faults in the Kashmir basin begins with field investigations, resulted a high angle high angle thrust fault (reverse) with an average northeast 60o dip and NW-SE strike length of ~40 km (Ahmad, 2010; Madden et al., 2010, 2011; Ahmad and Bhat, 2012; Ahmad et al., 2013). The fault was named as Balapur Fault (BF) because of its exposure on the left bank of Rambiara river at Balapur village in Shupiyan district (Ahmad, 2010; Ahmad and Bhat, 2012; Ahmad et al., 2013). The Balapur fault cut across (NW-SE) unconsolidated Karewa deposits with rotation of gravels at the fault contact has been marked (Ahmad and Bhat, 2012). Stratigraphic relations show that the fault has uplifted the Methawoin member of the lower Karewa and juxtaposed it to the Shupiyan member of the upper Karewa (Bhatt, 1989). The Balapur Fault (BF) was firmly established by paleoseismic investigation and field data (Madden et al., 2010; Madden et al., 2011; Ahmad et al., 2013) and recently further extended ~100 km in NW Kashmir Himalaya (Ahmad, 2014; Ahmad et al., 2015). This indicates that the Balapur fault is the only major structure explored in the Kashmir Himalaya.

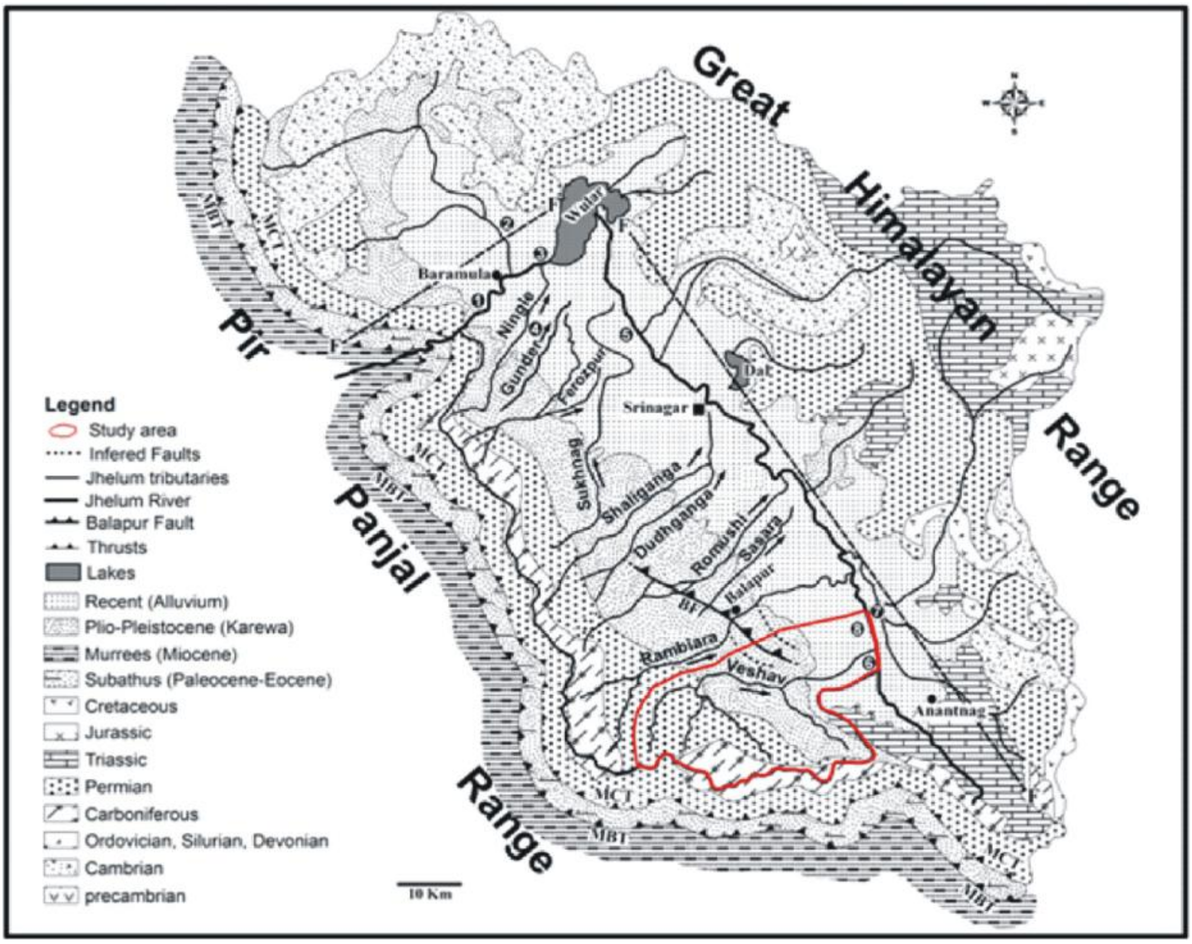

Fig. 2. Geological Formations of the Kashmir basin (adapted from Ahmad et al., 2015).

Table 1. Geological succession of southwest Kashmir (After Wadia, 1975; Bhatt, 1976, 1989).

Formation/Group			Lithology	Age
Alluvial deposits			Clay, sandy clay, silt with occasional gravel	Recent to Sub-recent
Loess-paleosol succession of Dilpur Formation	Dilpur Formation	KAREWA GROUP	Layers of brown silt vary from calcareous to non - calcareous types	Upper Pleistocene
Shopian Member	Nagum Formation		Gravels, sand, sandy clay, marl and silt	Middle Pleistocene
---Angular unconformity---			---Angular unconformity---	
Methawoin Member	Hirpur Formation		Clay, sandy clay, conglomerate, varve sediment, liginite and sand	Pliocene to Pleistocene
Rambiara Member				
---Er.Unconformity---				
Dubjan Member				
---------Unconformity---------				
Triassic Formation			Limestones, shales etc.	Lower, Middle and Upper Triassic
Panjal Trap	Panjal volcanic series		Andesite, Basalts etc.	Permian
Agglomeratic slate			Slates	Upper carboniferous

Drainage features of the Veshav Basin

Veshav drains on the major segment of northern face of the Pir Panjal between the Sundartop (3879m) and the Budil Pir pass (4264m), thus, possesses an extensive catchment area (888. 51 km2) of river Jhelum (Fig. 3). The four major source-area tributaries flowing either axial or transverse course until three of these principal streams (Harseni nala, Konsar nag nala and Gugal nala) meet at an elevation 2281m near Lasgasan village, about 2-3km upstream of Ahrabal village to constitute the origin of Veshav. Hence, after uniting several tributaries at Ahrabal Veshav came into existence and flows in hard rock terrain with much narrow course (Fig. 4). Subsequently, it enters soft rock terrain with wide appearance, prominent meanders, lateral avulsions and develops braided bar deposits and many terraces on both left and right banks (Fig. 5). From Ahrabal village, it becomes a sizable stream, and flows almost due east before its confluence with the Jhelum about 12km below Kulgam town between Palapur and Napur villages. It reaches 67.4km total length. Veshav is marked by a 10m waterfall in the vicinity of Ahrabal village in hard rock terrain (Fig. 6). Also, one of its major tributary named Kandai Kol, depicts barbed drainage pattern, flowing in opposite direction (NW) before it merges with Veshav in a hook-shaped bend between Largu and Bunagam villages, possibly reflecting tectonic control (cf. Jackson et al., 1996). The drainage pattern in the hard rock area is of dendritic to sub-dendritic whereas it is parallel, cross over and uneven in soft rock terrain.

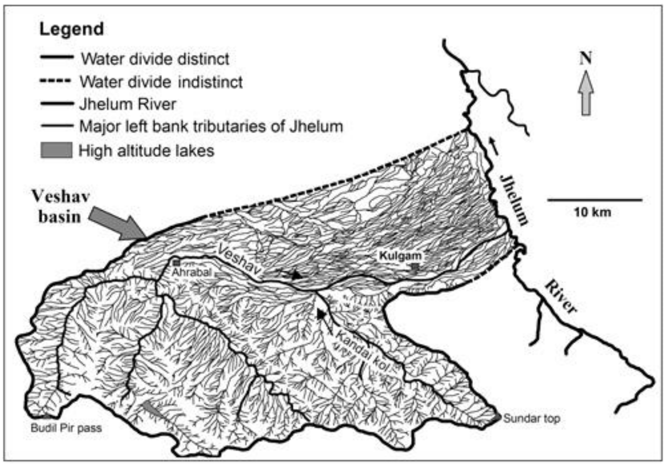

Fig. 3. Drainage characteristics of Veshav basin, SW Kashmir valley.

Fig. 4. Showing narrow course of Veshav in hard rock terrain at Ahrabal area.

Fig. 5. Showing five terraces at the outlet of Veshav near Sedau village (after De Terra and Paterson, 1939). Black arrows shows flow direction.

Fig. 6. Showing waterfall in the vicinity of Ahrabal village in hard rock terrain.

MATERIALS AND METHODS

With the help of quantitative measurement of a drainage basin, it becomes very easy not only to compare different landforms but also calculate geomorphic indices that may be useful for identifying particular drainage basin characteristics and its level of tectonic activity (Keller, 1986; Keller and Pinter; 1996). The present study was carried out to find the active tectonic signatures in the Veshav basin, SW Kashmir valley. To fulfill the objective, we employed Survey of India topographic maps (1: 50,000 scale), freely available SRTM DEM (90m resolution) together with field data using different software's like Arc view 3.2a, Erdas imagine 9.1 and Global mapper 12.1 versions. The definitions of geomorphic indices are given below subsequently, we present their results.

Mountain front sinuosity (S_{mf}): The mountain front sinuosity (S_{mf}) is defined as:

$$S_{mf} = L_{mf}/L_s$$

Where S_{mf} is the mountain front sinuosity; L_{mf} is the length of mountain front along the foot of the mountain, at the pronounced break in slope; and L_s is the straight line length of the mountain front (Bull, 1977, 1978; Keller and Pinter, 2002). S_{mf} reflects whether tectonic or erosional forces are dominant in shaping a mountain front.

Hypsometric integral (H_i): The hypsometric integral (H_i) or area elevation analysis (Strahler, 1952) is a powerful tool for differentiating tectonically active regions from inactive ones. It is a quantitative measure of the degree of dissection of a drainage basin and is calculated using the equation (Pike and Wilson, 1971):

$$H_i = (h_{mean}\ \ h_{min})/(h_{max}\ \ h_{min})$$

Where H_i is the hypsometric integral, and h_{max}, h_{min}, and h_{mean} are the maximum, the minimum, and the mean elevation, respectively. The maximum and the minimum heights are read directly from topographic maps. The mean elevation is obtained by randomly sampling a minimum of 50 points on the map and then calculating the mean value. It can be easily obtained from topographic maps or by using Digital Elevation Models (DEM) (Pike and Wilson, 1971).

Basin elongation ratio (E_b): The elongation ratio is a representation of the shape of a river basin. According to Schumm (1956), elongation ratio is defined as the ratio of diameter of a circle having the same area as the basin and the maximum basin length. The parameter is calculated by using the following equation (Schumm, 1956):

$$E_b = \frac{2\sqrt{A_b/\pi}}{l_b}$$

Where A_b is the diameter of a circle of the same area as the drainage basin and l_b is basin length measured from its mouth to most distant point on the watershed limit.

Drainage basin asymmetry (*AF*): This parameter allows determination of general tilt of the basin landscape irrelative of whether the tilt is due to local or regional tectonic deformation (Hare and Gardener, 1985). The parameter is calculated using the equation (Gardener *et al*., 1987):

$AF = (A_r / A_t)\ 100$

Where *AF* is the asymmetry factor, A_r is the drainage area on the downstream right of the main drainage line and A_t is the total drainage area. When *AF* is greater than 50, the channel has shifted towards the downstream left side of the drainage basin. On the other hand, when *AF* value is less than 50, it indicates the channel has shifted towards the downstream right side of the drainage basin.

Stream Gradient Index (SL); The stream gradient index is calculated using Hack's (1973) formula:

$SL = (\Delta H/\Delta L)\ L$

Where SL is the stream gradient index, $\Delta H/\Delta L$ is the local gradient of the stream reach where the index is computed, ΔH is the drop in elevation of the reach and ΔL is the length of the reach, and L is the total channel length from the drainage divide to the center of the reach measured along the channel.

RESULTS AND DISCUSSION

Mountain front sinuosity (S_{mf}): Tectonic activity produces a linear mountain front, which over the course of time degrades and loses its linearity due to erosion. Depending upon whether tectonics or erosion dominates will determine the type i.e., linear or crooked of a mountain front. According to Bull and McFadden (1977), the mountain front sinuosity values for active regions range between 1.2 to 1.6, for slightly active regions the values range between 1.8 to 3.4 and for inactive regions the values range between 2 to 7. S_{mf} index not only differentiates active regions from inactive ones but allows individual mountain fronts to be assigned different tectonic activity classes developed under decreasing uplift rates (Bull and McFadden, 1977).

Veshav basin is showing a prominent Veshav mountain front (VSF) with general NW-SE strike. Topographic sketch reveals that the VSF rises at the basal 2250m contour (Fig. 7). It is characterized by prominent V-shaped triangular facets. The calculation of the S_{mf} values along the 2250m contour (VSF) gives 1.14 values. Such low S_{mf} values, according to Bull and McFadden (1977) classification, suggest tectonically active character of the Veshav basin.

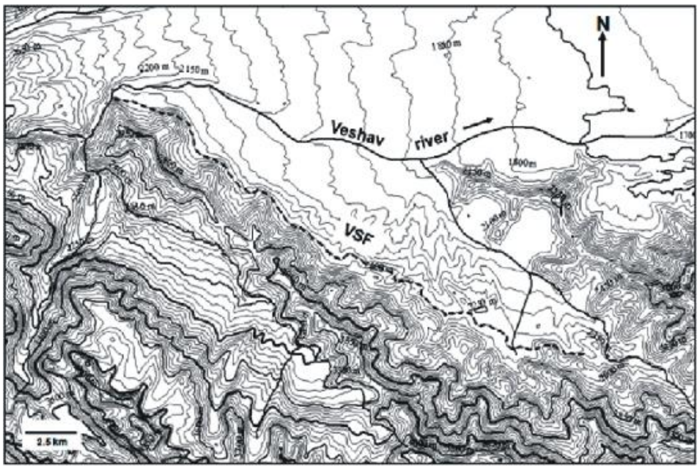

Fig. 7. Showing topographic sketch of Veshav mountain front.

Hypsometric integral (Hi): High values of hypsometric integral indicate that most of the topography is high relative to the mean, such as smooth upland surface cut by deeply incised streams. Intermediate to low values of the integral, reflecting exposure of the terrain to extended erosion, are associated with more evenly dissected drainage basins. Therefore, hypsometric integral would be expected to have a higher value for younger or youthful stage of landscapes and lower value for older ones as the landscape is denuded towards a stage of maturity and old stages (Strahler, 1952; Deleaillau et al., 1998; Keller and Pinter, 2002).

Comparing the size of different Pir Panjal basins, Veshav basin has extensive area, therefore we collected randomly 87 points using SRTM, and topographic maps for the calculation of hypsometric integral (Fig. 8). The calculated hypsometric integral value for the Veshav basin is 0.49, which indicates youthful landscape, despite the fact that maximum basin area being covered by weakly consolidated, easily erodible Karewa sediments. Therefore, this parameter also suggested that the watershed is tectonically active.

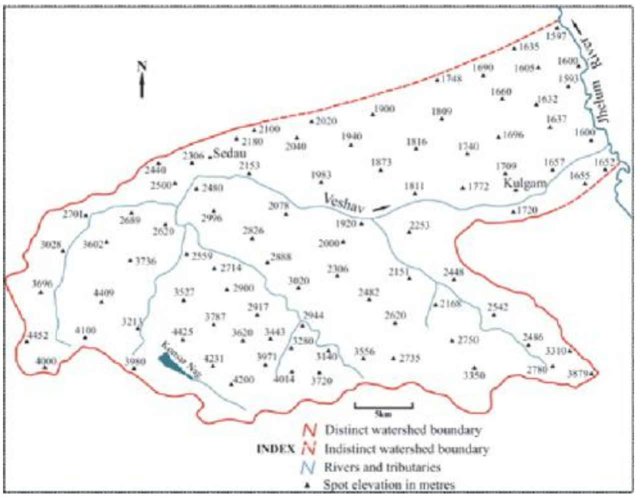

Fig. 8. Showing spot elevation points of the Veshav basin for computing hypsometric integral values.

Basin elongation ratio (E_b): Basin elongation ratio, like the two already discussed geomorphic indices, reflects competing roles of tectonics versus erosion. While the tectonics creates elongated basins, erosions over time tends to shape it into an oval/circular. According to Strahler (1964), E_b, over a wide variety of climatic and geologic types, usually ranges from 0.6 for an elongate, tectonically active/new basin to 1.0 for tectonically quiescent, oval to circular basin. Based on this general criteria, he classified drainage basins as: Circular (> 0.9), oval (0.8 0.9), less elongated (0.70.8), and elongated (< 0.7). According to Cuong and Zuchiewicz (2001), E_b values < 0.50 are characteristic of tectonically active basins, values ranging from 0.50 to 0.75 reflect slightly active basins, and values > 0.75 reflect inactive basin settings. Bull and McFadden (1977) consider low value for basin elongation ratio as a proxy indicator of recent tectonic activity. Molin *et al*. (2004) substantiated the view and noted that actively uplifting landscape and youthful basins are commonly held to be relatively elongate.

The computed E_b value of the Veshav watershed is 0.73, showing that the watershed is semi-elongate in shape which in turn suggest that the Veshav basin is slightly tectonically active, further substantiating the inference from previously discussed parameters.

Drainage basin asymmetry (*AF*): Since Veshav river has developed several unpaired terraces (Fig. 5). To verify if these terrace surfaces relate with tilt block tectonics, basin asymmetry factor was calculated. Following Strahler's (1957) stream ordering scheme, the *AF* for the Veshav basin was extracted from 5th order Veshav river. The calculated *AF* value of 35.00 indicates that the Veshav channel has shifted downstream to the right of the basin. Basin tilt to the right substantiates well with the development of higher number of unpaired terraces on the left bank of the Veshav river as compare to couple of terraces on the right bank (De Terra and Paterson, 1939; Ahmad, 2014), as well as with greater number of tributaries joining the river from the left bank than from the right bank (Fig. 5).

Longitudinal profile: A longitudinal river profile is a plot of a river or stream length with respect to river or stream elevation above mean sea level. It represents the channel gradient of a river from its source to its mouth and may indicate that the fluvial system is in a transient state of adjustment or disequilibrium because of tectonic, climatic, or rock-type perturbations (Mackin, 1948; Molin and Fubelli, 2005). The slight deviations in the longitudinal profile are called knickpoints or knickzones. The knickpoints or knickzones are formed due to number of variables however lithology and tectonic seems to be most dominant factors. Thus, the specific longitudinal profile anomalies (knickpoints or knickzones) can be investigated to evaluate tectonic perturbation at different scales ranging from large scale to local structures (Seeber and Gornitz, 1983; Molin *et al.*, 2004). In addition, several studies have emphasized the usefulness of longitudinal profiles in deriving information related to recent regional or local active tectonic activity (Hack, 1973; Seeber and Gornitz 1983; Ouchi 1985; Keller 1986; Rhea 1989; Demoulin 1998; Holbrook and Schumm 1999; Schumm *et al*. 2000) and are widely used in tectonic geomorphology.

The longitudinal profile of the Veshav river shows a broad but feeble knickzone developed between 2200 and 1800m in the Karewa terrain (Fig. 9). It contains ~16 km of stream reach. Within this reach, one of the major tributaries of Veshav (Kandai kol) (Fig. 3) exhibits a barbed drainage pattern, flowing in the opposite direction (NW) and merging with the Veshav in a hook-shaped bend between Largu and Bunagam villages. This drainage pattern indicates that the influence of a subsurface structure (e.g., Jackson *et al.*, 1996). Field investigations also revealed a prominent scarp, lateral spreading of active channel, development of braided bar deposit, and a broad anticline structure on the left bank of Veshav between Brazul and Amun villages of Kulgam (Fig. 10). The deformation of terraces (Ahmad, 2014) in the Veshav basin is certainly owing to the presence of the Balapur fault and its associated splays (Ahmad *et al*., 2015).

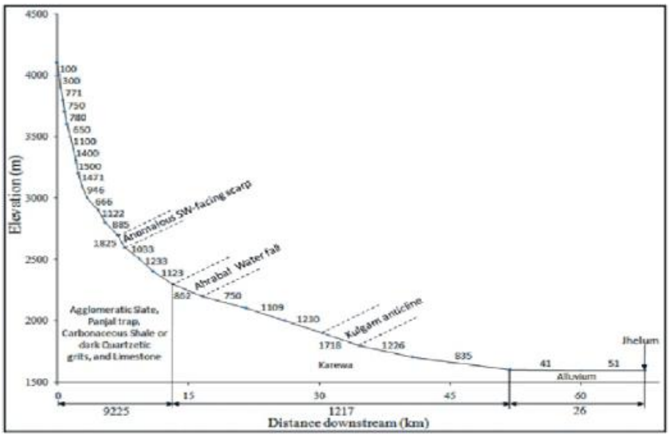

Fig. 9. Longitudinal profile of Veshav river with stream gradient index values.

Stream Gradient Index (SL): The stream gradient index reflects relationship among stream power, rock resistance and tectonics (Hack, 1973). SL is a useful parameter to evaluate if change in stream slope is due to rock resistance or tectonic deformation in particular, if it has a vertical component (Keller and Pinter, 2002). The SL values are high in areas where rocks are particularly resistant or where active tectonics has resulted in vertical deformation at the earths surface.

Therefore, high SL indices in rocks of low to uniform resistance are a possible indicator of active tectonics (Keller, 1986).

The SL values for the Vishav river increases from 26 over the alluvium, 1217 over the Karewa terrain and 9225 over the hard rock terrain (Fig. 9). The SL values shows a general agreement of hard and soft rock terrains with overall gradient of Veshav river irrespective of lithological or tectonic factors. However, slight fluctuations particularly in the soft rock terrain (Karewa) near Kulgam is strong indicator of recent tectonic activity. Field investigations revealed deformation of terraces, braided bar deposit, wide approach of Veshav channel with leteral avulsions and broad anticlinal stucture exposed on the left bank of Veshav river (Fig. 10).

Fig. 10. Photograph of an anticlinal structure on the left bank of Veshav river between Brazul and Amun villages of Kulgam district.

CONCLUSION

The SRTM DEM (90m resolution) and topographic maps (1: 50,000 scale) with interpretation techniques of GIS has been cost effective; in particular, calculation of geomorphic indices is precise and time saving exercise. We used geomorphic features, drainage analysis with emphasis on geomorphic indices for indications of active deformation in the Veshav basin, SW Kashmir Himalaya. Different geomorphic indices such as mountain front sinuosity (s_{mf}), hypsometric integral (Hi), basin elongation ratio (Eb), basin asymmetry (AF), longitudinal profile and stream gradient index (SL) were carried out using 1: 50, 000 topographic maps, SRTM 90m-DEM supplemented with field data. All the indices suggested that the Veshav basin is tectonically active. The study demonstrates the usefulness of drainage, tectono-geomorphic and geomorphic indices in exploring active tectonic features (e.g., anticlinal structure and several fault associated features) and suggests that the Balapur fault extending beyond study area (Veshav basin), which however need paleoseismic investigations for firm seismic hazard assessment.

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A Preliminary Study of Phytoplankton Community of Dal Lake

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ABSTRACT

The present study was carried out during June-October, 2013 to study the species composition and population density of phytoplankton community of Dal Lake. During the entire study period, a total of 51 genera of phytoplankton were recorded in which the class Chlorophyceae (21) was dominant followed by Bacillariophyceae (20) and Cyanophyceae (10). The highest number of taxa were found at site Gagribal B (31) followed by Hazratbal (28), Nishat (27) and Gagribal A (25). Some of the genera like *Scenedesmus* sp., *Cosmarium* sp., *Synedra* sp., *Cymbella* sp., *Cocconeis* sp., *Gomphonema* sp., and *Oscillatoria* sp. were present at all the study sites where as *Chlorella* sp., *Nostoc* sp., *Desmidium* sp., *Chlorococcus* sp. were found only at site IV (Gagribal B). The presence of some pollution tolerant taxa like *Cymbella* sp. and *Oscillatoria sp.* across the study sites indicated the nutrient enrichment of the lake. During the entire course of investigation, Bacillariophyceae was found to be the most dominant class in terms of density followed by Chlorophyceae and Cyanophyceae. The increased nitrate and phosphate contents seem responsible for the growth of Bacillariophyceae. The highest value of Shannon-Weiner Index was found at Gagribal (B) (3.277) and lowest at Gagribal (A) (3.059) depicting the highest and lowest diversity at these sites respectively.

Key words: *Phytoplankton, Species composition, Population density, Chlorophyceae, Bacillariophyceae, Cyanophyceae.*

INTRODUCTION

Phytoplankton are the autotrophic components of the plankton community. These are agents for "primary production," the creation of organic compounds from carbon dioxide dissolved in the water, a process that sustains the aquatic food web. The knowledge of the composition & abundance of phytoplanktonic organisms constitutes an essential feature for the assessment of the trophic status in lakes. Both the qualitative and quantitative abundance of plankton in a water body are of great importance for imposing sustainable management policies as they vary from location to location and in aquatic systems within the same location even with similar ecological conditions (Boyd, 1982). The role of phytoplankton in managing bio-energetics of lakes and their role as bio-indicators have been known for a long time (Kalyani and Singara, 1999).

Since a voluminous literature is available on the plankton population of fresh water habitats of the valley (Kant and Kachroo, 1977; Kaul *et al.*, 1978; Zutshi *et al*., 1980; Kaul and Pandit, 1982; Mir and Kachroo, 1982; Yousuf *et al.*, 1986; Wanganeo and Wanganeo, 1991; Pandit, 1996; 1998; Irfan and Sarwar,1996; Wanganeo *et al.*, 2004; Ganai *et al.*, 2010; Shafi *et al.,*2013). However available data on phytoplankton community of Dal Lake is highly scattered. Present study was undertaken to study the species composition and population density of phytoplankton community of Dal Lake.

Study area and study sites

Dal lake of Kashmir is situated in the northeast of Srinagar at an altitude of 1584 m above mean sea level between 34° 03 & 34° 13 N latitude and 74° 48

& 75° 08 E longitude (Fig.1). For the present study, four sampling sites of Dal Lake were selected. These sites are:

A. Site I (Hazratbal basin)

The site is located at 34° 08′ 00.4' N and 74° 50′ 50.9' E near the Hazratbal shrine situated on the left bank of Dal lake. The site possesses a dense population of macrophytes.

B. Site II (Nishat basin)

The site is located at 34° 07′ 32.6' N and 74° 52′ 37.7' E close to the aeration pumps installed in the lake just in front of the famous Nishat Garden.

C. Site III (Gagribal basin A)

The site is located at 34° 05′ 25.5' N and 74° 51′ 05.5' E near the Nehru park area. It is an open water site with low macrophytic vegetation.

D. Site IV (Gagribal basin B)

The site is located at 34° 05′ 55.1' N and 74° 51′07.8' E and is surrounded by the floating gardens. The macrophytic vegetation is dominated by *Nelumbo nucifera* and *Nymphea mexicana.*

METHODOLOGY

Phytoplankton samples for quantitative analysis were collected by sieving 60 litres of water through a plankton net (No. 25, mesh size 64 µm) in the vertical direction. The samples were then transferred to the properly labeled vials and preserved by fixing in 4% formalin (A.P.H.A., 1998). Then 30 ml aliquot was taken in the tube and identification of the plankton was done with the help of standard works of Prescott (1939), Nygard (1945), Smith (1950), Edmondson (1959), Cox (1996) and A.P.H.A. (1998). For quantitative study, the preserved planktonic samples were subsequently reduced to known volumes by concentrating in a centrifuge for about 5 minutes at 5000 rpm. The concentrated samples were used for

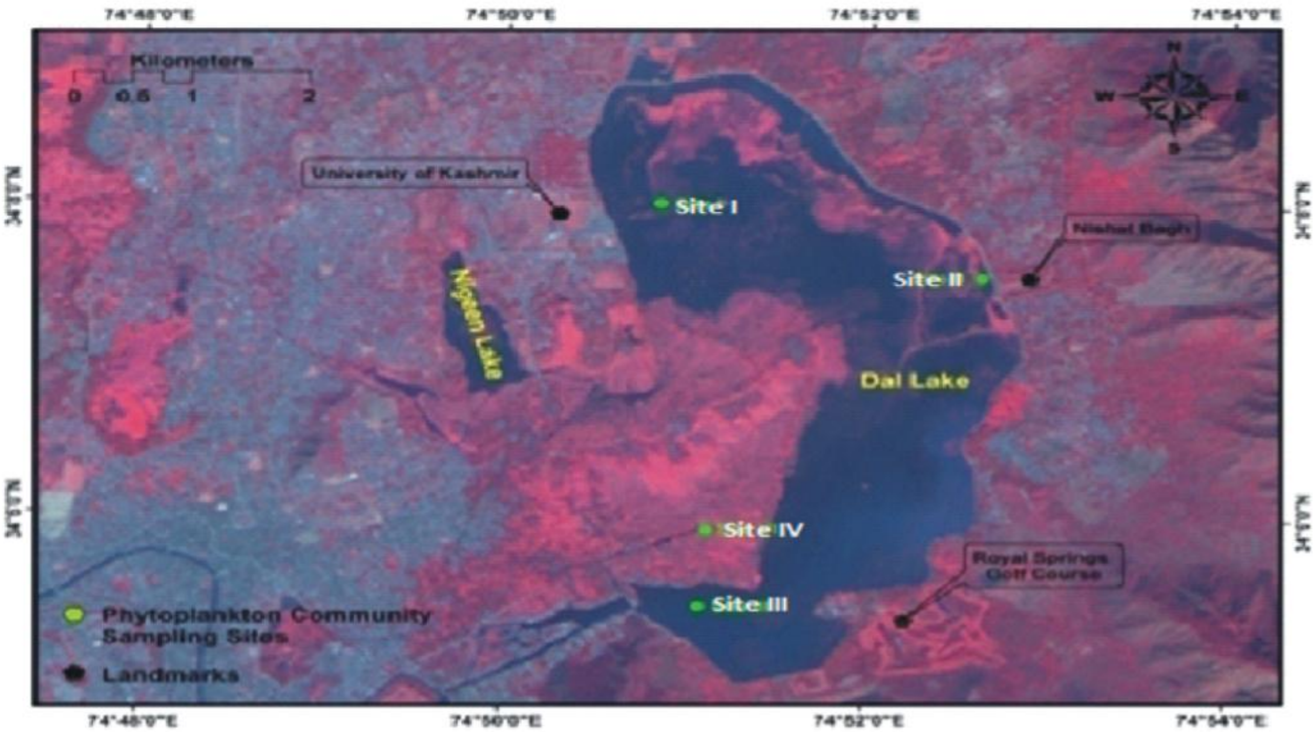

Fig.1. Satellite Image of study area and study sites

quantitative enumeration by using Sedgwick Rafter cell (1 ml capacity) under microscope. The unicellular algae were counted as individuals where as in the filamentous form, each filament was taken as unit and in colonial forms like *Volvox, Microcystis*, etc. the counting unit was taken as a colony (Jumppanen, 1976). Shannon-Wiener index (1949) was used to calculate species diversity between various sites. The species similarity between various sites was calculated by Sorenson similarity coefficient (Sorenson, 1948).

RESULTS AND DISCUSSION

During the entire study period a total of 51 genera of phytoplankton were recorded in Dal Lake in which the class Chlorophyceae registered the highest of 21 taxa followed by Bacillariophyceae (20) and Cyanophyceae (10) (Table 1). The most abundant species among Chlorophyceae were *Pediastrum* sp., *Scenedesmus* sp., *Cosmarium* sp., *Oedogonium* sp. and *Closterium* sp. and least abundant were *Selenastrum* sp., *Chlorella* sp., *Chlorococcus* sp., *Desmidium* sp. and *Microsterias* sp. where as among Bacillariophyceae, *Cymbella* sp., *Navicula* sp., *Gomphonema* sp., *Synedra* sp., *Nitzchia* sp., *Cocconeis* sp., *Fragillaria* sp. and *Amphora* sp. were the most abundant species and the least abundant were *Surirella* sp., *Amphipleura* sp. and *Frustulia* sp. Similarily among Cyanophyceae, *Oscillatoria* sp., *Phormidium* sp. and *Anabaena* sp. were the most abundant and *Spirulina* sp., and *Nostoc* were the least abundant species. Such a type of algal composition and the presence of some pollution tolerant taxa like *Cymbella* sp. and *Oscillatoria sp.* across the study sites indicated the nutrient enrichment of the lake (Findlay *et al.,* 1994).

The highest Shannon- Weiner index was recorded from Gagribal basin B (3.277) depicting the highest diversity at this site, followed by Hazratbal basin (3.213), Nishat basin (3.175) and the minimum from Gagribal basin A (3.059) depicting lowest diversity at this site (Fig.2). The highest number of taxa were found at Gagribal B (31) followed by Hazratbal (28), Nishat (27) and Gagribal A (25). Also, the highest diversity was recorded at Gagribal B possibly due to the presence of floating gardens which increase the nutrient load and indirectly the density of phytoplankton (Shafi *et al.*, 2013).

The highest Sorenson's similarity coefficient was shown by Hazratbal and Nishat (0.65) and lowest by Nishat and Gagribal A (0.46) (Fig.3). Some of the genera like *Scenedesmus* sp., *Cosmarium* sp., *Synedra* sp., *Cymbella* sp., *Cocconeis* sp., *Gomphonema* sp., and *Oscillatoria* sp., were present at all the study sites, where as, *Chlorella* sp., *Nostoc* sp., *Desmidium* sp., *Chlorococcus* sp. were found only at site IV (Gagribal basin B) and were absent at other three sites.

During the entire course of investigation, Bacillariophyceae was found to be the most dominant class in terms of density followed by Chlorophyceae and Cyanophyceae (Fig.4). The high density of Bacillariophyceae may be due to increased nitrate and phosphate contents which are critical for the growth of Bacillariophyceae (Mir and Kachroo, 1982). However, differences in the species composition are possibly due to the differences in the chemical characteristics of water. According to Dickman and Kralina (1975), *Cymbella* sp., *Synedra* sp., *Fragillaria* sp., *Gomphonema* sp. and *Cocconeis* sp. which were recorded in the present lake are commonly found in organically polluted waters, thus indicating the organic load of

Table 1. Monthly variation in Phytoplankton density (Ind/l) at four different sites during June 2013-October 2013

S.No	Taxa	Sites	June	July	September	October	Total	Mean
				Chlorophyceae				
1.	*Chlorella* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	67000	44000	16750	16750	141500	35375
2.	*Chlorococcus* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	67000	44000	33500	16750	161250	40312
3.	*Cladophora sp.*	Site I	67000	67000	50250	33500	217750	54437
		Site II	-	-	-	-	-	-
		Site III	33500	22000	16750	33500	105750	26437
		Site IV	-	-	-	-	-	-
4.	*Closterium* sp.	Site I	67000	44000	33500	16750	161250	40312
		Site II	100500	44000	33500	16750	194750	48687
		Site III	67000	67000	67000	50250	251250	62812
		Site IV	-	-	-	-	-	-
5.	*Cosmarium* sp.	Site I	100500	89000	67000	33500	290000	72500
		Site II	67000	22000	16750	16750	122500	30625
		Site III	33500	22000	16750	16750	89000	22250
		Site IV	133300	89000	67000	33500	322800	80700
6.	*Desmidium* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	33500	22000	16750	33500	105750	26437
7.	*Hydrodictyon* sp.	Site I	-	-	-	-	-	-
		Site II	100500	111000	100500	83750	395750	98937
		Site III	-	-	-	-	-	-
		Site IV	67000	44000	33500	16750	161250	40312
8.	*Microspora* sp.	Site I	-	-	-	-	-	-
		Site II	67000	44000	33500	16750	161250	40312
		Site III	-	-	-	-	-	-
		Site IV	-	-	-	-	-	-
9.	*Microsterias* sp.	Site I	33500	22000	16750	16750	89000	22250
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	-	-	-	-	-	-
10.	*Mougeotia* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	33500	22000	33500	16750	105750	26437
		Site IV	-	-	-	-	-	-
11.	*Oedogonium* sp.	Site I	133300	111000	100500	67000	411800	102950
		Site II	167500	89000	33500	50250	340250	85062
		Site III	-	-	-	-	-	-
		Site IV	167500	156000	150750	117250	591500	147875
12.	*Pediastrum* sp.	Site I	-	-	-	-	-	-
		Site II	100500	67000	16750	16750	201000	50250
		Site III	-	-	-	-	-	-
		Site IV	-	-	-	-	-	-
13.	*Penium* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	33500	44000	33500	33500	144500	36125
		Site IV	33500	44000	33500	33500	144500	36125

14.	*Scenedesmus* sp.	Site I Site II Site III Site IV	100500 67000 133300 167500	111000 44000 111000 134000	83750 50250 100500 134000	50250 33500 67000 83750	345500 194750 411800 519250	86375 48687 102950 129812
15.	*Selenastrum* sp.	Site I Site II Site III Site IV	33500 - - -	89000 - - -	83750 - - -	50250 - - -	256500 - - -	64125 - - -
16.	*Spirogyra* sp.	Site I Site II Site III Site IV	67000 - 100500 100500	44000 - 89000 89000	33500 - 67000 83750	16750 - 50250 67000	161250 - 306750 340250	40312 - 76687 85062
17.	*Tribonema* sp.	Site I Site II Site III Site IV	- - 100500 67000	- - 89000 44000	- - 67000 16750	- - 50250 16750	- - 306750 144500	- - 76687 36125
18.	*Ulothrix* sp.	Site I Site II Site III Site IV	- 67000 - 100500	- 44000 - 67000	- 16750 - 67000	- 33500 - 50250	- 144500 - 284750	- 36125 - 71187
19.	*Uronema* sp.	Site I Site II Site III Site IV	33500 - 67000 133300	22000 - 44000 111000	16750 - 16750 100500	16750 - 16750 67000	89000 - 144500 411800	22250 - 36125 102950
20.	*Volvox* sp.	Site I Site II Site III Site IV	- - 67000 100500	- - 44000 89000	- - 33500 67000	- - 16750 50250	- - 161250 306750	- - 40312 76687
21.	*Zygnema* sp.	Site I Site II Site III Site IV	- - 100500 67000	- - 89000 67000	- - 83750 50250	- - 67000 33500	- - 340250 217750	- - 85062 54437
				Bacillariophyceae				
22.	*Amphipluera* sp.	Site I Site II Site III Site IV	67000 - - -	67000 - - -	50250 - - -	33500 - - -	217750 - - -	54437 - - -
23.	*Amphora* sp.	Site I Site II Site III Site IV	33500 33500 33500 33500	44000 44000 44000 44000	33500 50250 33500 16750	16750 33500 33500 16750	127750 161250 144500 111000	31937 40312 36125 27750
24.	*Cocconeis* sp.	Site I Site II Site III Site IV	67000 67000 33500 33500	89000 44000 44000 22000	83750 50250 16750 16750	50250 16750 16750 16750	290000 178000 110900 89000	72500 44500 27725 22250
25.	*Cyclotella* sp.	Site I Site II Site III Site IV	67000 100500 - -	89000 156000 - -	67000 150750 - -	33500 134000 - -	256500 541250 - -	64125 135312 - -
26.	*Cymbella* sp.	Site I Site II Site III Site IV	133300 201000 100500 133300	134000 178000 111000 134000	117250 150750 100500 134000	67000 117250 83750 83750	330950 647000 395750 485050	82737 161750 98937 121262

27.	*Diatoma* sp.	Site I Site II Site III Site IV	167500 100500 - -	178000 134000 - -	167500 117250 - -	117250 83750 - -	630250 435500 - -	157562 108875 - -
28.	*Diatomella* sp.	Site I Site II Site III Site IV	- - - 33500	- - - 44000	- - - 33500	- - - 16750	- - - 127750	- - - 31937
29.	*Eunotia* sp.	Site I Site II Site III Site IV	- - 67000 67000	- - 67000 67000	- - 67000 50250	- - 50250 33500	- - 251250 217750	- - 62812 54437
30.	*Fragilaria* sp.	Site I Site II Site III Site IV	100500 133300 100500 -	134000 134000 111000 -	100500 117250 100500 -	50250 100500 83750 -	385250 485050 395750 -	96312 121262 98937 -
31.	*Frustulia* sp.	Site I Site II Site III Site IV	- 33500 - -	- 67000 - -	- 33500 - -	- 16750 - -	- 150750 - -	- 37687 - -
32.	*Gomphoneis* sp.	Site I Site II Site III Site IV	- 67000 67000 -	- 67000 89000 -	- 33500 67000 -	- 16750 50250 -	- 184250 273250 -	- 46062 68312 -
33.	*Gomphonema* sp.	Site I Site II Site III Site IV	67000 100500 67000 100500	89000 111000 67000 111000	67000 100500 50250 100500	33500 67000 33500 83750	256500 379000 217750 395750	64125 94750 54437 98937
34.	*Melosira* sp.	Site I Site II Site III Site IV	- - 67000 -	- - 89000 -	- - 83750 -	- - 50250 -	- - 290000 -	- - 72500 -
35.	*Meridion* sp.	Site I Site II Site III Site IV	33500 33500 - -	67000 44000 - -	50250 50250 - -	33500 16750 - -	184250 144500 - -	46062 36125 - -
36.	*Navicula* sp.	Site I Site II Site III Site IV	100500 167500 133300 -	156000 201000 134000 -	117250 167500 117250 -	83750 134000 100500 -	457500 519250 485050 -	114375 129812 121262 -
37.	*Nitzchia* sp.	Site I Site II Site III Site IV	- 133300 - 100500	- 134000 - 134000	- 83750 - 117250	- 67000 - 67000	- 418050 - 418750	- 104512 - 104687
39.	*Pinnularia* sp.	Site I Site II Site III Site IV	33500 67000 - -	44000 89000 - -	33500 117250 - -	16750 83750 - -	127750 357000 - -	31937 89250 - -

40.	*Surirella* sp.	Site I	-	-	-	-	-	-
		Site II	33500	44000	50250	33500	161250	40312
		Site III	-	-	-	-	-	-
		Site IV	-	-	-	-	-	-
41.	*Synedra* sp.	Site I	133300	156000	117250	83750	349900	87475
		Site II	133300	156000	134000	100500	523800	130950
		Site III	133300	134000	100500	67000	434800	108700
		Site IV	67000	89000	83750	50250	290000	72500
42.	*Tabellaria* sp.	Site I	133300	134000	134000	83750	485050	121262
		Site II	100500	111000	100500	50250	362250	90562
		Site III	-	-	-	-	-	-
		Site IV	-	-	-	-	-	-
				Cyanophyceae				
43.	*Anabaena* sp.	Site I	67000	67000	33500	33500	201000	50250
		Site II	67000	67000	50250	33500	217750	54437
		Site III	-	-	-	-	-	-
		Site IV	67000	67000	50250	33500	217750	54437
44.	*Calothrix* sp.	Site I	33500	22000	16750	33500	105750	26437
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	33500	44000	16750	16750	111000	27750
45.	*Merismopedia* sp.	Site I	-	-	-	-	-	-
		Site II	100500	44000	33500	16700	194700	48675
		Site III	-	-	-	-	-	-
		Site IV	100500	67000	67000	50250	284750	71187
46.	*Microcystis* sp.	Site I	234500	223000	201000	134000	792500	198125
		Site II	-	-	-	-	-	-
		Site III	100500	111000	83750	67000	362250	90562
		Site IV	234500	223000	201000	134000	792500	198125
47.	*Nostoc* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	100500	89000	83750	67000	340250	85062
48.	*Oscillatoria* sp.	Site I	201000	156000	134000	50250	541250	135312
		Site II	167500	89000	83750	67000	407250	101812
		Site III	167500	156000	134000	100500	558000	139500
		Site IV	201000	178000	167500	117250	663750	165937
49.	*Phormidium* sp.	Site I	67000	44000	50250	33500	194750	48687
		Site II	-	-	-	-	-	-
		Site III	67000	44000	16750	16750	144500	36125
		Site IV	67000	89000	67000	33500	256500	64125
50.	*Rivularia* sp.	Site I	100500	67000	33500	16750	217750	54437
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	-	-	-	-	-	-
51.	*Spirulina* sp.	Site I	-	-	-	-	-	-
		Site II	-	-	-	-	-	-
		Site III	-	-	-	-	-	-
		Site IV	67000	44000	33500	33500	178000	44500
52.	*Tetrapedia* sp.	Site I	133300	89000	50250	16750	289300	72325
		Site II	-	-	-	-	-	-
		Site III	133300	89000	67000	33500	322800	80700
		Site IV	133300	111000	83750	67000	395050	98762

−Taxa not found

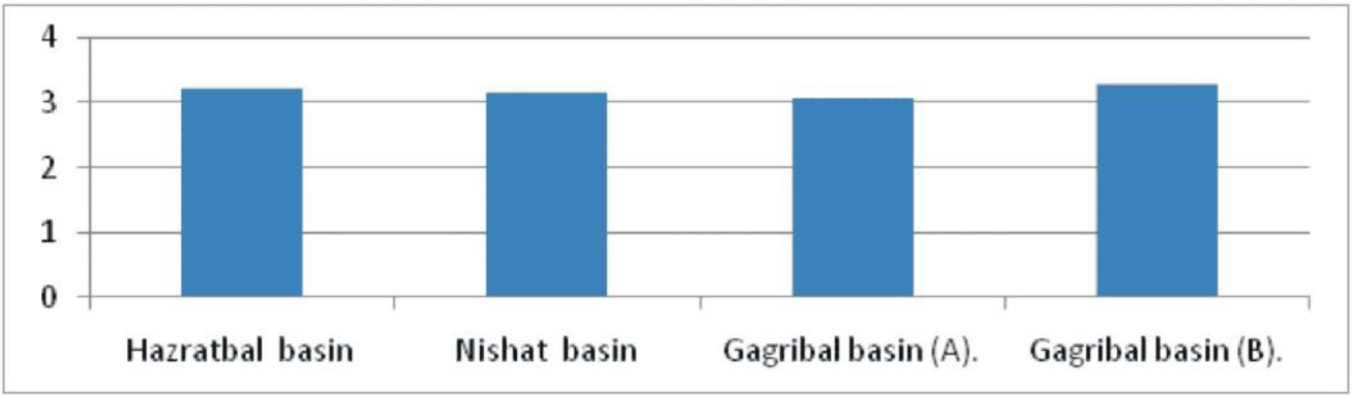

Fig.2. Shannon-Weiner Index of various study sites

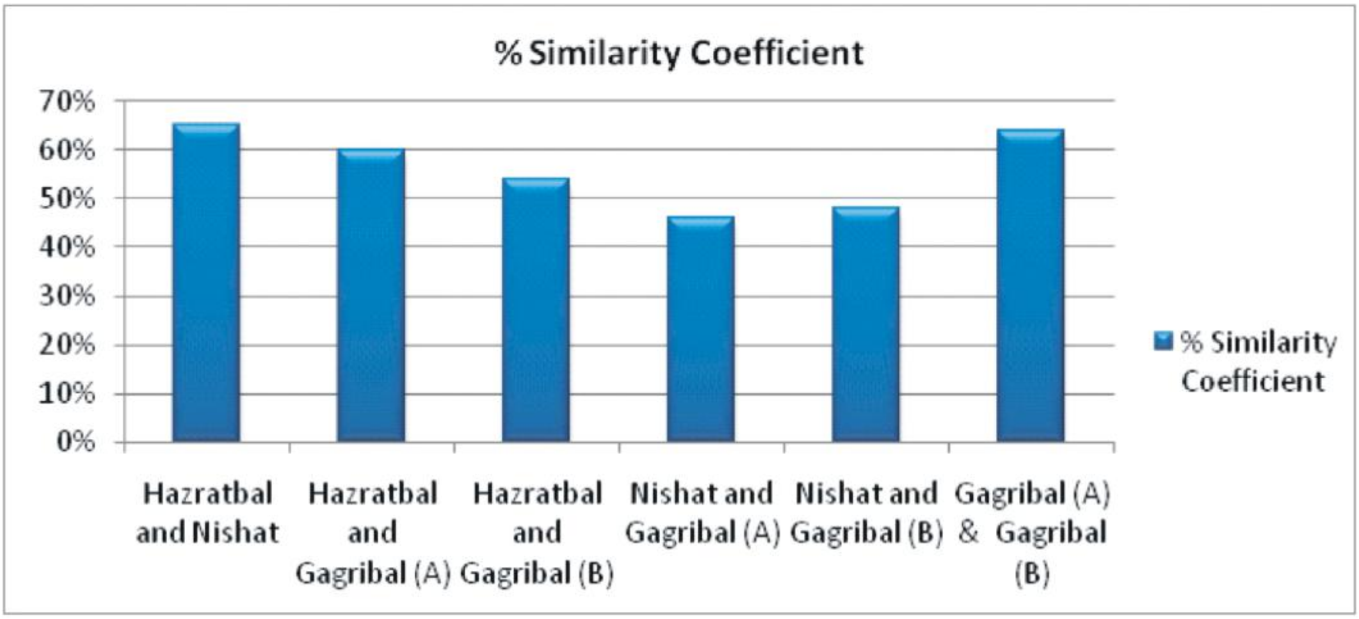

Fig.3. Sorenson's similarity coefficient between various sites

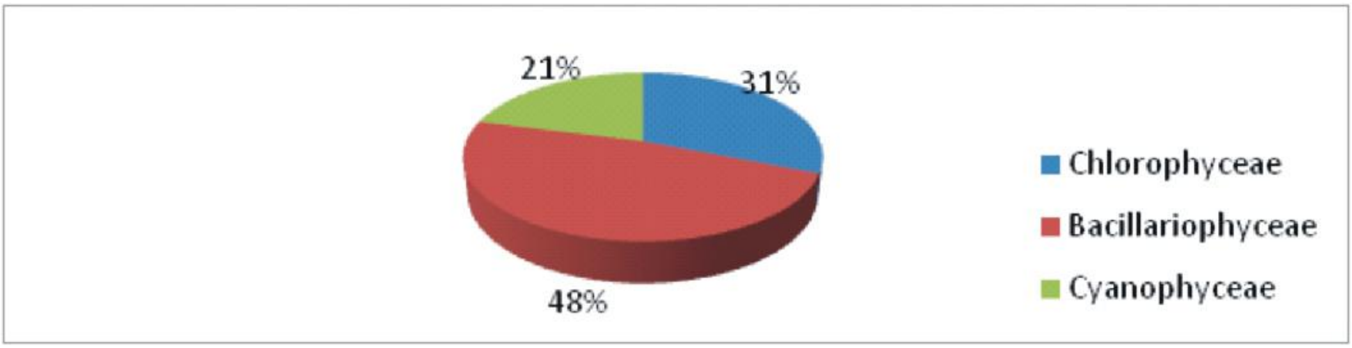

Fig.4. Overall percent contribution of various phytoplankton classes to the total population in the lake

the lake. According to Rawson (1956), the eutrophic waters are characterised by *Anabaena* sp. and *Microcystis* sp. which were recorded in the present lake.

The Chlorophyceae formed the second dominant group in terms of density. A number of green algae like *Cosmerium* sp., *Scenedesmus* sp., *Pediastrum* sp., etc. which have been reported to be abundant in eutrophic waters (Hutchinson, 1967) were recorded during the study.

The high phytoplankton density was observed in the months of June and July. The peak value of phytoplankton in summer seems due to the result of high regeneration rate, temperature, light and availability of nutrients (Prescott, 1984). This preposition has been supported by Davis (1964) and Kaul *et al.* (1978). The same reason seems responsible for the reduction in the number of organisms in winter and spring seasons which might be related to lower light intensity during low temperature seasons.

CONCLUSION

The present study on the phytoplankton community of Dal Lake revealed the dominance of Chlorophyceae over Bacillariophyceae and Cyanophyceae qualitatively. Quantitatively the diatoms showed the highest dominance. Among all the study sites, the highest density was recorded at Site IV (Gagribal basin B).

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Streamflow Changes of Ferozpur Watershed in the Upper Indus Basin, Kashmir Himalayas

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ABSTRACT

River Jhelum is the main source of water usage in Kashmir valley which is glacier and snow bound area situated in Upper Indus Basin. This study was carried in Ferozpur watershed which is one of the 24 watersheds of Jhelum basin in Kashmir valley. Streamflow data from three gauge stations located at Drung, Terran and Trikulbal during the last 42 years (197-2013) were used to understand the stream flow changes in Ferozpur watershed. Changes were analyzed graphically and statistically. Non- parametric approach, three non-parametric statistical tests, Mankendall, Spearman's Rho and Distribution free Cusum, were employed to determine the significance of the observed trends in the time series streamflow data. Mankendall and Spearman's Rho tests were used to check the strength of trend while as Cusum test for abrupt change in mean of the streamflow data from 1971-2013.Results showed significantly decreasing trend for Drung and Terran annual and seasonal stream flows at the 0.01 and 0.05 level of significance while as decreasing trends were found non-significant for Trikulbal station. Analysis of the inter-decadal variability of the streamflow data from all the three stations showed increasing trend from 1971-1990 and decreasing trend from 1990-2013. The significance of the abrupt change in stream flow was statistically confirmed by Cusum at 0.05 level of significance. Drung and Terran station data showed good relationship in terms of the trends observed in the annual and seasonal streamflow data.

Key words: *Mankendall, Spearman's Rho, Ferozpur, Streamflow*

INTRODUCTION

Streamflows in a particular catchment represents an integrated response to catchment heterogeneity and spatial variability of main hydrological processes (precipitation, infiltration and evapotranspiration) and can be an indicator variable providing insight into long-term hydroclimatic changes. Well over half of the world's potable water supply is extracted from rivers, either directly or from reservoirs (Barnett *et al.,* 2005). Streamflows in unregulated catchments can carry signatures of climate forcing and changes. Main drivers of streamflow changes in unregulated watersheds are climatic variability and changes and other factors (Gautam and Acharya, 2012; Romshoo *et al.,* 2015; Zhang *et al.*, 2000; Kahya and Kalayci, 2004; Romshoo *et al.*, 2012).

Climate change phenomenon almost influences all the processes in the biosphere someway. Consequently, these happenings affect upon the several environmental and hydrological variables negatively (Abdul Aziz and Burn, 2006; Yavuz and Erdogan, 2012; Romshoo *et al.*, 2010; Rashid *et al.,* 2015). One of the most important and immediate effects of global warming would be the changes in local and regional water availability, since the climate system is interactive with the hydrologic cycle (Allen and Ingram 2002; Barnett *et al.,* 2005;

Arora M. 2008; Immerzeel *et al*., 2010; Romshoo *et al*., 2015).Such effects may include the changes in the magnitude and timing of runoff, changes in frequency and intensity of floods and droughts, rainfall patterns, extreme weather events, and the quality and quantity of water availability. These changes, in turn, influence the water supply system, power generation, sediment transport and deposition, and ecosystem conservation. Projected global changes in temperature are likely to intensify the hydrologic cycle and, hence, alter hydrologic systems. (Zhao *et al.,* 2010; Sharif *et al.,* 2013). As a result, hydrological systems are anticipated to experience, not only changes in average availability of water, but also changes in extremes (Simonovic and Li*,* 2003; Jiang *et al.,* 2007). However, the impacts of climate change on hydrological systems may vary from region to region.

Detection of trends in instrumental records of hydroclimatic variables such as air temperature, precipitation and streamflow is very important in understanding the climate variability and climate change. Variability in precipitation and temperature has been the primary focus of climate research community (Sharif, et al., 2013; Zaz and Romshoo, 2013). It has been found that trends in observed daily precipitation are generally a complex function of the climatic environment, precipitation intensity and season (Karl and Knight, 1998; Osborn *et al.,* 2000; Brunetti *et al.,* 2001; Ventura *et al.,* 2002). Consequently, numerous studies of stream flow time series have been carried out using trend analysis (e.g. Hisdal *et al.*, 2001; Burn and Hag Elnur, 2002; Robson, 2002; Romshoo *et al.,* 2015; Lindstrom and Bergstrom, 2004; Lins and Slack, 1999; Zhang *et al.*, 2001).

In context to the Himalayas, several studies have been conducted in the field of hydrology and its linkages to various climatic parameters (Archer 2003; Archer and Fowler, 2004; Archer and Fowler, 2008; Singh and Bengtsson, 2005; Kumar *et al.,* 2006; Tahir *et al.,* 2011; Biemans *et al.,* 2013; Immerzeel *et al.,* 2013; Lutz *et al.,* 2014; Mukhopadhyay and Khan, 2014b).In Kashmir Himalayas, metrological stations are scanty and sparsely located and for that reason, it is difficult to generate a good understanding of the hydrological processes. However, despite this constraint, quite a few studies have been carried out on the subject recently (Ali and Romshoo, 2015; Dar and Romshoo, 2012; Romshoo *et al*., 2012; Murtaza and Romshoo, 2016; Romshoo and Rashid, 2014; Romshoo et al., 2015; Meraj *et al.*, 2015). The problem of few and scanty data is a major constrain for deriving a spatially representative distribution of the hydro meteorological parameters in Kashmir Himalayas (Romshoo and Rashid, 2010; Hachem*,* 2012; Altaf *et al*., 2013). The purpose of this study is to understand the pattern of streamflow changes in Ferozpur watershed which is located in Pir Panjal ranges of Jhelum (upper Indus basin) in Kashmir Himalayas, India.

Study area

Ferozpur watershed covers an area of about 445 sq. kms and is a tributary of Jhelum in the upper Indus basin. The Ferozpur river rises in the slopes of the Pir Panjal between the Jamianwali Gali (4084 m) and the Apharwat (4143 m). On entering the relatively plain area, the Ferozpur river gets divided into two branches, both retaining the original name. The two branches individually enter the flood spill channel and the marshy land on the left bank of Jhelum. The spill channel empties into the Walur Lake. The Ferozpur river has a course of about 51 km. The upper portion of the catchment shows dendritic drainage pattern while as lower portion shows more or less parallel drainage pattern.

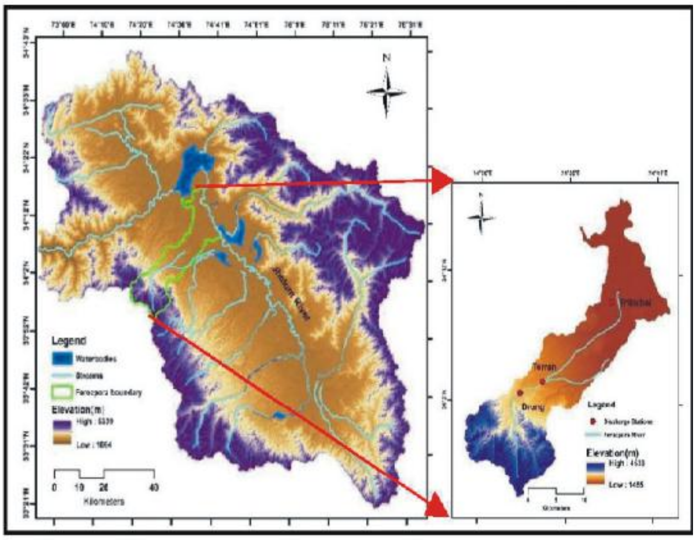

Fig 1: Study area Map of Ferozpur Watershed

MATERIAL AND METHODS

Data sets used

The data used in the study includes streamflow data of three discharge stations namely Drung, Terran and Trikulbal station of Ferozpur watershed procured from Irrigation and Flood control department, Srinagar. Drung is the head station and the Trikulbal is the tail station of the Ferozpur river. Terran is located in the upstream portion of the river. Location of gauge stations is shown in Fig1. Streamflow data analysis was performed on annual and seasonal basis for a period of 42 years from 1971-2013. For the seasonal analysis of streamflows, a year is divided into 4 seasons of 3 months each, namely winter (DecemberFebruary), spring (MarchMay), summer (JuneAugust), and autumn (SeptemberNovember). (Khattak *et al.,* 2011).

To accomplish the research for determining the magnitude and significance of the trends observed in the streamflow data of 3 stations of Ferzopora watershed, statistical trend analysis was performed. Changes in the streamflow data generally occur gradually (a trend) or abruptly (a step change). The change may affect any aspect of the data including the mean, median or variance (Kundzewicz and Robson, 2004).

Statistical trend analysis:

Many techniques are available to analyse trends in hydrologic data. Statistically, the aim is to identify a trend as the increase or decrease of streamflow over time. To identify the presence of a significant trend, the TREND software package by the Cooperative Research Centre for Catchment Hydrology (Chiew and Siriwardena, 2005) was used.

Table 1. Details of Statistical tests used

Name of the Test	Type	Purpose
Mann-Kendall	Non-parametric test	For trend
Spearman's Rho	Non-parametric test	For trend
Cusum	Non-parametric test	For Step jump in mean

Non Parametric tests were used, the details of which are given in the Table 1 for understanding the significance of streamflow trends in the Ferozpur watersheds. Many parametric and non-parametric methods have been applied for detection of trends (Kundzewicz and Robson, 2004; Zhang *et al.,* 2006). Parametric tests are more powerful than non-parametric tests, but the assumption that the data are normally distributed must be satisfied. Hydro-meteorological time series are often characterized by data that exhibit departures from normality, and, therefore, non-parametric tests are considered more robust compared to their parametric counterparts (Hess *et al.,* 2001).

Non-parametric tests are generally distribution-free. They detect trend/change, but do not quantify the size of the trend/change. Though there are many non-parametric tests for drawing probabilistic inferences from a set of statistical tables, but standard procedure must be followed. Three non-parametric tests were used to test the significance of the streamflow data used in this study.

Mann Kendall Test:

One of the most widely used non-parametric tests for detecting a trend in the hydro-meteorological time series is the Mann Kendall test (Mann 1945; Kendall, 1975). A major advantage of the Mann-Kendall test is that it can tolerate outliers. Several researchers have employed the Mann-Kendall test to identify trends in the hydrological and hydrometeorological time series (Steele *et al.,* 1974; Hirsch *et al.,* 1982; Hirsch and Slack, 1984; van Belle and Hughes, 1984; Hipel *et al*., 1988; Lins and Slack, 1999; Douglas *et al.,* 2000; Burn *et al.,*. 2004a,b; Chen *et al.,* 2007; Burns *et al.*, 2007; Singh *et al.*,2008; Zaz and Romshoo, 2013).

The Mann-Kendall test is a ranked based approach that compares each value of the time series with the remaining values in a sequential order (Hirsch *et al.,* 1982). The test statistic S is given by:

$$S=\sum_{i=1}^{n-1}\left[\sum_{j=i+1}^{n} sgn(x_j-x_k)\right] \qquad (1)$$

where,

sgn (x) = 1 for x > 0, *sgn* (x) =0 for x = 0 and *sgn* (x) = -1 for x< 0

and x_j and x_k are the sequential data values, and n is the length of the dataset. A positive value of S indicates an upward trend, and a negative value indicates a downward trend.

Spearman's Rho Test

Spearman's rank correlation coefficient is a non-parametric measure of correlation means it assesses how well an arbitrary monotonic function describes the relationship between two variables without making any other assumptions about the particular nature of the relationship between the variables. Spearman's Rho, also called rank correlation, uses ranked data in the ordinal scale measurement. Spearman's Rho test is widely used for determining the statistical significance of the hydro-meteorological data trends (Yue and Pilon, 2004; Bouza-Deano *et al.,* 2008). It assesses how well an arbitrary monotonic function describes the relationship between two variables without making any other assumptions about the particular nature of the relationship between the variables.

The test static ρ_s is the correlation coefficient, which is obtained in the same way as the sample correlation coefficient but by using ranks as under:

$$\rho_s = S_{xy}/(S_x S_y)^{0.5} xy \qquad (2)$$

where,

$$S_y = \sum_{i=1}^{n}(yi-y')^2$$

$$S_{xy} = \sum_{i=1}^{n}(xi-x')(yi-y')$$

and 'xi' represents time, 'yi' variable elements, x' and y' refer to ranks. x', y', S_x, and S_y are normally distributed with mean of zero and variance of one.

Distribution Free CUSUM Test

This method tests whether the means in two parts of a record are different (for an unknown time of change). It is a non-parametric test (distribution free). Given a time series data ($x_1, x_2, x_3 \ldots x_n$), the test statistic is defined as:

$$V_k = \sum_{i=1}^{k} Sgn(x_i - x_{median}) \quad k = 1, 2, 3....n \qquad (3)$$

where

sgn(x) = 1 for x > 0

sgn(x) = 0 for x = 0

sgn(x) = -1 for x < 0

x median is the median value of the xi data set.

RESULTS AND DISCUSSION

Statistical trend analysis

Trend analysis of the time series was conducted for Drung(H), Terran(M) and Trikulbal(T) stations of Ferozpur watershed. Exploratory data analysis was performed for visually identifying any data problems (i.e. outliers) and temporal patterns (i.e. trend or step-change). After identifying the pattern in the data, statistical trend tests were performed on annual and seasonal time series data.

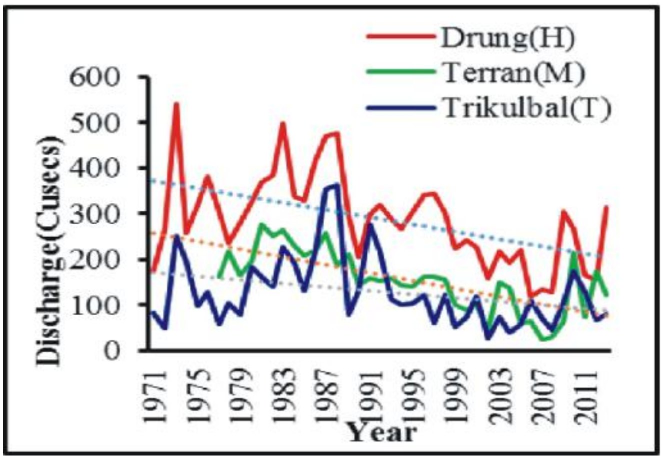

Fig 2. Annual Time series plot for Drung (H), Terran (M) and Trikulbal (T) discharge station of Ferozpur watershed.

Annual Trends

Highest streamflow is found in the year 1973 for both head and tail stations which was a flood year.

Table 2: Statistical trend tests results for Drung (H), Terran (M) and Trikulbal (T) discharge station of Ferozpur watershed.

Name of Test	Drung	Terran	Trilk ulbal
Mann-Kendall	S (0.01)	S (0.01)	NS
Spearman's Rho	S (0.01)	S (0.01)	NS
Cusum	S (0.05)	S (0.01)	S (0.05)

Fig 2 clearly showed decreasing trend of discharge Ferozpur river for all the three discharge stations but significantly decreasing trend were found for Drung (H) and Terran (M) discharge station at 0.01 level of significance based on Man-Kendall and Spearman's Rho tests while as CUSUM test showed significantly change in the mean at 0.05 level of significance (Table 2). Downstream station, Trikulbal (T) showed decreasing trend but statistically non- significant according to Man-Kendall and Spearman's Rho tests but CUSUM test shows that there is step jump in the mean at 0.05 level of significance (Table 2) which was confirmed from estimated mean of the streamflow data series (Table3).

Inter-decadal variability was also observed in the time series of the three discharge station as the streamflow data from 1971 to 1990 showed increasing trend while as from 1990 to 2013 decreasing trend was observed (Fig 3) for Drung and Trikulbal station. This variability can be statistical confirmed by comparing mean between two time periods.

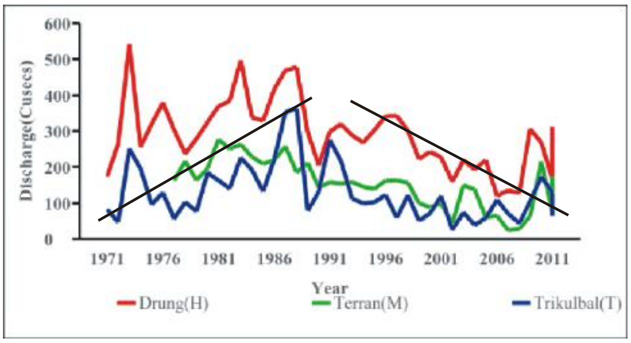

Fig 3. Plot showing increase in the streamflow from 1971-1990 (Brown line) and decreasing trend from 1990-2013(Black line) for Discharge stations of Ferozpur watershed.

Table 3: Showing mean discharge(Q) in cusecs for time period 1971-1990,1990-2013 and 1971-2013 for Drung(H), Terran(M) and Trikulbal(T) discharge station of Ferozpur watershed.

Time Period	Drung Q	Terran Q	Trilku-lbal Q
1971-1990	343.06	213.19	161.41
1990-2013	245.15	115.82	102.90
1971-2013	288.29	153.26	129.32

Table 3 shows that from 1971 -1990 mean for all the three stations is greater than the mean of streamflow data series from 1990-2013 which implies that in previous decades of the observed data, we were getting more discharge in rivers compared to now.

As the main source of streamflow in the region has been traditionally from snowmelt and glacier melt so the enhanced melting due to increasing temperatures (1960-1990) might explain the initial increase and the subsequent decrease in the observed stream flows (Romshoo et al., 2015).The declining glacier contribution during the later period (1990-2013) in the Jhelum basin is attributed to the loss of substantial glacier mass observed in the area (Romshoo *et al.,* 2015).

Seasonal Trends

Annual time series data was categorized into 4 seasons, viz., Winter, Spring, Summer and Autumn seasons. Decreasing trend of the streamflow data

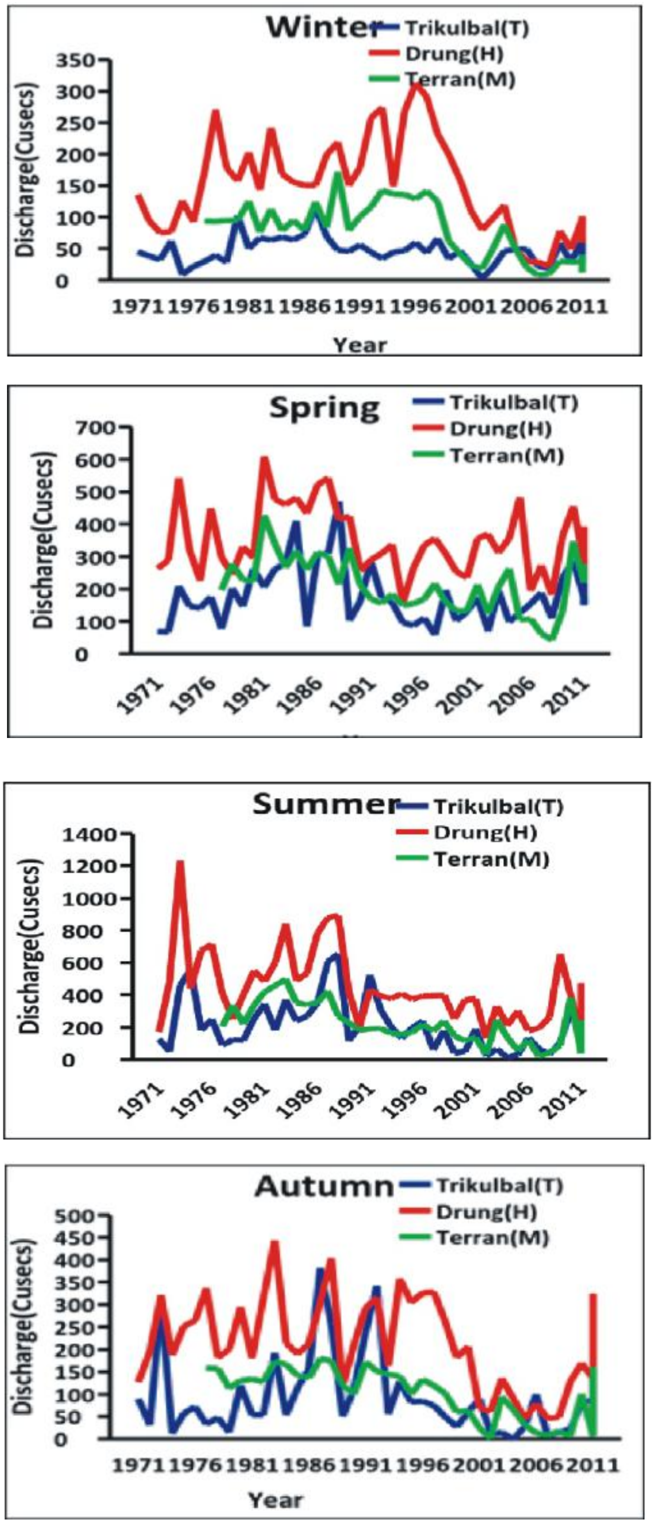

Fig 4. Seasonal Time series plot for Drung(H), Terran(M) & Trikulbal(T) discharge station of Ferozpur watershed.

was found in winter, summer spring and autumn seasons for Drung(H), Teeran(M) and Trikulbal(T) gauge stations in Ferozpur watershed (Fig 4). Main reason for this variability is decreased net snow accumulation on glaciers. The enhanced melting of glaciers under increasing temperatures in the region has led to glacier recession and ultimately decreased contribution to runoff from glacier melt (Archer and Fowler, 2004, Romshoo et al., 2015).

Table 4: Statistical trend tests results for Drung (H), Terran (M) and Trikulbal (T) streamflows data of Ferozpur watershed

Station Name	Name of Season	Mann-Kendall	Spearman's Rho	Cusum
Drung	Winter	S (0.01)	S (0.01)	S (0.01)
	Spring	S (0.05)	S (0.05)	S (0.01)
	Summer	S (0.01)	S (0.01)	S (0.01)
	Autumn	S (0.05)	S (0.05)	S (0.05)
Terran	Winter	S (0.01)	S (0.01)	S (0.01)
	Spring	S (0.01)	S (0.01)	S (0.01)
	Summer	S (0.01)	S (0.01)	S (0.01)
	Autumn	S (0.01)	S (0.01)	S (0.01)
Trilkulbal	Winter	NS	NS	S (0.05)
	Spring	NS	NS	NS
	Summer	S (0.05)	S (0.05)	NS
	Autumn	NS	NS	NS

Table 4 shows the statistical trend test results for all the four seasons. From the data presented in the table, it was found that Drung(H), Terran (M) stations shows statistically significant decreasing trend for winter, spring , summer and autumn season at 0.01 and 0.05 level of significance which means 90% to 95% chances rejecting the null hypothesis H_o (i.e there is no trend in the data). CUSUM test which analyses the step jump in mean of the time series data also gave significant result at 0.05 and 0.01 level of significance which can also be determined from Fig. 4 which clearly depicts overall decreasing trend with an increase in streamflow from 1971-1990 and decrease from 1990-2013.

At downstream Trikulbal (T) station depicts non-significant decreasing trend for winter, spring and autumn seasons while as summer season showed significantly decreasing trend at 0.05 level of significance. The different trends of the streamflow observed at the tail station might be because of the complex changes in the water usage in the Ferozpur watershed since 1971 till date.

Annual as well as seasonal trend analysis shows streamflows have declined in Ferozpur watersheds at upstream as well as downstream stations. As Ferozpur watersheds falls in the Pir Panjal range of Kashmir Himalayas where main contribution to streamflows have been either snowmelt as is the situation currently or glaciermelt in the past, therefore the changes in snow and glaciers have directly impacted the streamflows. Several studies in the Upper Indus basin have reported decline in glacier area and snow cover (Romshoo *et al.,* 2015, Murtaza and Romshoo, 2016). Overall all the four seasons are showing decreasing trend in discharge data and some inter-seasonal and inter-decadal variations in the observed for all the three stations. In summer months, there is more streamflow due to the increase in temperature which enhance melting of Glacier and Snow covered areas (Romshoo *et al.,* 2015). As the minimum temperatures have increased in the Jhelum basin (Zaz and Romshoo, 2013) and there is less snowfall in the region (Romshoo *et al.,* 2015), the proportion of the snowmelt contribution in the total precipitation is decreasing particularly in winter and spring seasons which is also believed to be responsible for the decrease in the summer streamflow. . In spring season, the overall trend of streamflow is decreasing but the total amount of streamflow during spring is more compared to summer season reason. This points towards early melting of snow cover due to increase in temperature and more precipitation in the form of rain during the season.

CONCLUSION

From the analysis of the time series streamflow data in Ferozpur watershed, it is concluded that there is significant decrease in streamflow for all the three discharge stations i.e Drung(H), Terran(M) and Trikulbal(T) during the last 42 years (1971-2013). Overall, the upstream and downstream stations showed good relationship in terms of streamflow changes as both are showing significantly decreasing trends. Inter-decadal variability is shown in annual time series data with an increase observed in the streamflow from 1971-1990 and a decrease in the streamflow from 1990-2013. Seasonal decline are clearly seen in the streamflow data of Ferozpur watersheds. The study gives a clear picture of decline in streamflow in glacier and snowfed Kashmir Himalayas which are adversely effected by the climate change in terms of decrease in glacier and snow cover area, increase in temperature, change in form of precipitation, land system changes, wetland dynamics and socioeconomic changes. These change observed in the streamflow amount and seasonal proportion could have serious consequences for the timely water availability for agriculture and other activities in the region and downstream.

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The Influence of Water Depth on Morphological Traits of Trapa Natans in Valley Lakes of Kashmir

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ABSTRACT

In this study, we investigated whether there is any differential impact on various morphological traits of *Trapa natans* by water level gradients and different trophic status of lakes. The response of plant traits viz., mean number of ramets, mean spacer length, mean shoot length, mean inter-node distance, mean leaf length & width and mean number of fruits were observed in three depth ranges i.e., D1 (0-100cm), D2 (101-200cm) and D3 (201-300cm) in three lakes viz., Dal, Anchar and Manasbal. The results showed that only depth was having a significant effect on some of the plant traits such as shoot length (F=97.90, p = 0.00), inter-node distance (F=11.60, p=0.00), leaf width (F=4.80, p=0.00) and fruits (F=14.39, p =0.00). Neither the trophic status of lakes nor the interaction between depth and site was noticed to have any significant influence on morphological characters of plant species. From the study it can be concluded that morphological characteristics of *T. natans* did not show significant variation with respect to the trophic status of lakes, however water depth depicted significant impact on some of the important traits meant for plants progressive growth and thus can be used as a method to control the growth of *T. natans* in lakes.

Key words: *Macrophytes, Eutrophication, Himalaya, Dal, Manasbal, Anchar, Management*

INTRODUCTION

Macrophytic vegetation in the lakes are usually habitat opportunists and that favourable condition for their growth is a direct result of human influence. The development of residential colonies on the lake shore can alter lake ecosystems because of firm relation between the riparian and littoral zones (Steffenhagen *et al.,* 2011). To cope up with the continued degradation of lakes, many researchers have been focusing on the ecological restoration of these aquatic ecosystems (Asgher and Bhatti, 2012). Recovering lacustrine ecosystems, especially the macrophytes, is very important because they have multiple ecological functions to play such as improving the self-purification capacity of a lake ecosystem (Soana *et al.,* 2012; Tanner and Headley, 2011), stabilizing sediments, preventing sediments from re-suspension and improving the general environmental conditions (Chen *et al.,* 2012).

However, macrophytic vegetation upon getting favourable environment grows up to nuisance levels and cause silting by adding large amount of plant material to the lake bottom and release pollutants to the lake water when they decompose (Vereecken *et al.,*2006) and thus assist in eutrophication. The eutrophication of lakes often leads to a shift in the macrophyte community from dominance of sub-merged plants to dominance of floating-leaved plants (Egertson *et al.,* 2004). The mechanism behind the shift is the formation of a dense canopy that has key role in inter-specific competition among several morphologically similar macrophytes (Hofstra *et al.,* 1999). A comprehension about responses of individual species to hydrological conditions thus, may enable more efficient restoration or promote ecologically sensitive hydrological management (Khanday *et al.,* 2015). Hence, managing aquatic macrophytes in eutrophic lakes is important both as a technique and as a tool for conservation of lakes.

The Valley lakes in Kashmir Himalaya are also witnessing such deplorable states where a huge chunk of water bodies have been engulfed by the growth of aquatic vegetation, especially the rooted floating macrophytes.One such type of plant species viz., *Trapa natans*, has been studied in the present research.

T. natans is an annual aquatic plant with a submerged stem and have very fineroots to anchor the plant into the mud. Leaves are rosette type and triangular in shape having saw tooth margins and connects to an inflated petiole which provides added buoyancy for the leafy portion. Additional feather like leaves are also found along the submerged stem. In the spring, the plants emerge as rosettes from seeds and cover the water surface with dense foliage, often becoming the dominant species. They develop into mono specific stands of plants that are rooted in the sediment with petioles holding leaves that float on the surface. *T. natans* form dense floating mats, severely limiting light which is a critical element of aquatic ecosystems.

The present study thus, was undertaken to understand the effect of water depth and site characteristics (trophic status of lakes) on the growth of morphological characters of *T.natans*.

MATERIALS AND METHODS

Study Area

The present study was pursued in three Valley lakes of Kashmir (Fig. 1) - the Dal, the Anchar and the Manasbal.

Dal Lake

The Dal Lake, situated about 2 km to the Northeast of Srinagar city is lying at an altitude of 1584m (amsl). The lake has witnessed tremendous amount of human pressure from past few decades (Badar *et al.*, 2013) due to which the water quality of the lake has been deteriorated and is now considered as eutrophic (Mushtaq *et al.*, 2014). Four sampling locations (D1-D4) were selected in the lake, the geographical position of which is given in Table 1.

Anchar Lake

The Anchar, a hyper-eutrophic lake (Zargar *et al.,* 2012), is about 14 km to the northwest of Srinagar, at an altitude of 1584 m (amsl). Due to increased human perturbations, the open water of the lake represents only about 1.69 km^2 out of total 6.6 km^2 surface area. Four sampling sites, A1-A4 were identified in the lake for the collection of the data.

Manasbal Lake

The Manasbal, being the deepest and mesotrophic fresh water Valley lake (Shah *et al.,* 2013), is positioned 32 km northwest of the Srinagar city, at an altitude of about 1585m (amsl). The lake is oblong in outline covering an area of 2.80 km^2 with the maximum depth of 12.5m (Yousuf, 1979). Four study sites were selected on the basis of depth and vegetation in the lake for studying the preferred macrophyte (Table 1).

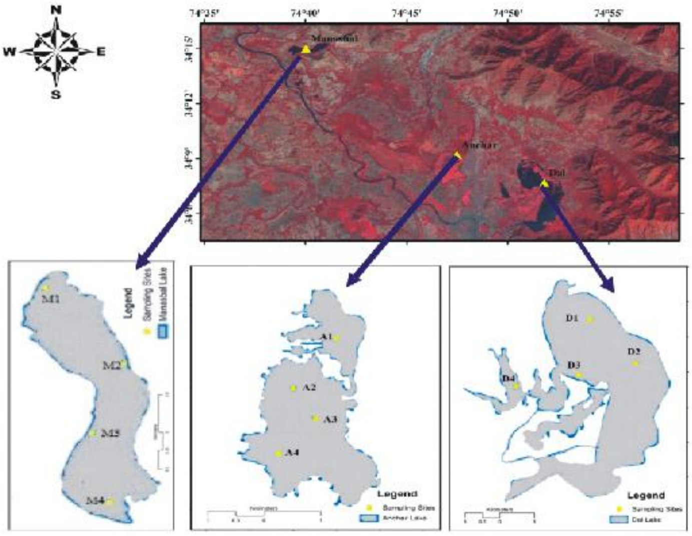


Fig.1 Study area map showing location of sites

Table 1. Geographical co-ordinates of selected sites

LAKE	SITE	LATITUDE	LONGITUDE
DAL	D1	34°08′28″	74°51′20″
	D2	34°07′15″	74°50′55″
	D3	34°07′30″	74°52′10″
	D4	34°07′00″	74°50′00″
ANCHAR	A1	34°08′13″	74°46′50″
	A2	34°08′ 42″	74°47′15″
	A3	34°09′00″	74°47′00″
	A4	34°09′41″	74°47′30″
MANASBAL	M1	34°15′15″	74°41′10″
	M2	34°14′55″	74°40′10″
	M3	34°15′03″	74°39′57″
	M4	34°14′55″	74°39′20″

Architectural analysis

The plant samples were collected during their peak growth season. In the present study architectural analysis and terminology by Wolfer (2004) was used, which defines 'plant' as a complete unit of ramets connected by stolons/rhizomes originating from a single primary shoot.'Ramet' is a single module of a clonal plant, consisting of shoots/petiole, rhizome and roots. 'Spacer length' is the stolon/rhizome length between two consecutive shoots of the same plant.

The plant was extracted from different range of depths viz., D1 (0-100cm), D2 (101-200cm) and D3 (201-300cm) from all the four sites in each lake with a rake consisting of adjustable rods. Polybags were used to collect the plant samples after due cleaning. The morphological features measured are described below:

Number of ramets: These are the single modules of a clonal plant, comprising of shoots, rhizome and roots. A plant produces different number of ramets at different water depth zones and the same was enumerated for data analysis.

Shoot length: The plant emerged from the bottom to the surface of water by elongation of its shoots. The length of shoot was calculated from the rhizome of plant to the leaf base of main stem.

Inter-node distance: It is the length between two consecutive nodes of shoots.

Leaf length and width: The leaf length of *T. natans* was taken between leaf base (attached to petiole) and the tip of leaf while as width of the leaves was measured at their widest points.

Fruits: The plant species in different depth ranges was counted for number of fruits at their peak growth for data analysis.

Statistical analysis

Univariate General Linear modeling procedure was used to test the combined effects of water depth and site (lake) on various morphological traits of the selected plant species. Tukey's HSD test was run to determine statistical significance between means. Differences were considered signifi-cant at $P < 0.05$. All statistical analyses were performed using SPSS 16.

RESULTS AND DISCUSSION

A number of morphological traits viz., number of ramets, mean spacer length, mean shoot length, mean leaf length, mean leaf width, and mean number of flowers of studied aquatic plant species, namely *T. natans,* was recorded at three depths of 0-100 cm (D1), 100-200 cm (D2) and 200-300 cm (D3) in Manasbal, Dal and Anchar lakes. The results obtained for these traits are as follows:

Number of ramets

The morphological characters of *T. natans* at different depths in three different lakes are given in Table 2. The number of ramets per plant at all study sites in the three lakes increased with depth having maximum number of 7.3±0.6 ramets per plant at D3 depth in Manasbal lake and minimum number of 4.3±0.6 ramets at depth D1 in Anchar lake (Table 2). However, the mean number of ramets did not show any significant variation with respect to depth ($F = 3.63$, $p = 0.05$) and lakes ($F = 3.43$, $p = 0.05$) studied. The plants were seen to form large patches in all the three lakes in deeper water areas due to relatively low growth rate in comparison to the other plants and thus avoid competition with them by occupying deeper areas (Wu *et al.,* 2007). In addition, in shallow zones even slight fluctuations in water-level can be detrimental to its survival (Vuorela and Aalto, 1982). Thus, the plant species, *T. natans* in present study was observed to prefer deeper waters than littoral areas in all the lake ecosystems.

Spacer length

The largest mean spacer length (15±1.1cm) was registered at D2 depth in Dal lake, while smallest (13±0.6cm) was noticed at D3 depth in lake Manasbal (Table 2). Similarly, the mean spacer length was maximum at Dal lake (14.6±1cm) followed by Anchar (14.5±1cm) and Manasbal lake (13.7±1cm). However, difference in mean spacer length either with respect to depth ($F = 2.31$, $p = 0.13$) or lakes ($F = 3.62$, $p = 0.057$) was not significant (Table 3) (Fig.2c,d). This is because plant species at higher water depths remains under stress and thus prevents dispersion by producing longer spacer lengths and hence less number of ramets. In contrast, the plants were noticed to generate small spacers between ramets in the lesser water depth ranges (i.e.,0-200cm). This decrease in spacer length is attributed to the fact that plants at these water-levels allow ramet production to enhance and thereby colonize large areas by utilizing their favorable environment (Cain, 1994).

Shoot length

Mean shoot length of *T.natans* showed a progressive increase with increase in depth in all the lakes. The maximum (220.9 ±8.5cm) mean shoot length was observed in Manasbal lake at D3 depth, while least value (58.9±1cm) for the plant trait was noticed at D1 depth in Anchar lake (Table 2). Moreover, only depth ($F = 97.90$; $p = 0.00$) was noticed to have a significant influence on the mean shoot length of the plant (Table 3). The mean shoot length did not show any significant variation with respect to lakes ($F = 1.05$, $p = 0.37$), although highest values were recorded in Manasbal lake (147±59cm) and lowest in Anchar (133±69cm) lake (Fig.2e,f). The shoot elongation is the key response to water depth that enables them to emerge from the water (Lieffers and Shay, 1981; Grace and Wetzel, 1981) in order to prevent carbon starvation or limitation of light for photosynthesis (Grace, 1993).

Mean inter-node distance

An increase in mean inter-node distance in *T. natans* was observed in all the lake ecosystems with increase in depth of water. The maximum (13.4±0.9cm) mean inter-node distance was recorded at D3 depth in Manasbal lake and minimum (10.8±0.5cm) was found in Dal lake at D1 depth (Table 2). Mean inter-node length of plants recorded in Manasbal (12±1cm), Dal (11.9±1cm) and Anchar (12.5±1cm) lakes did not show any significant difference. But with respect to depth the plant trait showed a significant (*F =11.60, p=0.00*) differ-ence (Table 3) (Fig.2g,h). The reason for elongation of internodes as furnished for shoot length is because of ethylene production in plant stems which cause plasticity of cell walls and thereby generates longer internodes (Blom and Voesenek, 1996). Further, in the present study, shorter inter-nodes of the plants at lower depths (0-200cm) were responsible for causing intense branching in plants and thus resulting in dense mono-specific vegetation beds. As water depth increases, so does the inter-node distance in shoots of the plants and hence less protrusion of branches. This seems exactly the reason of observing plants to be restricted below 300cm water depth range.

Leaf length and width

The maximum length (4.5±0.4cm) and width (5.9±0.1cm) of leaves was recorded at depth D3 in Manasbal and Anchar lakes, while minimum length and width was found at depth D1 in Dal (4.1±0.1cm) and Manasbal (5±0.2cm) lakes respectively (Table 2). Although, there was not a significant difference in mean leaf length with respect to lakes and depth, but mean leaf width was observed to be significantly high (*F =7.69, p = 0.02*) in Anchar lake when compared to other lakes (Table 3; Fig. 2i,j). Further, a significant difference (*F=4.80, p= 0.00*) was noticed in the mean leaf width of the plants between low (D1) and high depths (D3) (Fig.2k,l). Even though, there was a weaker response of leaves to water levels but still at deep water depths they show a slightly higher growth in comparison to plants which were present towards the shallow depth zone (0-100cm). It is perhaps that plants invest a more proportion of their resources to leaves as they are the manufacturer sites for the whole plant.

Number of fruits

The number of fruits per plant depicted an increasing trend with increase in depth in the lakes. (Table 2). The maximum number of 7.3±0.6 fruits per plant was found at D3 depth in Manasbal lake, while minimum number of 4.3±0.6 fruits were recorded at D1 depth in both Manasbal and Dal lake. Although there was no significant variation in number of fruits per plant with respect to lakes, but shallow depth D1 (4.4±0.5) has significantly lower (*F =14.39, p = 0.00*) number of fruits per plant than D2 (6±1) and D3 (6.4±1) depths (Table 3) (Fig.2m,n). The plant at shallow depths produced more number of fruits, which seems to be allied with the accessibility of adequate resources. On the other hand, in deeper waters the plant is at stress by possessing limited number of resources and accordingly allocates them incisively to minimize imbalances in any critical resource in a manner that maximizes plant growth (Bloom *et al.,* 1985).

CONCLUSIONS

It can be concluded from the study that water depth has significant effect on some morphological traits of *T. natans*. The higher water levels restrict the growth of *T. natans*, however, the trophic status of lakes (mesotrophic, eutrophic and hyper-eutrophic) did not have any significant effect on its growth. The study thus depicts that the water depth can be used as a management tool for controlling the spread of *T. natans* in aquatic ecosystems.

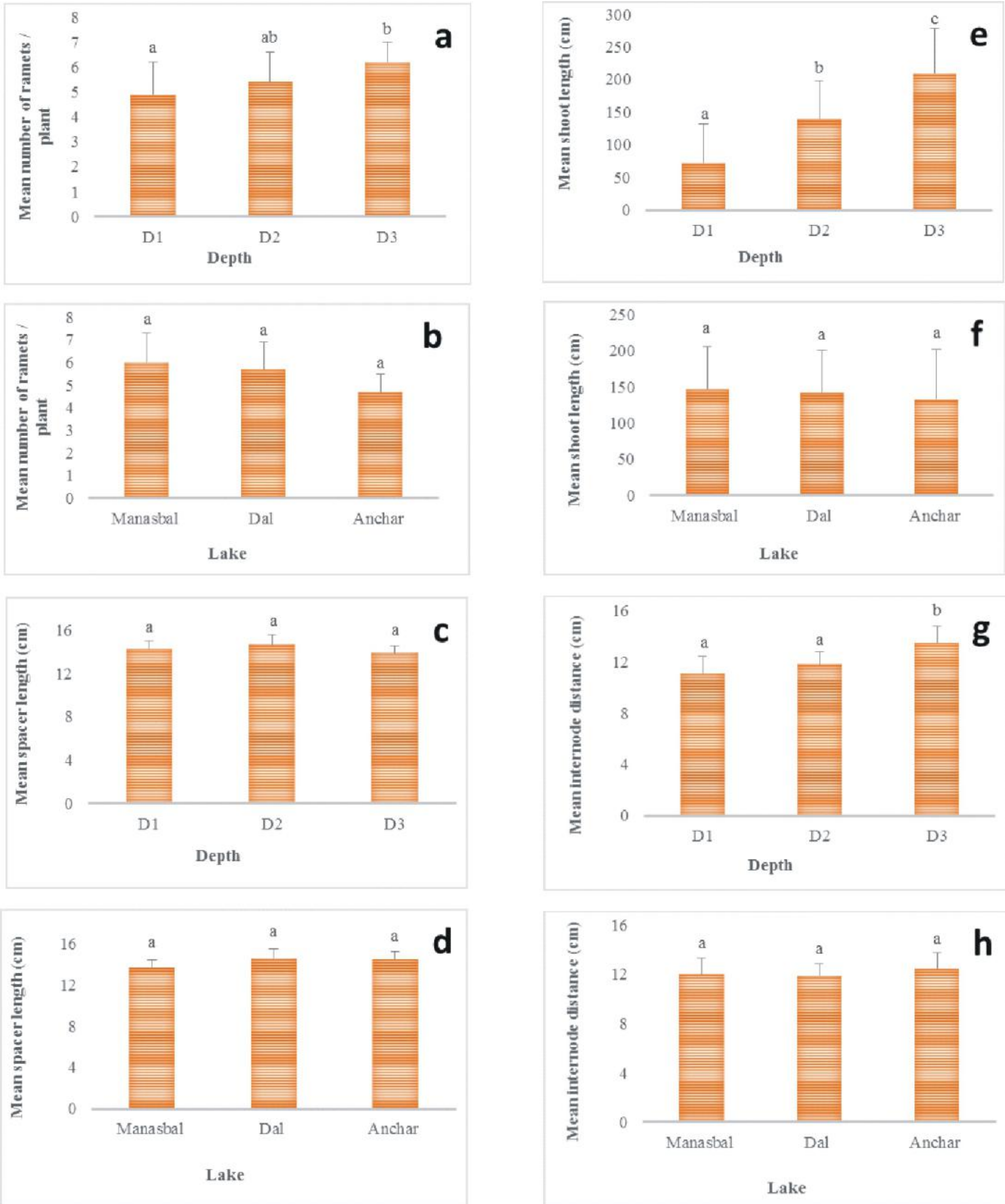
Table 2. Variability in traits (mean ± SD) of *T. natans* in relation to different depths and lakes.

SITE (LAKE)	DEPTH (cm)	MNOR	MSL	MSHL	MINTD	MLL	MLW	MNOFr
MANASBAL	D1 (0-100)	5±1	13.7±0.4	88.7±3.6	11.3±1	4.1±0.02	5±0.2	4.3±0.6
	D2 (101-200)	5.6±1.15	14.5±0.3	131.6±16	11.4±1	4.2±0.08	5.1±0.1	5.3±0.6
	D3 (201-300)	7.3±0.6	13±0.6	220.9±8.5	13.4±0.9	4.5±0.4	5.6±0.3	7.3±0.6
DAL	D1 (0-100)	5.3±0.6	14.3±1	70.3±2.9	10.8±0.5	4.1±0.1	5.1±0.4	4.3±0.6
	D2 (101-200)	5.6±1.5	15±1.1	151.6±9	11.5±0.6	4.1±0.1	5±0.6	5.6±1.15
	D3 (201-300)	6.3±1.5	14.5±0.9	203.9±8	13.4±2.1	4.2±0.1	5.6±0.6	6.6±1.5
ANCHAR	D1 (0-100)	4.3±0.6	14.9±0.2	58.9±1	11.2±0.9	4.1±0.1	5.5±0.1	4.6±0.6
	D2 (101-200)	5±1	14.6±1.3	137.3±57	12.5±1.2	4.2±0.1	5.9±0.1	6.6±0.6
	D3 (201-300)	5±1	14.2±0.1	203.1±6.6	13.1±0.4	4.3±0.1	5.8±0.1	5.3±0.6

MNOR=Mean number of ramets, MSL=Mean spacer length (cm), MSHL=Mean shoot length (cm), MINTD=Mean inter-node distance (cm), MLL=Mean leaf length (cm), MLW=Mean leaf width (cm), MNOFr=Mean number of fruits. (n= 3/depth).

Table 3. Statistical analyses of the effects of water depth and site(lakes) on different morphological traits of *T.natans* .

Dependent Variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Number of ramets	Site	7.63	2	3.81	3.43	0.05
	Depth	8.07	2	4.04	3.63	0.05
	Site * Depth	3.04	4	0.76	0.68	0.61
	Error	20	18	1.111		
Mean spacer length	Site	4.44	2	2.22	3.62	0.05
	Depth	2.83	2	1.42	2.31	0.13
	Site * Depth	1.83	4	0.46	0.74	0.58
	Error	11.056	18	0.6142		
Mean shoot length	Site	899.60	2	449.80	1.05	0.37
	Depth	84101.32	2	42050.66	97.90	0.00
	Site * Depth	1698.93	4	424.73	0.99	0.44
	Error	7731.583	18	429.532		
Mean inter-node distance	Site	1.76	2	0.88	0.74	0.49
	Depth	27.58	2	13.79	11.60	0.00
	Site * Depth	1.22	4	0.30	0.26	0.90
	Error	21.392	18	1.188		
Mean leaf length	Site	0.08	2	0.04	1.49	0.25
	Depth	0.20	2	0.10	3.48	0.05
	Site * Depth	0.14	4	0.03	1.21	0.34
	Error	0.505	18	0.028		
Mean leaf width	Site	1.81	2	0.90	7.69	0.00
	Depth	1.13	2	0.56	4.80	0.02
	Site * Depth	0.36	4	0.09	0.76	0.56
	Error	2.114	18	0.117		
Mean number of fruits	Site	0.07	2	0.04	0.06	0.95
	Depth	19.19	2	9.59	14.39	0.00
	Site * Depth	9.26	4	2.31	3.47	0.03
	Error	12	18	0.666		


a
Mean number of ramets / plant
Depth
D1
D2
D3
a
ab
b
e
Mean shoot length (cm)
Depth
D1
D2
D3
a
b
c
b
Mean number of ramets / plant
Lake
Manasbal
Dal
Anchar
f
Mean shoot length (cm)
Lake
Manasbal
Dal
Anchar
c
Mean spacer length (cm)
Depth
D1
D2
D3
g
Mean internode distance (cm)
Depth
D1
D2
D3
d
Mean spacer length (cm)
Lake
Manasbal
Dal
Anchar
h
Mean internode distance (cm)
Lake
Manasbal
Dal
Anchar

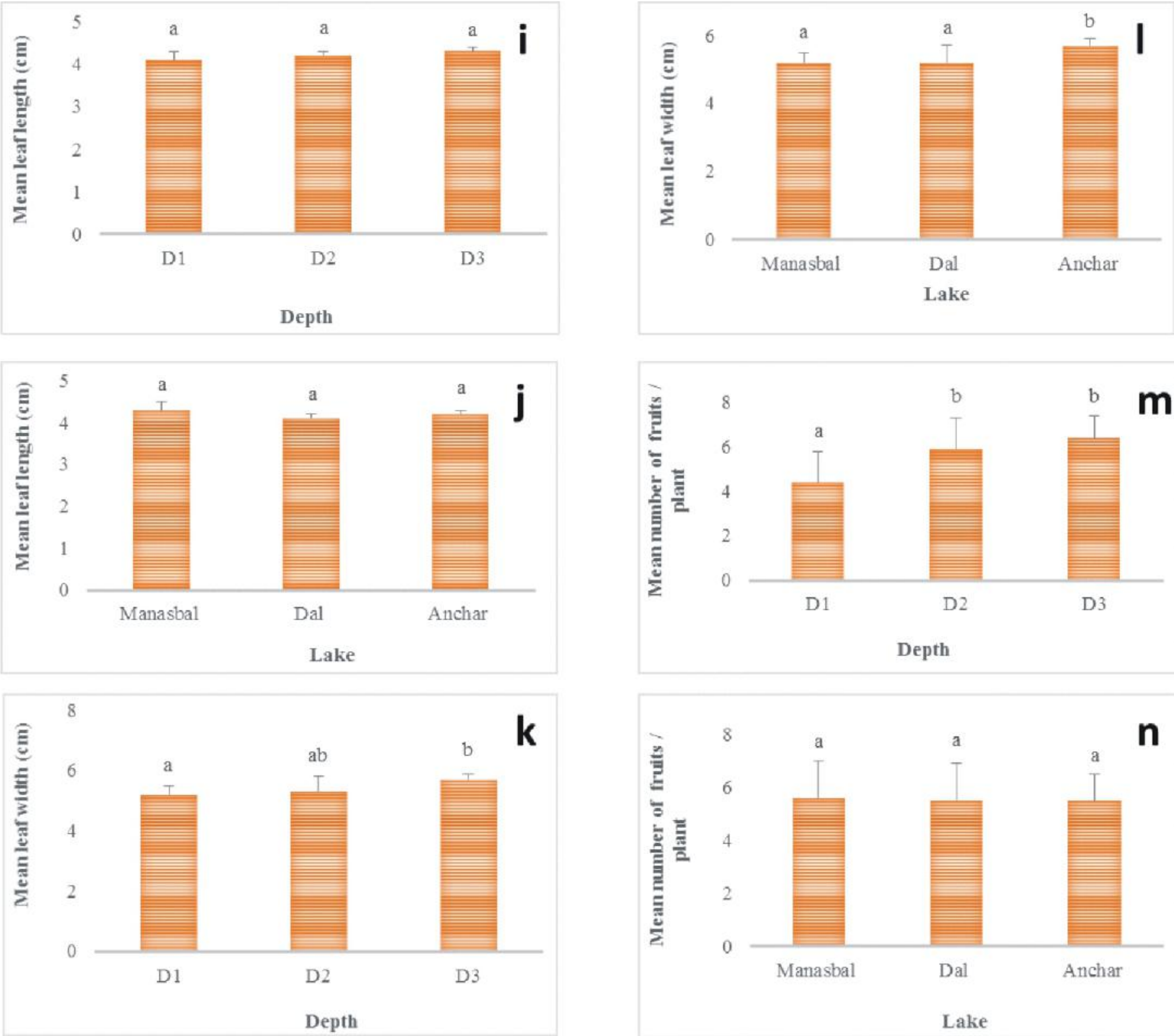


Fig.2. Variation in mean number of ramets (a,b), mean spacer length (c,d), mean shoot length (e,f), mean inter-node distance (g,h), mean leaf length (i,j), mean leaf width (k,l) and mean number of fruits (m,n) across different depths and lakes. Error bars represent ± SD. Bars sharing the same letter are not significantly different using Tukey's HSD-test.

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Evaluating the Morphometric and Hydrological Characteristics of Dal Lake using Remote Sensing and GIS

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ABSTRACT

Baseline morphometric and hydrological information of lakes is essential to develop appropriate strategy for sustainable, socially acceptable, ecofreiendly and economically viable development of lakes and wetland. The present study was carried out in 2013 to evaluate the basic morphometric and hydrological features of Dal lake. The morphological features namely mean depth, surface area, maximum length, maximum breadth, volume, shoreline length, shoreline development and index of basin permanence have been evaluated using remote sensing and GIS. The study revealed that the lake is shallow (mean depth 2.32m) with volume capacity of 4464600m^3. The maximum length (5.1km) and width (3km) of lake along with other factors did not allow significant wind-induced wave action which reduced the resuspention of sediments. The low inflow (3.87m^3/s) and volume coupled with high hydraulic residence time (18.3days) has acted synergistically with high nutrient loading from catchment and has accelerated the eutrophication process.

Key words: *Morphometry, Hydraulic residence time, Shoreline development, Index of basin permanence.*

INTRODUCTION

The morphology of lakes is one of the most important factors controlling the physico-chemical and biological processes that determine the distribution of aquatic organisms within lake basins. Morphometry regulates thermal stratification, flushing of nutrients and algal cells, sedimentation rates, resuspension of bottom sediments, diffusion of gases, mixing of water column and burial of organic and inorganic matter (Wetzel, 2001). These processes in turn govern nutrient loading, water quality and biological productivity of lakes (Hakanson, 2005). Morphometric analysis of lakes can be helpful in anticipating the changes that may occur due to management practices or prevailing climatic conditions (Noges, 2009). Lake surface area governs the wind-induced resuspension, nutrient fluxes from sediments to overlying water column and under water light climate (Cole, 1975, Fee *et al*., 1994). Thermal stratification, water transparency, concentration of chlorophyll and organic matter are strongly related to mean depth (Noges, 2009). Due to faster nutrient cycling and better light conditions, shallow lakes have higher productivity per unit of area than deep lakes at comparable phosphorus and dissolved matter concentrations (Schindler and Scheuerell, 2002). Lakes with high shoreline development have an extensive littoral zone and as such are suitable sites for macrophyte colonization and waterfowl habitat. Moreover, lakes with high shoreline development index (DL) have stronger ties to riparian habitats, thus receive more terrestrial inputs of nutrients and organic matter (Noges, 2009).

On the other hand, hydrology provides knowledge about the water yield from a basin, its occurrence, quantity and frequency. The water balance of lake ecosystems is regulated by basic hydrological relationship in which change in water storage is governed by inputs from all sources minus water losses. These losses and gains vary from season to season and year to year depending on climatic conditions. Hydrological changes have a strong impact on lakes where they cause significant changes in the water volume and lake depth. Shallow and small lakes are considered more sensitive to large scale stressors such as climate variation, floods, thermal pollution, oxygen stress and changing pH due to their lower buffering capacity. In the past few studies have been conducted on the morphology and hydrology of Dal lake. It is in this back drop the present study was undertaken to evaluate the recent morphological and hydrological features of Dal lake.

Study area Dal Lake, situated in the north east of Srinagar in Kashmir valley, is one of the most beautiful lakes in India and the second largest lake in Jammu & Kashmir. It lies between 34° 05′ and 34° 10′ N latitude and 74° 08′ and 71° 09′ E longitude at an altitude of 1583m MSL. The lake is probably fluvial in origin formed from the oxbows of river Jhelum. The lake is multi-basin comprising of four basins viz., Hazratbal, Nishat, Gagribal and Nigeen basins. The four basins of Dal Lake differ markedly with regard to their areas, volume, depth and indices of shoreline development. Among the different basins of Dal lake, Hazratbal basin is the

Fig.1.Satellite image of a Dal Lake showing location of study sites

largest in area, Nigeen basin is the smallest and deepest (6.0m) and the Gagribal basin is the shallowest one (2.5m). The lake is fed by perennial Telbal Nallah which supplies 80% of water to the lake (Qadri and Yousuf, 1980) and remaining 20% is contributed by Doubkoul, Harishkoul, Boutkoul and springs rising from the lake bed. The surplus water flows via Dalgate into Tsunthkul into river Jehlum and Nallah Amir Khan connecting Nigeen basin to Anchar lake via Gilsar and Khushalsar.

MATERIALS AND METHODS

The Morphometric and hydrologic survey of the Dal Lake was carried out from June to December using the standard methods of Hutchinson (1957), Wetzel and Likens (1979), and Hakanson (1981). The depth was recorded with the help of graduated rope at 107 points within the lake at an average grid size 50 x 50 m^2 using GPS (model: Etrex Garmin). The positions of the GPS points taken in the field were rectified to fit the map. The depth points collected were converted into data points on the georeferenced map of Dal Lake using Arc View software. The data was treated using the Kriging formula option, which analyses the given data and extrapolates depths for areas where no data is available. The resulting file was then subjected to a blanking file representing the shoreline of the lake in order to reduce any data that the Kriging program had extrapolated outside the boundary of the lake to a nil value and finally bathymetric map was generated. ERDAS IMAGINE software was used for on screen digitization, georefrencing and obtaining the boundary of Dal lake from the registered SOI topographical map. Volumetric calculations and morphometric parameters like surface area, shoreline length, maximum length, and maximum width were calculated by field studies supplemented with GIS software Arc view 3.2 and formulas. The hydrological parameters inflow and outflow were determined by float method. A segment of the inlet/outlet was selected and its average depth, average cross-sectional area and average flow were measured. Subsequently discharge was calculated by multiplying flow with cross-sectional area. The flowchart of the methodology for assessing the morphometric and hydrological parameters is given in Fig. 2.

Mean Depth (Z_{mean}):

The mean depth was calculated by summing up all the field reading of the measured depths and dividing it by the number of soundings. It was calculated by using the formula.

$$Z_{mean} = \Sigma Z/n$$

Where,

Z = values of measured depths

from 1- n.

n = number of soundings.

Maximum Depth (Z_{max}):

Maximum depth was observed by thoroughly sampling the lake.

Volume (V):

Volume was calculated by using the formula. Where,

$$V = A x Z_{mean}$$

A = Area of lake (km^2)

Z_{mean} = Mean Depth of Lake (m)

Relative Depth (Zr):

Relative Depth was calculated by using the formula.

$$Zr = 50 \; x \; Z \; max \; x \; \frac{\sqrt{\pi}}{\sqrt{Ao}}$$

Where,

Z_{max} = maximum depth of the lake.

A_o = surface area of the lake.

Shoreline Development (DL):

Shoreline development was calculated by applying the formula.

$DL = SL / [2\sqrt{(\pi A)}]$

Where,

SL= Shoreline length (km)

A= Area of lake (km^2).

Inflow and Outflow of water:

Inflow and outflow was calculated by applying the formula.

$Q = X V$

Where,

Q = Rate of flow of water (m^3/sec).

X= cross section area of channel (m^2).

V= velocity of water in m/sec.

Hydraulic Residence time (HTR):

Hydraulic residence time was calculated by applying the formula.

$HRT = V/Q$

Where,

V= Volume of the lake (m^3).

Q= Discharge (m^3/sec).

Index of Basin Permanence (IBP):

Index of Basin Permanence was calculated by applying the formula

$IBP = V/SL$

Where,

V= Volume of the water body (m^3).

SL = shoreline length *SL* (km)

METHODOLOGY

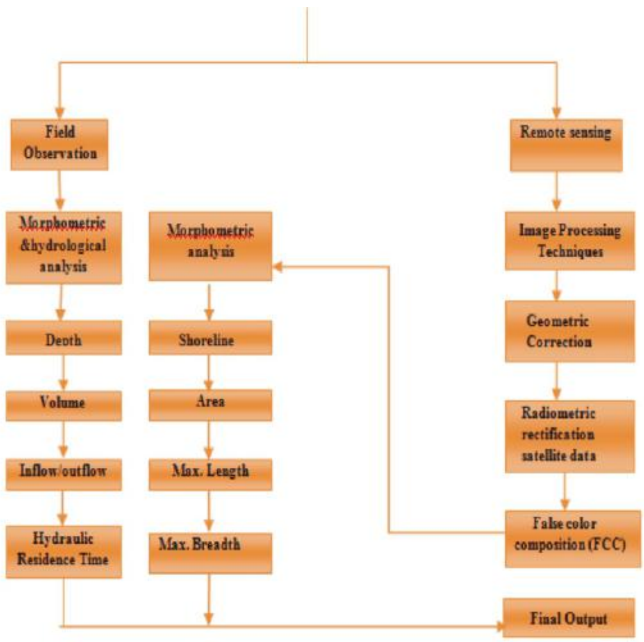

Fig.2. Flowchart showing steps adopted in methodology

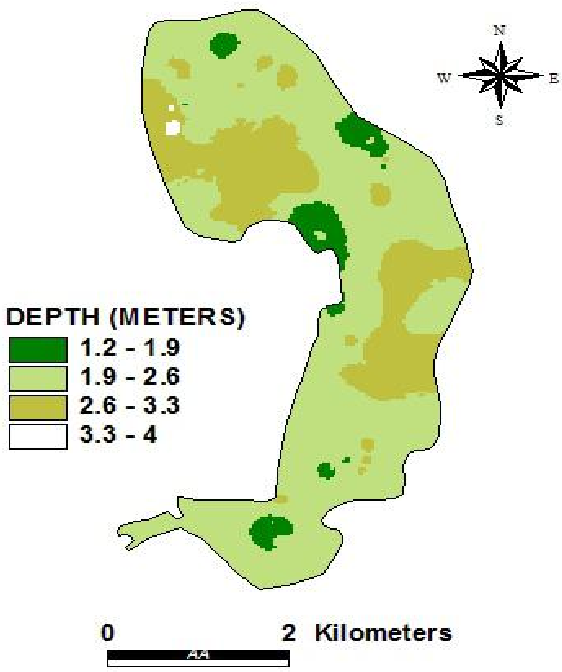

Fig.3. The Bathymetric Map of a Dal Lake.

RESULTS AND DISCUSSION

The morphometric characteristics and bathymetric map are represented in Table 1 and Fig. 3 respectively. The bathymetric map generated depicts the contours of different colors are far apart from each other indicating gentle slope, however on the northwestern area of the lake the contours are relatively close to each other's having slight steepness which could be attributed to dredging process carried out by LAWDA. The maximum depth (4m) as depicted by the bathymetric map is on northwest side of the lake. Generally, the maximum depth is found towards the limnetic zone of the lake but in case of the Dal lake the maximum depth was observed towards the littoral zone and could be attributed to dredging process which is carried out by LAWDA.

The mean depth of the lake was 2.32m (Table1) which indicates that the Dal lake is a shallow lake and as such thermal stratification process could not be possible in the lake. The fast nutrient cycling and better under water light climate due its shallowness stimulates the productivity of lake (Sakamoto, 1996; Noges, 2009).

The maximum length (L_{max}) and maximum width are 5.1 km and 3km respectively. The L_{max} and B_{max} of a lake are sufficient to cause resuspension of fine organic sediments, but the low wind speed (2.5Km/h) and dense macrophytic beds did not favour resuspension (Moses *et al.,* 2011). However, during high storms there are high chances of resuspension of sediments.

Table 1. Morphometric parameters of Dal Lake

S.No	Parameter	Results
1.	Surface area (A)	13.32km^2
2.	Mean Depth (Z_{mean})	2.32m
3.	Relative Depth (Zr)	0.0000989%
4.	Shoreline Length (SL)	23.90km
5.	Shoreline Development (DL)	1.84
6.	Maximum Length (L_{max})	5.1km
7.	Maximum width (B_{max})	3km
8.	Volume (V)	4464600m^3
9.	Index of Basin Permanence (IBP)	186

The present surface area of Dal lake excluding Nigeen basin was 13.2km^2 which is less as compared to earliest records 25km^2 (Drew, 1875; Lawerence, 1895) and 16km^2 in 2001 (Kanth and Rather, 2001). The reduction in the surface area of the lake may be attributed to encroachments by local population living in and around Dal lake. Moreover, a significant portion (20%) of the lake is covered by floating gardens reducing the open water area of the total Dal lake area (Khan, 2000). The present area of the lake is approximately in conformity with Kanth and Rather (2001) as we have excluded Nigeen basin from the present study. lake size determines fetch length which in turn governs stability thermal stratification. Since Dal lake has relatively less area as such there is low possibility for generation of large waves. In the present study the volume of water estimated in the Dal Lake was 0.0044km^3 (Table 1) which is low as compared to earlier studies 0.00983km^3 (ENEX, 1978). The reduction in volume may be attributed to silting of a lake due to catchment area degradation (Zutshi and Yousuf, 2000) and encroachments. The low volume of the lake also could be due to exclusion of the Nigeen basin from the present study. The eutrophication process is not only regulated by high nutrient loading but also by volume of the lake (Wetzel, 2001), thus reduction in volume has decreased its dilution capacity and has accelerated eutrophication process. Shoreline length is the linear measurement of a water body's entire perimeter at a given water level. It provides a measurement of the actual amount of interface between a water body and the surrounding land. The shoreline length of the Dal lake is 23.90 km and the shoreline development of the Dal lake is 1.84. The higher number indicates that greater is the shoreline development. This means that the interface between the water and the surrounding land is more. It shows the potential for development of littoral communities. The pollution from a densely developed shoreline is more; hence restriction should be given to the development activities along the shoreline of the Lake. The shoreline development of the Dal lake indicates that the lake is less irregular in shape and productive (Wetzel and Likens, 1991). A perfectly circular basin has DL=1 and varies from 1.4 to <3 for sub-circular to elliptical (Hutchinson, 1957). The value (1.84) of shoreline development reflects the potential for development of littoral communities. However, it is slightly low which has resulted in fewer interfaces between the water and surrounding land and creates lesser habitat sites for waterfowl. The index of basin permanence (IBP) is a morphometric index that indicates the littoral effect on basin volume (Kerekes, 1977; Moses *et al., 2011*) The lakes with IBP less than 0.1 are dominated by rooted aquatic plants which are an indication of excessive shallowness and high water colour. Lower the IBP value (< 0.1) stronger is the littoral effect on basin volume whereas higher values indicate insignificant effect on basin volume. The value of this parameter for very big lakes like Baikał is >10,000; and lake Ontario is >1,200 (Kerekes, 1977). The value of Index of Basin Permanence of the Dal lake is 186 which reflects that it is not having significant littoral effect on basin volume.

Table 2. Monthly variations in inflow and outflow of different inlets and out lets sites

Site	Month / Parameter	June	July	Sept.	Oct.	Nov.	Dec.	Mean
Boutkul Creek	Inflow(m^3/s)	0.46	2.27	0.86	0.48	0.32	0.23	0.77
Telbal Creek	Inflow(m^3/s)	2.22	6.23	3.48	2.01	1.32	1.15	2.73
Meerak-shah Creek	Inflow (m^3/s)	0.32	0.87	0.41	0.33	0.18	0.11	0.37
Dalgate	Outflow(m^3/s)	1.38	2.14	0.97	0.80	0.68	0.54	1.08
Ashai bagh bridge	Outflow(m^3/s)	2.69	3.33	1.28	1.40	1.38	0.83	1.81

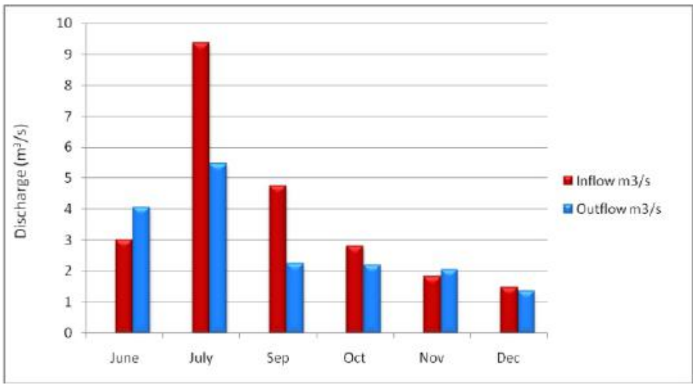

Fig.4. Monthly variations in inflow & out flow (m^3/s) in Dal Lake.

Table 3. Mean inflow and out flow and hydraulic residence time of Dal lake

Inflow (Q)	3.87 m^3/s
Outflow (Q)	2.89m^3/s
Hydraulic residence time (HTR)	~18.3 days

The inflow of Boutkul fluctuated from $0.23m^3/s$ to $2.27m^3/s$. The mean inflow of the Boutkul Creek was $0.77m^3/s$. The inflow of Telbal Creek varied from $1.15m^3/s$ to $6.23m^3/s$ with a mean value of $2.73m^3/s$. The inflow of Meerakshah fluctuated from $0.11m^3/s$ to $0.87m^3/s$ with mean value of $0.37m^3/s$. (Table 2). The total inflow of the lake fluctuated from a minimum $1.49m^3/s$ in the month of December to a maximum of $9.37m^3/s$ in the month of July, 2013 (Fig. 4). The total inflow to Dal lake was $3.87m^3/s$ ($10.03\times10^6m^3$/month) (Table 3) and is not sufficient to dilute and flush out nutrients from the lake. Provision of additional water i.e, $5.27\times10^6m^3$/month is required for the dilution purpose (Solim, 2009).

The mean outflow recorded at Dalgate was $1.08m^3/s$ with minimum outflow ($0.54m^3/s$) found in the month of December and maximum outflow ($2.14m^3/s$) in the month of July, 2013 (Table 2). However, the outflow of Ashai bagh bridge showed fluctuation from $0.83m^3/s$ to $3.33m^3/s$ with a mean outflow of $1.81m^3/s$ (Table 2). The total outflow of lake fluctuated from a minimum $1.37m^3/s$ to a maximum $5.47m^3/s$ in the month of July, 2013 (Fig.4). The total outflow of the lake is $2.89m^3/s$ ($7.49\times10^6m^3$/month) (Table 3).

Hydraulic residence time of Dal *l*ake is 18.3 days. Residence time favours the development of planktonic community and enhances productivity. The fate of substances in lake is also strongly dependent on the water residence time in the lake basin (Carmak *et al.,* 1986). The Dal Lake has high hydraulic residence time and this reflects that the nutrients will be flushed after a time period of 18.3 days. The high residence time might increase concentration of the nutrients in the lake and degrade the water quality of water.

CONCLUSION

Morphometry and hydrology has significant effects on water quality and ecosystem functioning by regulating resuspension of sediments, flow and flushing and residence time.

The shallow nature, low volume holding capacity and the low mean depth makes the lake more productive and sensitive to large scale stressors such as climatic change, nutrient enrichment and siltation. The small surface area, low maximum length, small fetch and large beds of submerged aquatic plants retard the resuspension of sediment due to wind induced wave action. The low inflow and volume coupled with high hydraulic residence time of 18.3 days are responsible for increasing nutrients concentration in the lake

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Indigenous Knowledge of the Tribes of Northeastern Hill Region of India in Land Management for Environment and Food Security

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ABSTRACT

The northeastern region of India is endowed with rich water resources but, their indiscriminate use has rendered them in a fragile state. The prevalence of shifting cultivation in 369.3 thousand ha, annually, has resulted in resource degradation, soil erosion in the hills and silting of river beds and floods in the plains. The region receives about 510 km^3 of water as annual rainfall. It has two major rivers, the Brahmaputra and Barak, which drain 194 413 and 78 150 km^2 area with an annual run-off of 537.2 and 59.8 km^3, respectively. The government of India introduced two major water policies of 1987 and 2002 to stream line the development, management and utilization of water resources. There is no rainwater harvesting system in the region and, so, the huge runoff from hill slopes carries heavy sediment load to the valley areas and river channels, resulting in their choking and over-flowing their banks. Annual erosion of 601 and 1.5 million tonnes of soil and nutrients from the region has caused land and environmental degradation. Nevertheless there exists some scientifically sound water management systems, practiced by some tribes in isolated pockets of the region which are resource and environment friendly and have remained sustainable for centuries. Due to lack of communication in the un-hospitable terrain of the region, these water management systems have remained confined to their places of origin. The *'zabo'* is an indigenous system practiced in Phek district of Nagaland state and has a combination of forest, agriculture, livestock and fisheries with a water and soil conservation base. It envisages proper utilization of rainwater and sustainable maintenance of soil and eco-health due to the use of organic source of crop nutrition. The *Apatani* tribe of Arunachal Pradesh state has developed an excellent system of regulating rainwater from streams and other sources and the crop productivity in the area is 3 to 4 times higher than the average of the state. The *Khasi* and *Jaintia* tribes of Meghalaya state have evolved a system of water management in higher slopes using indigenously available bamboo, known as 'Bamboo Drip Irrigation' system. The water is used for irrigating plantation crops. To make judicious use of rainwater on hill slopes and its high *in-situ* retention, the *Angami* and *Chakhesang* tribes of Nagaland state have developed perfect terraces for wet rice cultivation, known as *'Panikheti'*. The study has shown that the annual sediment yield due to erosion in these water management systems varied from 0.14 to 2.8 t ha^{-2} as against 36.2 t km^{-2} in shifting cultivation, on 45% slope.

Keywords: *Indigenous knowledge, Tribes, Land management, Environment and Food security, Northeastern region of India*

INTRODUCTION

Although effective and valuable tools have been introduced to evaluate the risk to construction in areas prone to geo-hydrological hazards, fewer steps have been made in the field of ordinary land use planning at different scales. Northeastern region of India is vulnerable to water induced disasters because of its location in the eastern Himalayan periphery, fragile geo-environmental setting and economic underdevelopment (Sharma, 1999). In the region, the combined effects of prolonged and intense rainfall, steep slopes and the fragile geology of the mountains make flooding an annual event. The frequent flood events result not only from the climatological factors, but also due to human interference, deforestation because of shifting cultivation and short-term economic gains. Every year, a large number of natural hazards like landslides, muddy-debris flows and floods occur in the Brahmaputra basin. In many cases, this problem must be considered as a direct consequence of uncontrolled or ineffective land management that has allowed the urbanization of areas potentially prone to geo-hydrological risks. Floods are the most damaging of all natural disasters (Cosgrove and Rijsberman, 2000). The Intergov-ernmental Panel on Climate Change (IPCC) stated that "projections of future climate indicate a tendency for increased flood risks for many areas under most scenarios" (IPCC, 2002).The region is predominantly hilly and mismanage-ment of rain water causes heavy loss of soil in the hills and silting of river beds and floods in the plains (Sharma & Prasad, 1995; Sharma 1998). The prevalence of shifting cultivation in 3689 km^2, also results in heavy soil erosion, deforestation and water resources degradation (Sharma & Sharma, 2004). Social sanctions and belief system maintained a balance between resource potential and their utilization for a long time but due to the increase in the demographic pressure and indiscriminate use of natural resources, imbalance has been created. The fast growing population in the region has pressurized the food production base and to satisfy their needs, the people have mismanaged and misused water resources (Sharma, 2003, Sharma and Sharma, 2004a, Sharma and Sharma, 2004b). There is annual loss of 83.3 million tonnes of soil and 10.65, 0.37 and 6.05 thousand tonnes of available N, P_2O_5 and K_2O, respectively due to shifting cultivation alone (Sharma & Prasad, 1995).

Eroded soil is deposited in the foothills of slopes and hollows and soil crusting, erosion rills and eroded soils make crop production methods more difficult (Sommer and Lindstrom, 1998). This paper discusses the isolated indigenous land use systems, having simple inbuilt low cost affordable hydrological structures developed by the tribal farmers due to their ingenuity and skill and capable of arresting soil erosion through runoff and thus, mitigating floods in the basin.

STUDY AREA AND METHODOLOGY

The place of study is the northeastern region of India, comprising seven states and having an area of 255090 km^2 (Fig. 1). The region is predomina-ntly hilly, with elevation above mean sea level varying from 73m to more than 15000m. The agriculture is mostly done on hill slopes. Shifting cultivation is the predominant mode of cultivation. The practice was acceptable when the population was low and the shifting cycle was 25 to 30 years. The period was sufficient for the rejuvenation of vegetation but, with increase in demographic pressure, the shifting cycle has come down to 2 to 5 years, rendering the

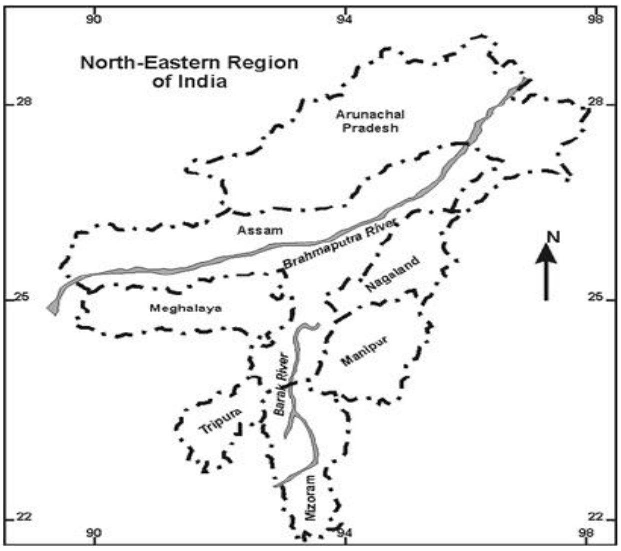

Fig.1 Northeastern region of India

practice as most uneconomical and resource eroding. However, there exists some sustainable, eco-friendly and economically viable land use systems, followed in isolated pockets of the region. These systems, devised due to ingenuity and skill of the tribal people, are unique in water resources development and land management. The region is endowed with rich water resources but their indiscriminate use has rendered them in a fragile state (Sharma, 2001). The indigenous land use systems, having simple low cost hydrological structures, were studied by frequently visiting these systems in different states of the region and collecting the relevant data as well as interaction with farmers and elders. The officials of the line departments were also contacted to discuss about the improvement in these land use systems with state of the art technologies in the field and frequent relevant interventions.

RESULTS AND DISCUSSION

Present scenario

The irrigation potential and the food production of the northeastern hills region is given in Tables 1 and 2. Besides climatic parameters, anthropogenic factors also play an important role in the basin. Rapid population growth, urbanization, uncontrolled developmental works, encroachments and land use have significantly contributed to flood events and risk enhancement in the region. There is enormous loss of property, human and animal lives and infrastructure. The combined effect of prolonged and intense rainfall, steep slope, well-developed drainage network and the fragile geology of the mountain make the land inundation an annual event (Kattlemann, 1990). Problems related to high stream flows are complex and are affected by natural as climatic, hydro-geologic, morphology etc. and anthropogenic such as urbanization, irrigation, water works, socio-economic factors and human interference through deforestation and land use. Three types of processes causing flood events in the region are (i) long - rain floods, where long duration rainfall saturate the catchment resulting in high flows causing floods, (ii) short rain floods, where high intensity rainfall occurs for short duration and (iii)flash floods, when short but high intensity rains cause floods even when the catchment is dry. Extreme floods in the basin are a product of meteorological input, precipitation being the major player; as well as spatially and temporally variable basin properties. Frequent floods have caused land degradation in about 34.7% of the total geographical area of the region (Borthakur, 1992).The highest land degradation is in Meghalaya State (48.9%),followed by 38.2% in Assam, 31.7% in Arunachal Pradesh and 29.4% in Nagaland. The Brahmaputra river has more than 100 tributaries, of which 15 in the north and 10 in the south are fairly large. More than 660 m3 km-2 silt load is brought by the northern and about 100 m3 km-2 by the southern tributaries. This has resulted in land and environmental degradation in the basin area. The fast increase in the population in the region has

Table 1. Irrigation potential in the north eastern states of India (Anonymous 2000).

State	Net irrigated to net sown	area to area (%)	Ultimate potential	Irrigation (000, ha)
	1977-78	1995-96	Major projects	Minor projects
Arunachal Pradesh	20.0	19.4	100	10
Assam	21.3	20.5	970	1700
Manipur	46.4	46.4	100	5
Meghalaya	26.9	22.4	85	15
Mizoram	10.3	6.8	55	5
Nagaland	29.7	30.0	75	5
Tripura	11.8	12.6	100	15
Total region	22.1	21.3	1485	1755

pressurized the food production base and water resources (Table 2). The deficit gap in food production and requirement has increased over the years. Concerted efforts are needed to close this gap for sustenance of the ever growing population and dependence on supply from outside the region.

Table 2. Population and food grains situation in the northeastern region of India.

Year	Population (millions)	Foodgrains (million tonnes)		
		Production	Requirement	Deficit
1951	10.5	2.10	1.79	0.31
1961	14.5	2.90	2.08	0.82
1971	19.6	3.92	3.01	0.91
1981	24.7	4.94	3.84	1.10
1991	31.5	6.30	4.93	1.37
2001	40.2	8.04	5.96	2.08
2021	60.9	12.18	9.02	3.16

The important issue is to promote the conservation and sustainable use of natural resources which allow long term economic growth and enhancement of productive capacity, along with being equitable and environmentally acceptable (El Bassam, 1997).

Tribal beliefs

The tribes of northeastern states of India have many beliefs, rituals etc. affecting their routine life and existence. Some beliefs related to water and soil include:

1. Rain Making Ritual
2. Fertility cult
3. Soil and Water Conservation

Historical

The tribal population in northeastern India remained more or less static for a very long period until inter-tribal warfare, head hunting, and pestilence and epidemics got effectively controlled. The observations revealed that equilibrium was maintained for centuries between the population and available land on long cycles of 30 to 35 years for shifting cultivation. The equilibrium, however, got upset when the population started increasing paradoxically because of stopping of warfare amongst the tribes, health care and general awareness. Shortening of shifting cultivation cycle became inevitable as no migration could be contemplated till it had come to so short a period as 3 to 5 years. The factor that sustained crop yields in shifting cultivation of 30 to 35 years cycle disappeared when it came down to 3 to 5 years. Poor crop yields in shifting cultivation, the higher population and economic and social goals were no longer compatible with shifting cultivation as a way of life. The practice of shifting cultivation, which was prevalent in northeastern region of India since 7000 B.C. (Sharma, 1976) did not keep pace with the food, fodder, fuel and fibre needs of growing tribal population. The Homo sapiens were under the awe of natural objects such as oceans, rivers, forest, springs etc. from the pre-historic age. Population was small in number, primitive in technology and their needs were extremely limited. With decrease in shifting cultivation cycle as a result of increase in population, the crop productivity decreased considerably, thereby necessitating the tribal people to migrate from one place to another for an easy access to food and water. Due to their ingenuity and skill, some tribes developed excellent farming systems which ensured food and environment security.

1. Zabo system

The tribal people of northeastern region have some social taboos and superstitions regarding the settlement of community. These tribal people have tried to adjust with the environmental setting and have succeeded in developing ways and means to have a better quality of life and resource management. Over a period of time they have been able to develop their own method of water resource management. The realization of importance of water and development of water resources transformed the life of the people of this tribe to a much better quality compared to others. This system of water harvesting and management is called 'Zabo' system (Sharma, 1997, 1998, Sonowal *et al.,* 1989).The environment of a place shapes and determines the habits, the mode of life and progress of civilization. The practice of shifting cultivation was evolved during Neolithic age and tribal people are involved with this socio-culturally. Shifting cultivation is not only a set of agricultural practices but implies the whole nexus of people's belief, attitude, self-image and tribal identity. The 'Zabo' system, not only enhanced the crop productivity but helped in water resources development and sound resource base, improved the quality of life of the people and environment around as the deforestation was totally checked and soil erosion is negligible. The whole ecology of the region is in peril due to mismanagement of rain water as high intensity of rainfall causes soil erosion, especially from hill slopes.

'Zabo' means impounding of water in local language. The system has forest land on the top of the hill, water harvesting tanks (silt retention ponds and water storage tank) next down the hill slope, livestock enclosures and then terraced rice fields at the foot hills (Fig.2). The system is a unique combination of forest, agriculture, livestock and fisheries with a water and soil conservation base, which encourages purification of environment besides increasing crop productivity (Prasad and Sharma, 1997; Sonowal et al., 1994).The system is followed on the land belonging to the farmers, a group of 10 to 15 farmers join together to practice Zabo system.

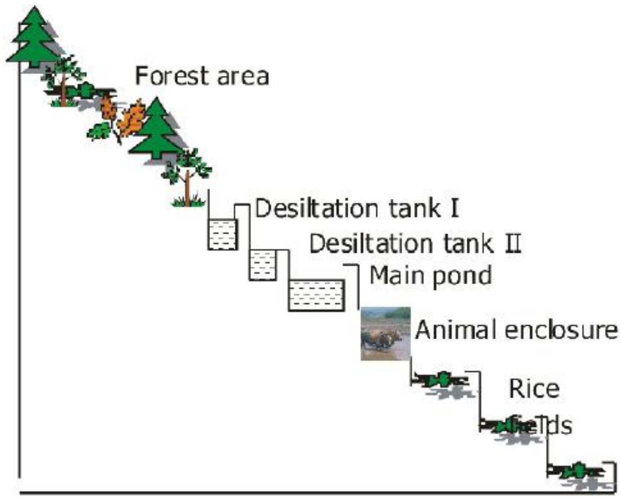

Fig. 2. Outline of Zabo system of water management

Forest land

The area on the hill top serves as catchment for rain water and is kept under natural vegetation. This area is normally not disturbed by cutting forest trees. The slope of this area is up to 100% or even more. Being permanent under vegetation, there is hardly any loss of soil through erosion.

Water harvesting system

Water harvesting ponds are dug-out with formation of earthen embankment below the catchment area. First two small ponds serve as silt retention tanks followed by a big tank down the slope. The size of these tanks depends on the catchment area but usual capacity is 300 to 600 m^3 with a depth varying from 1.5 to 2.5m. Silt retention tanks are constructed in between forest land and the main water storage tank to store run-off water from the catchment area for few days in these tanks so that soil, humus and organic matter is retained here before passing on the water to the main tank. Soil retention tanks are desilted annually and the soil containing organic matter is put in the rice fields for enhancing fertility. The ponds are rammed and compacted from inner sides so as to avoid water loss through seepage. The main water-harvesting tank is plastered on inner surface with mud mixed with chopped paddy straw to minimize water losses due to seepage. The bottom of the tank is rammed and animals are let loose in the beginning to make the bottom surface hard to reduce water losses.

Cattle enclosure

Enclosures are made with wood and bamboo for cattle and are managed by a group of farmers by stocking cattle on rotation basis. The enclosure is constructed on lower side of the pond. Buffaloes, cows, and pigs are the common animals with the farmers and about 30 to 50 of them are kept in one enclosure for a period of 10-15 days. During irrigation the water from the main tank is taken to the paddy fields by passing through the cattle enclosure and it carries dung and urine of the animals making the fields highly fertile.

Agricultural land

Paddy and other crop fields are located at lower elevation. Application of cow dung and run-off through open cattle yard are the common methods of manuring. Besides, leaves and succulent branches of *Alnus nepalensis* and *Albizia* lebbeck are also added to the fields and decomposed for soil fertility. No inorganic source of nutrients is added, making the whole system as organic farming. There is no pollution of water and environment due to fertilizer use. Some farmers practise paddy-cum-fish culture and about 50 to 60 kg of fish is obtained per ha which is an additional source of income to the farmers.

Impact on society

The 'Zabo' system of water resource development and management is a unique system of farming which has helped the society in improving their quality of life and environment around. The farmers in other iso-agroclimatic condition are adopting the system to their advantage. The paddy yields in 'Zabo' system are more than double compared to the average yields of the state and three-folds than shifting cultivation. The higher productivity not only fulfil food requirement of the tribal people and reduce their dependence on outside sources but also it is a source of income to be utilized for other rituals, festivities, marriages etc. The community lives under unpolluted environment free of frequent occurrence of common ailments. The system has added sustainability to agricultural productivity and healthy environment as it makes use of only locally available resources.

2. *Apatani* System

Water management

The *Apatani* tribe has developed a remarkable system of water management and irrigation. Every stream rising from the surrounding hills is tapped soon after it emerges from the forest, channelized at the rim of the valley and diverted by a network of primary, secondary and tertiary channels (Chaudhary *et al.* 1994, Prasad *et al.* 1994, Sharma, 1997). At a short distance above the terraces, occurs the first diversion from the stream. Usually only a little water is allowed to flow in the first feeder channel while the stream continues its course. The feeder channel branches off at angles which lead water through the series of terraces, so that by blocking or opening the connecting ducts (*Huburs*), any field can be flooded or drained, as required (Fig. 3). The cross section of main channels ranges from 1.0-1.7 m in width and 0.45-0.65m in depth, while that of sub-channels from 0.75-0.96 m in width and 0.38-0.65 m in depth. These channels are generally pitched with boulders at the entry, which checks erosion of channels due to high flow of water. The most important aspect of right water management in low land rice fields is to keep water layer on the soil surface at the permissible depth. The *Apatani* farmers drain off the water from the rice fields twice during tillering, once during flowering and finally at maturity of rice crop. A 10cm water table is maintained in the plots by adjusting the height of outlet pipes. The water from the terraces is finally drained into the "Kale" river which flows through the middle of the valley. The discharge of this river recorded during rainy season was 4.8, 13.9 and 32.2 m^3 sec^{-1}, at the entrance, middle and end of the plateau, respectively.

Nutrient management

Nutrient and fertility management of the terraces is done mainly through the recycling of agricultural wastes. Paddy straw, approximately 10.0 t ha^{-1}, is allowed to decompose in the wet terraces and finally incorporated at the time of land preparation. Burning of undecomposed straw during January-February is also in practice especially on dry terraces. Pig and poultry manure, rice husk, kitchen wastes, ash and weeds removed during weeding are also recycled in the terraces every year for improving the soil fertility. After the rice crop is harvested, cattle are allowed free grazing in the fields from December to February and thus the cow dung is also recycled. Approximately, 20,000 cattle graze in the surrounding upper ridges of the plateau and discharge around 26,600 tonnes of dung every year. Since entire rain water of the

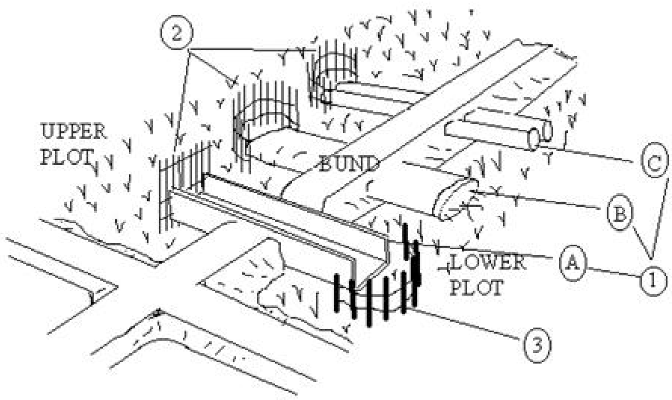

Fig. 3. Structures used for inter-plot irrigation cum drainage system in Apatani plateau. 1. *Hubur* (A, Made of plank; B, Made of pine tree trunk; C, Made of bamboo stem); 2. Obstruction for fish- Bamboo net; 3. Erosion control at water outlets wood sticks

surrounding hills is tapped for irrigation, nutrients from dung and even foresthumus is also partly utilized through irrigation water. No inorganic fertilizers are used in the plateau and the yields of crops are 2 to 3 times higher in Apatani plateau than average of the state. Higher income from selling the produce after the family use has enhanced the quality of life of the people of Apatani tribe on sustainable basis.

Paddy-cum-fish culture

Fish channels of about 30 cm x 150 cm with 30 cm depth are dug at various locations in the rice fields. Fish fingerlings are put in these channels at the start of the cropping season and the fields are flooded. When the rice fields are drained before the harvest of the crop, the water remains in the fish channels. Average weight attained by the fish in four months varies between 130 and 400g. Normally, a loss of 50% fingerlings, either due to escape or mortality, is observed. In general, 185 to 250 kg fish is harvested per ha. Even after the family consumption, some fish is left for disposal. It is a subsidiary source of income for the farmers.

Community participation

In Apatani society, many big and hard operations, like small dams for diversion of water from the streams, making of primary, secondary and tertiary channels for carrying water to the fields, maintenance of the whole system to keep it always operational, fencing, maintenance of main irrigation channel and many unforeseen tasks are performed by the community as a whole.Men folk generally take care of hard works such as building terraces, irrigation channels, fencing, removing earth and planting trees while women folk look after nurseries, transplanting seedlings, weeding, fish management, harvesting, threshing, drying and storage. The periods of different operations and manpower requirement are given in Table 3. A proper code for construction of risers as well as maintenance and release of water for irrigation is followed. Community labour, gangs of boys and girls called "Patang" are always ready to help each other in various farming operations on mutual basis. Besides, there are landless people in the plateau whose services are always available on payment of wages.

Environment preservation

Apatani farmers are well aware and extremely cautious of their environment and ecology and have conserved their forests as sacred objects for improving the quality of environment and their health. Nobody can cut forest trees and vegetation without the permission of the community. The community decisions are binding and have to be honoured. Apart from conserving the soil from erosion, farmers have taken up the plantation of *Terminalis myrinalia, Altingia excelsa, Michelia*sp., *Magnolia* sp., Pines and bamboos. Thus, the entire hills surrounding the valley and uplands surrounding the villages are fully kept conserved as forest. This helps in conserving of natural resources, maintenance of ecological balance and continuous flow of streams. Thus, soil erosion, silting in rivers, drying of water sources, loss of nutrients, loss of flora, fauna and forest resources are negligible in this plateau and ecology has been properly taken care of.

Use of local resources

Use of local resources has made the system more sustainable. Apart from the utilization of rain water for irrigation and recycling of household wastes and by-products for fertility management, most of the important tools used in the *Apartani* farming *viz. Sampya, Hilita, Damous and Mideing hiita etc.* are made of wood. The plot to plot outlets in rice fields are made with wood or bamboos. Fishing nets and fish catching baskets are also made of bamboos. Local baskets and containers called *yagli, Yopho*

Table 3. Period and manpower requirement of different operations

Operations required	Period	Mandays	Remarks
Fencing	February - March	4	Community operation
Maintenance of channels	January - April, July	3	- do -
Maintenance of risers	January - February	31	Individual operation
Nursery raising	February - March	18	-do-
Manuring	February - April	15	- do -
Land preparation	April - May	28	- do -
Transplanting	April - May	40	- do -
Weeding	Transplanting to harvest	41	- do -
Fish culture	May - September	7	- do -
Bird scaring and supervision	September - October	15	- do -
Harvesting, threshing and transporting	October - November	115	- do -
Drying and storage	October - November	11	- do -
Total		328	

and Rajhu are made of bamboos too. Cattle and other animal thrive on forest resources while pigs are partly fed from the forest flora and partly from cultivated crops. Use of modern tools, implements and fertilizers is still not known to the *Apatani* farmers. However, the Department of Agriculture, Arunachal Pradesh is making all out efforts to make the system more productive and remunerative by introducing new techniques and improving the rice cultivation system of *Apatanis.*

Land tenure system, geographical location, adequate rainfall and existence of natural streams in the plateau are the major factors for success of the Apatani system of water management and its utilization for higher productivity, resource conservation and long term sustainability. Due to their ingenuity and skill, the Apatani tribe has utilized the natural resources judiciously and exploited them for their benefit and improving the quality of their life. Unlike other tribes, the land is individually owned by the *Apatanis*. The community approach in the system has made difficult tasks possible as individually, taming of streams could not have been possible. The inhabitants of the plateau do not migrate out of the valley and the pressure on the land is on the increase. Sufficient rainfall and availability of natural streams at a higher altitude, help in gravitational irrigation. Thick forest cover surrounding the valley, gentle slope and workable soils help in rice cultivation in the area. It would be better to popularize this indigenous integrated water management system to other areas of the region with similar physiographic situations. There is also need to improve the system scientifically with modern technologies and introduction of suitable high yielding crop and fish varieties. The use of locally available organic resources for crop nutrition is the key for sustainability and success of the system and must be adhered to in future.

3. Bamboo Drip Irrigation

Bamboo drip irrigation system is a unique example of efficient management of soil and water and reflects the ingenuity and skill of the tribal farmers. This is practiced by the *Khasi* and *Jaintia* tribes of the Meghalaya state of the region. The systems is based on the gravity flow and has been fully exploited by the farmers. The water is brought from upper reaches of hills to lower level through gravitational flow. The water is carried from the source to the place of use with the help of bamboo pipes cut into different shapes and forms (Singh, 1989) (Fig. 4, 5). The flow of water can be controlled as per requirement by blocking and opening of bamboo slits at diversion points. The water is allowed totrickle down in drops at the plant site by having small holes at appropriate points. Once laid out, the system works round the clock, if desired. The farmers have the necessary skill to lay-out the bamboo network with proficiency and the whole system works efficiently and perfectly (Singh, 1989). Depending on the plant positions where the water is to be applied, the network of bamboo channels is made with diversion and water control devices. Bamboos of large diameter areused at the start and the size is subsequently reduced as per requirement. Irrigation by this system is generallyprovided to plantation crops. Natural perennial as well as seasonal streams are the source of water for domestic and irrigation needs of the tribes of the region. Since the topography of the region is undulating, the cost of constructing of concrete channels for carrying the water to the desired sites is very high and the area for irrigation is very relatively low. A low cost technique can only be a suitable measure for carrying water through gravitational flow in such situations and the tribal farmers devised the bamboo drip irrigation system to satisfy their needs for water. Locally available bamboo is used for fabricating and laying-out the system, which can work as desired. The fabricating cost and maintenance costs of the whole system are nominal. The tribal community takes care of the system together. Use of local resources has made these systems more sustainable.

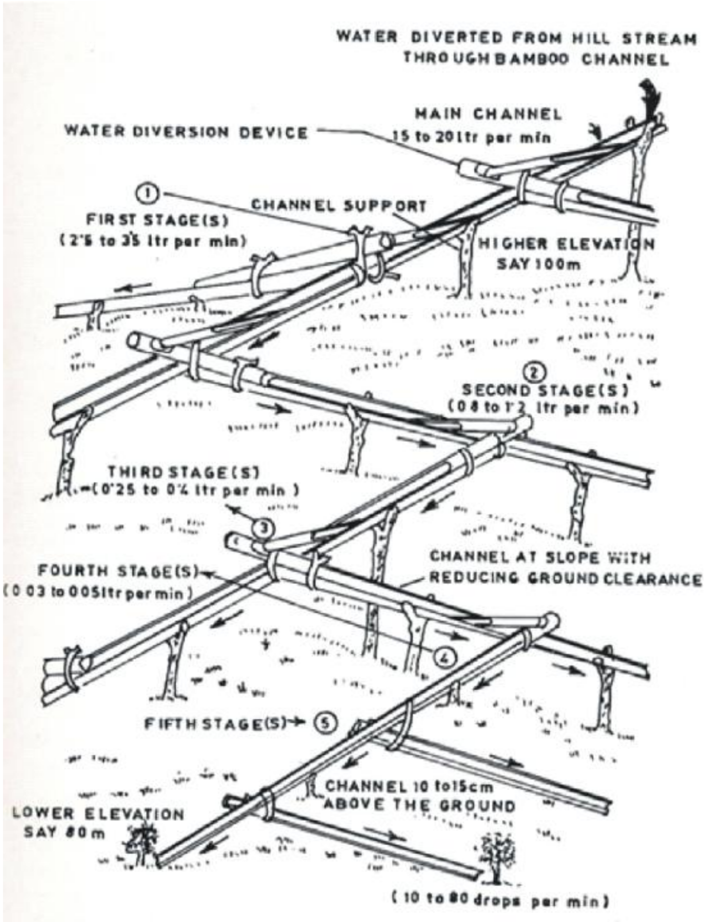

Fig 4. Bamboo drip irrigation system

4. *Panikheti* (wet rice cultivation)

Angami and *Chakhesang* tribes of Nagaland state have developed a system of water management and construction of terraces on hill slopes for wet rice cultivation called '*Panikhet*i (Prasad and Sharma, 1994). This indigenous system is followed in the states of Manipur and Sikkim. One of the finest stretches of terraces found in the world can be seen in Kohima district of Nagaland and Mao and Ukrul districts of Manipur. This shows the ingenuity and skill of the local tribes who have constructed these terraces manually with indigenous tools. The farmers became aware of the fact that weeds are a problem in upland rice for higher productivity and standing water in the rice fields would prevent the growth of weeds as well as ensure the availability of water to the crop. Since the region is predominantly hilly, only the hills were available for cultivation and construction of terraces became inevitable.

Fig. 5. Bamboo drip irrigation system laid-out in the hilly terrain

CONCLUSIONS

The practice of shifting cultivation in northeastern region of India has become uneconomical with increase in demographic pressure and reduction in the shifting cycle period. The practice needs to be replaced with sustainable, socially acceptable and eco-friendly land use systems. There are some unique indigenous systems of integrated water resources management, prevailing in isolated pockets of the region. Theses system have remained sustainable for centuries because of their sound scientific base and dependence only on locally available resources. Since no inorganic fertilizer are used, there is no pollution of surface and ground water regimes in the area. Improving these land use systems with state-of-the-art technologies in water and soil conservation would ensure judicious rainwater management, reduction in runoff and soil erosion, and environmental compatibility. Proper policy framework for planning, development and management of water resources in the region can be devised, taking advantage of the advances made in water science and technology as well as from positive and negative experiences of the developed countries. I feel that a study needs to be conducted to see the feasibility of replicating these land use systems in Jammu and Kashmir state in the hill ecosystem.

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House Hold Economic Evaluation and Extraction Methods of *Nelumbo nucifera* Root (Nadroo-an important aquatic food) in Manasbal Lake, Kashmir Valley

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ABSTRACT

A study was conducted to evaluate economic potential of economically and nutritionally important aquatic plant *Nelumbo nucifera* Root (Nadroo) in five villages viz. Hanji Mohalla, Kondabal, Gratabal, Bhagwan Mohalla and Nannynara located on the banks of Lake Manasbal. The extraction of Lotus root was found adding annual income of the people directly involved in extraction and increasing their economic status. It was observed that extraction methods and income generated by people from lotus root were dependent on each other. 1507 souls of 302 families were directly involved in extraction. The percentage of people (adult males) involved in extraction from all the five villages was 43.6%. The highest percentage of people involved in extraction was from Hanji Mohalla (92.6%) followed by Bhagwan Mohalla (56.2%), Nannynara (39.4%), Gratabal (36%) and Kondabal (29.8%) respectively. It was observed that almost all the people (males) were having licenses for extraction (1st October to 15th of November) and the average extraction of the Lotus root per head was as 15 kg /individual/day and the percentage of people involved during this period was 100%. From 15th November onwards, there was slight decline in involvement of people (only 65%) in the extraction and the average extraction of the Lotus root was 5-8 kg/individual/day. Towards mid of November there was further decline in the people involvement (3-5 %) as well as Lotus root extraction (4-5 kg/individual/day). The annual income that an individual of the studied population got from extraction was Rs 29,250. The rate at which Nadroo was sold to dealers was Rs 325/5kg and from the retail market it was available at Rs 500/5kg. The increase in rate was found related to the decrease in production.

Key Words: *Lotus root; Manasbal Lake; People, Annual income; Nadroo.*

INTRODUCTION

Kashmir is blessed with a number of lakes with different hydrological settings such as lakes Manasbal, Dal, Wular etc. (Balkhi *et al*., 1987; Bhat and Yousuf, 2004). The origin of the lakes in Kashmir Valley is either tectonic or fluviatile, as almost all the lakes lie on the flood plain of river Jhelum. However, these freshwater lakes of the Valley are under anthropogenic pressures, as a result of which many water bodies have deteriorated during past 50 years. Manasbal Lake is located at Safapora Ganderbal of Kashmir. The lake with distinct grandeurs is situated on the Jhelum Valley at a distance of 30 kms from Srinagar city. The word Manasbal is derived from Manusarwar, the sacred lake which skirts the Kailash Mountain along with Gauri-Sar and Rakhas Talav and encircled by villages viz., Jarokbal, Kondabal (also called Kiln place), Gratabal, Bhagwan Mohalla & Nannynara and is stated to be the deepest plane lake with 13 m depth (Dar *et al*., 2013) in Kashmir. It lies between 34´´15´ N latitude and 74´´40´ E longitude. The volume of water has been estimated as 12.8×10^6 m^3 (Yousuf, 1992). The lake lies at an altitude of 1,585 masl and has a catchment area of 33 km^2. The lake has maximum length of 5 km and width 1km. with an average depth of 4.5m. Manasbal lake is situated in rural area and most of domestic wastes, detergents, agricultural wastes and other anthropogenic activities have deteriorated the Lake so much that it has resulted in serious disturbance to its environment and bio-diversity.

The huge growth of lotus (*Nelumbo nucifera*) at the periphery of the lake (blooms during July and August) adds to the beauty of the clear waters of the lake. The rootstocks of lotus plant which grow extensively in the lake are harvested and marketed, and also eaten by the local people. The lake is the only main source of water for fish culturing ponds and seed producing Chinese hatchery for grass carps, silver carps and common carps located at National Fish Seed Farm Manasbal Kashmir. The drainage basin for the lake has no major inlet channels and is thus fed mainly by precipitation (rain and snow fall) and springs (more than 1,200 springs). Lake water outflows to the Jhelum River through a regulated outflow channel Nannynara about 1.6 km near Sumbal village. The lake is the source of portable water besides some economically important food and fodder plants.

Aquatic plants can only grow in water or in soil that is permanently saturated with water and are therefore a common component of wetlands. Aquatic plants grow profusely in lakes and waterways all over the world and have become weedy in many lakes and ponds in India as well (Gupta, 2001). These may be categorized as floating submerged and emergent aquatic plants. For centuries, aquatic plants have been perceived as a nuisance rather than resource. They block canals, hinder boat traffic and increase water borne diseases. In the recent past numerous workers all over the globe have tried to explore the possibilities of using these plants as a source of animal feed (Anon ,1984; Benergy and Matai, 1990) and as medicinal plants (Nandkarni, 1992;Nagma and Sarwat, 2005; Deepa *et. al*. 2009). In Jammu & Kashmir numerous aquatic plants like Nymphoides, Rannunculus, Nymphaea, Hydrilla, Azolla, Nelumbo, Trapa etc. species are found in different lakes and water bodies (Bhat, 2002) which reduce their water quality and reduce their area. Owing to acute shortage of fodder in the valley, utilization of these plants as animal feed could be considered after evaluating their nutritional potential. Aquatic weeds are known to differ widely in their chemical composition depending upon species, season and location (Anon, 1984). An appropriate population of aquatic macrophytes contributes to the general fitness and diversity of a healthy aquatic ecosystem (Flint and Madsen, 1995). In addition, they provide habitats for insects, fish and other aquatic or semi-aquatic organisms (Madsen *et al.,* 1996). Submerged and emergent macrophytes also aid in the anchoring of soft bottom sediments and removing suspended particles and nutrients from the water column (Madsen *et al.,* 1996).

Among the aquatic macrophytes, Lotus rhizome is very good source dietary fibre, 100g provides 4.9 g or 13% of daily-requirement of fiber. The fibers together with slow digesting complex carbohydrates in the root help reduce blood cholesterol, sugar, body weight and constipation conditions. Lotus root is also one of the excellent sources of vitamin C. In addition the root contains moderate levels of some of the valuable B complex group of vitamins such as pyridoxine (vitamin B-6), folates, niacin, riboflavin, pantothenic acid and thiamin. Further, the root provides healthy amounts of some important minerals like Copper, Iron, Zinc, Magnesium and Manganase. Lotus plant *(Nelumbo nucifera* (Figure 1a &b) is one of the important food for people in Kashmir. Lotus is herbaceous, perennial aquatic plant belonging to the family *Nelumbonaceae*. The roots of this aquatic plant have high market value & is preferred by all types of people in Kashmir. The root is popular as Nadroo in Kashmir. Due to its health benefits and as economical commodity, the present study was taken to study its economic status and extraction methods in Manasbal Lake.

Fig. 1. a) Lotus Plant

b)Lotus root (edible part)

MATERIALS AND METHODS

The study was conducted from *July to December, 2014* in five villages viz, Hanji Mohalla, Nannynara, Kondabal, Gratabal and Bhagwan Mohalla encircling the Manasbal Lake (Figure 2). Total no. of population , no. of families and people involved in the extraction of Lotus roots of each village was undertaken. In the months of Aug. and Sept. 2014, total no. of licences registered for extraction of Lotus root were procured from Dept.of Fisheries J&K. The licence fee wasfound as Rs 1000/- per individual of age group above 20 for three months. But some unlicenced people and the persons below the age group of 20 were also seen extracting the lotus root. People involed in the extraction were only males and were of the age group of 15-50 years. In the month of October when the extraction started, the average weight of total Lotus roots were calculated from each village on daily basis and the rate at which they sold it to dealers was also recorded. The rate at which customers buy Nadroo from retailers was also recorded.

Extraction Months: Extraction of lotus roots

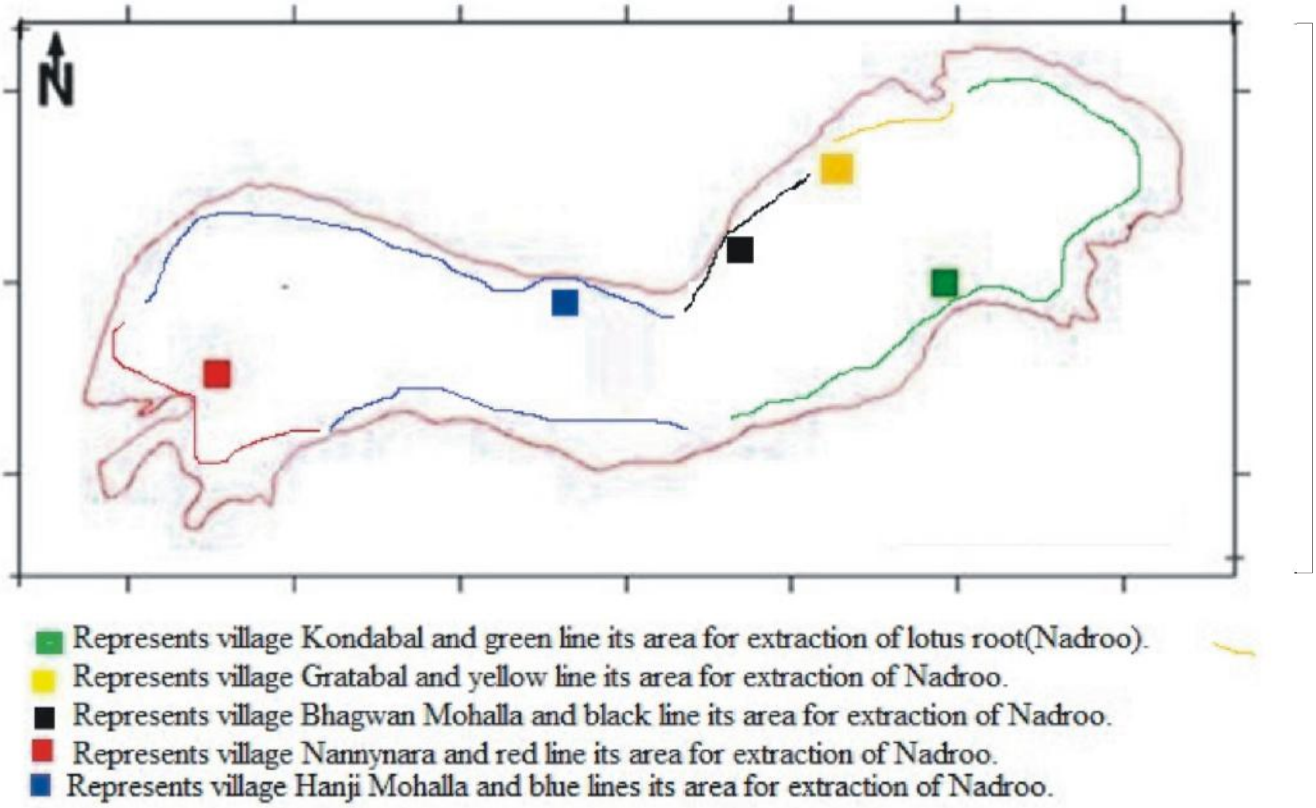

Fig. 2. Location of different villages around the Lake and their area for extraction.

started from October upto 1st Jan.

Time of extraction: Most people liked to start extraction of Lotus roots (Nadroo) from 10:30 am onwards upto 5 p.m in the early month of October. But due to more cold in the month of November the extraction started from 11:30 am onwards upto 4.p.m. In the month of December due to severe cold and least availability of lotus plant, extraction slowed down and people start the extraction after 12 p.m.

Methods of extraction adopted by people: Three methods of extraction of lotus roots were found depending upon the depth of water:

a). Traditionally, people sink their legs in knee-deep lake and tried to feel for the rhizome through their toes, which are then dug out by hand (Figure3). When they feel rhizome under the mud, its thick part was collected and the other part being thin is being thrown away. The thick part was pulled out of water with 2-3 efforts. In this extraction type, head remained above water level and extraction was very high. This type of extraction was done during the months of October up to late November.

Fig. 3. Extraction from knee deep depth

Fig. 4. Extraction by dipping in the water depth

b) In the second method, the pattern remained same but due to more depth of water than type a, it became slightly different, in which the extractors sunk their head into water (Figure 4). In this case, extraction was also high, but extended for shorter period of time. This method of extraction was also adopted in the month of October but ended in the early month of November.

c) In the 3rd case, as the water level decreases, then they select some area at shallow portion near the bank of lake and encircled it by mud discharge water from that portion and also prevent water to enter. In this type of extraction, spade, plastic mug etc. are used to extract the lotus roots(Figure 5). In this type, extraction was recorded very low than the above two cases. This was usually done in the month of late November up to Jan 1st .

In the first two types a) & b) boat (Naw in Kashmir) was used to extract the Lotus root so as to hold the boat and also to rest upon during intervals where a fire pot (kangri) was used to warm themselves during that time. Fire pot was used in all the three types. In the 3rd type of extraction usually a group of 2-3 people together were involved in extraction.

Fig.5. Extraction by removing the mud

Overall Percentage of people (males) involved for extraction:

$$\frac{\text{No. of people (male) involved for extraction}}{\text{Total No. of male population}} \times 100$$

The percentage of other viilages like Kondabal, Gratabal, Bhagwan Mohalla and Nannynara were also calculated:

$$\frac{\text{No. of people (male) involved for extraction}}{\text{Total No. of male population of Mohalla}} \times 100$$

RESULTS AND DISCUSSION

The local name of *Nelumbo nucifera* is Nadroo. Nadroo are actually modified tubers, storing energy in the form of starch. The rhizome develops into sausage-like three to five jointed nodes of about 2-4 feet length. Each rhizome segment features smooth grey-white color and measures about 10-20 cm in length, 6-10 cm in diameter. Internally, the root has white, crunchy flesh with mild sweet, water chestnut like flavor. The roots of the Lotus plant are firmly set in to the mud or wet dirt and it gives out elongated stems. The leaves of the plant are attached to these long stems. While the Lotus flowers are at all times found above the surface of the water, sometimes even the leaves can be seen floating on the water. The leaves of Lotus plant are known as Khel in Kashmir.

Precisely speaking, almost all the parts of the Lotus plant, including its rhizomes (roots), flowers, tender leaves as well as the seeds are edible. The lotus root is crunchy, delicate flavored, an edible rhizome (root) of lotus plant. In Kashmir, Nadroo Yakhni cuisine (curd and lotus root), Nadar Munj (lotus root and basin), Nadaroo Aanchar (pickles) and many other kashmiri cuisines are very popular. The peeled cut pieces of lotus root about 3 inches long are boiled with salt and then sun dried so as to preserve it for longer period locally known as Nadir Ara.. This Nadir Ara along with beans are often used as vegetables in winter and is very famous in Kashmir. Lotus root (Nadroo) harvest begins by October and lasts in the month of December.

long are boiled with salt and then sun dried so as to preserve it for longer period locally known as Nadir Ara. This Nadir Ara along with beans are often used as vegetables in winter and is very famous in Kashmir. Lotus root (Nadroo) harvest begins by October and lasts in the month of December.

Results of the present study showed that all type of people were involved in extraction of Lotus roots to add their annual income. Particularly, the fishers living near the banks of lake were almost 100% involved in extraction. It was observed that these people do not have taken any particular training for extraction of lotus roots. Some kids were also seen in using efforts to extract the lotus roots near the shallow places of lake. Results also showed that all the villages located on the banks of the lake occupied their own territory for extraction of lotus root and prevented other villagers from extracting the same in their area as shown in Figure-1.

The total population of Hanji Mohalla, Kondabal, Gratabal, Bhagwan Mohalla and Nannynara was 214, 577, 276, 265 and 175 souls respectively and the total population of these villages forms 1507. Total number of families living in Hanji Mohalla, Kondabal, Gratabal, Bhagwan Mohalla and Nannynara were 42, 117,56 ,51 and 36 respectively. In Hanji Mohalla people of the age group of 20-50 were all involved in extraction and has highest percentage of people involved in exraction (Table 1). Kondabal village had the highest number of licenses about 88 of the total of 295 in all the five villages. Then Hanji Mohalla was next and had 75, while as Bhagwan Mohalla ,Gratabal and Nannynar had 59, 45 and 28 licenses respectively. The percentage of total number of people (male) involved in the extraction in all the five villages was calculated as 43.6%. All the license holders and also a very good number of non- license holders were seen indulged in extraction during the first phase i.e. from 1st October up to 15th November but as the cold increases in coming months (November onwards) extractions of Nadroo and involvement of people in the extraction decreased. The study on daily basis revealed that from first 20 days in the month of October the extraction was very high in all five villages with an average extraction of about 15kg/individual per day. From 21st October onwards, it reduced abruptly to about 5-8kg/individual /day up to 15th November. From 15th November onwards there was very high decline in extraction and was recorded as 4-5kg/individual/day up to January 1st. From 1st October upto 20th of October the percentage of people involved in extraction was 100%. After 15th of November, it reduced to about 65%. There was abrupt decline in extraction of lotus root from here onwards and was only 3-5% from all the villages. The reason for decline in extraction of Nadroo and involvement of people in extraction process was due to severe cold and less availability of lotus plant. In this phase people from Gratabal and Bhagwan Mohalla were only seen in extraction. All the extractions of the day from each village is kept under water by each individual for night. In the early morning different dealers from city Srinagar came to each village and buy the harvest at a price of Rs. 325/5kg. The extractions were kept in bundles usually of 5kg wt. These bundles consist of mixtures of both thin and thick Lotus roots. The market rate of bundle for 5kg being Rs 500. This type of rate was available only in the 1st phase of extraction. As soon as the extraction slows down, the price increases and each bundle is sold @ Rs 650/5kg. That varying rates show the good demand and market of Lotus root in Kashmir and almost 100% consumption. The study showed that an individual (involved in extraction) on an average extracted 630 kgs of Nadroo during three months and earns Rs 40,950. However, the annual income of Individual / population (all were not involved in extraction) remained to about Rs 29250. The amount of Rs 29250 earned by each individual of the population is for one and a half month only and therefore adds this income to his overall income as for the rest of the year they are doing different kinds of jobs also. However, as per the people involved in the trade the production during the study period has decreased as compared to previous years and the main cause for decline in extraction as per them was increased water level due to which they could not reach up to the Lotus root to dug it out. Besides increased water level, the big threat to the lake is the pollution due to washing of clothes, entry of kitchen wastes, latrines etc. directly from the residential areas living around the lake. The other cause of decrease in production seems tourist flow as the passing boats through these plants damage the rhizome. These activities eventually would alter the diversity of Lotus plant that grow naturally and other important species in the Lake. A holistic approach and management of the lake is needed for the production of Nadroo in it.

Table.1. Population structure of villages situated around the lake.

Name of Villages	Total no. of Population	No. of adults male population	No. of people Involved in Extraction	Percentage of people involved in extraction
HanjiMohalla	214	81	75	92.6%
Kondabal	577	295	88	29.8%
Gratabal	276	125	45	36%
BhagwanMohalla	265	105	59	56.2%
Nannynara	175	71	28	39.4%

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Study of Groundwater Quality Around Dal Lake for the Purpose of Irrigation

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ABSTRACT

Kashmir valley has potentially rich deposits of groundwater most of which remain unexploited and can be utilized to meet the growing water demands of the valley. It is in this context that present study was carried out in the year 2013 to assess the groundwater quality around Dal Lake for the purpose of irrigation. A total of seven groundwater samples, representing tube well, bore wells and springs were collected and analyzed for physico-chemical parameters viz; pH, conductivity, total dissolved solids, alkalinity, calcium, magnesium, sodium and potassium. The samples were also evaluated for sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR), soluble sodium percentage (SSP), percent sodium (%Na), permeability index (PI), Kelley's ratio (KR) and residual sodium carbonate (RSC). The results showed that the groundwater under study is suitable for irrigational purpose, however, MAR (42% of samples) and RSC (71% of samples) were found to be deviating from the prescribed norms and thus representing a hazard for soil as well as plants.

Key words: *Tube well, Bore wells, Springs, magnesium adsorption ratio, Permeability index*

INTRODUCTION

Ground water is a vital resource of water for many people on the earth and provides them with water for various purposes. The resource gets accumulated beneath earth's surface in aquifers and then supply to springs and wells (Williams, 1996). Surface waters like streams, rainfall and rivers are among the natural sources which contribute to the recharge of groundwater (Vasanthavigar *et al.*, 2010).

Agriculture is the leading consumer of freshwater and accounts about 70% of its use (Gleick *et al.,* 2015). Globally groundwater comprises about 40% of irrigation water and India being its largest user (Aeschbach-Hertig and Gleeson, 2012) accounts for 70% of production and supports some 50% of population (World Bank, 1998; Shah, 2010). As much as 95% of rural areas of India depend on groundwater for their domestic purposes. Thus, the quality of groundwater is assuming great value due to the expanding pressure on agriculture and increase in standard of living (Wijnen, 2012).

In the past, quality as well as quantity of groundwater was considered to be fairly good but now the problem of groundwater deterioration is well recognized due to urbanization, over-exploitation, improper waste disposal etc. Approximately one fifth of all the water exploited in the world is groundwater and in some areas it is the only source of water. Scarcity of other fresh water resources is also pushing people to exploit groundwater and to meet their demands (Abbulu and Rao, 2013). Further, groundwater chemistry is governed by many factors like weathering of rocks, quality of recharge water and other sources in addition to water-rock interaction (Schuh *et al.*, 1997; Kuldip-Singh *et al.*, 2011). Evaluation of water quality is thus very essential for knowing its use for various purposes (Ifatimehin and Musa, 2008; Jehangir *et al.,* 2011).

Till now no work has been carried out on the irrigational aspects of groundwater quality around Dal Lake. Therefore, an attempt was made to obtain a baseline data on groundwater quality around Dal Lake and its suitability for irrigation purposes.

STUDY AREA

Dal Lake is situated at an altitude of 1584m a.s.l. between 34° 03′- 34° 13′ latitude and 74° 48′- 75° 08′ longitude in the north-east of Srinagar city (Fig.1). The lake covers an area of about 11.4 km^2 (LAWDA, 2009). It is a Himalayan urban lake probably derived from an enlarged oxbow in the flood plains of river Jhelum (Dianelle, 1922; De and Paterson, 1939)

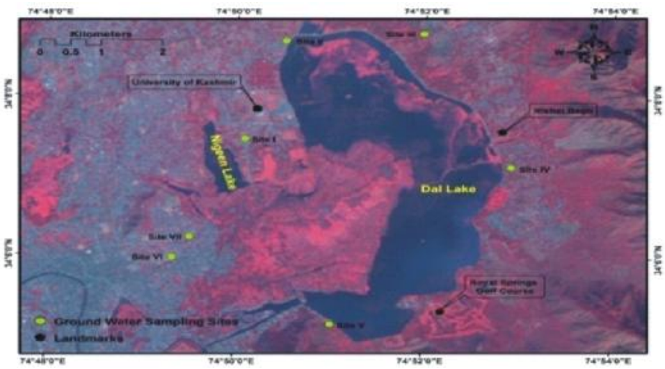

Fig.1. Satellite image of Dal Lake showing study sites

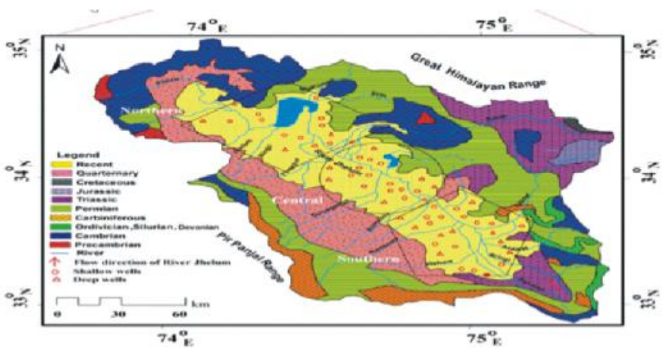

Fig.2. Geological map of Kashmir valley

Geology

Dal Lake is a valley floor lake located at the bottom of Kashmir basin, with a large part filled with recent alluvium deposited by river Jhelum (Fig. 2). These deposits include alluvial tracts, flood plains, river terraces and talus screen fans. Thus, the lake and its surrounding areas will be comprised of such depositions and the hydrochemistry of the groundwater in the study area will be influenced by it.

Study sites

Seven sampling sites were selected for determination of various irrigational parameters of groundwater quality around Dal Lake. The description of study sites is as follows:

Site I. Hazratbal

The site is a borewell situated in a residential area between 34° 07' 28.3" N and 074° 50' 05.4" E at an elevation of 1594m. The site is about 80m away from Dal Lake having a depth of 60ft and is used for domestic purpose.

Site II. Habbak

The site is a fresh water spring located in an open field between 34° 08' 42.2" N and 074° 50' 30.6" E at an elevation of 1580m. The site is about 30m away from Dal Lake having a depth of 60ft and is used for domestic purpose.

Site III. Foreshore road

The site is a fresh water spring called Zakheer Naag located at an elevation of 1595m between 34° 08' 48.0" N and 074° 51' 58.4" E on foreshore road about 95m from Dal Lake. The spring is situated near a paddy field and is surrounded by some trees. The spring has a depth of 2.93ft and is used for irrigating the fields and other domestic purposes.

Site IV. Nishat

The site is a fresh water spring located in a commercial area at an elevation of 1600m between 34^o 07' 08.3" N and 074^o 52' 55.5" E and is about 40m away from Dal Lake. The spring has a depth of 4.6ft and is used for commercial purpose.

Site V. Nehru park

The site is a borewell located in a commercial area at a latitude of 34^o 05' 09.3" N is and 074^o 51' 01.8"E with an elevation of 1597m. The site is about 33m away from Dal Lake having a depth of 12ft and is used for commercial purpose.

Site VI. Rainawari

The site is a borewell located in a car service station between coordinates of 34^o 05' 58.7" N and of 074^o 49' 20.5"E at an elevation of 1595m. This site is about 1500m away from Dal Lake with a depth of 55ft and is used for washing cars.

Site VII. Saidakadal

The site is a tube well station located about 40m away from Dal Lake between 34^o 06' 14.4" N and 074^o 49' 31.3" E at an elevation of 1607m. The tubewell has a depth of 250 ft and is supplied for drinking.

MATERIAL AND METHODS

For the present study seven sites were selected for obtaining ground water samples around Dal Lake, which included three springs, three bore wells and one tube well. Water samples were collected in clean and dry polyethylene bottles. Prior to sampling all the sampling containers were washed and rinsed thoroughly with groundwater. Also in case of tube-well and borewells water was first allowed to flush for 2-3 minutes. Each sample was analyzed for certain physico-chemical parameters like pH, conductivity, total dissolved solids, alkalinity, calcium, magnesium, sodium and potassium. The results obtained were used to calculate irrigational parameters like sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR), soluble sodium percentage (SSP), percent sodium (%Na), permeability index (PI), Kelley's ratio (KR) and residual sodium carbonate (RSC). The analysis was done as per standard methods given by APHA (1998).

The quality of groundwater for irrigational purposes was calculated using following equations:

SAR was calculated using equation (Richards, 1954) as:

$$SAR = \frac{Na^+}{\frac{\sqrt{Ca^{2+}+Mg^{2+}}}{2}}$$

All the ions are expressed in meq/l

MAR is calculated using equation (Ragunath, 1987) as:

$$MAR = \frac{Mg^{2+} X\ 100}{Ca^{2+} + Mg^{2+}}$$

All the ions are expressed in meq/l

SSP is calculated using equation (Todd, 1980) as:

$$SSP = \frac{Na^+\ X\ 100}{Ca^{2+} + Mg^{2+} + Na^+}$$

All the ions are expressed in meq/l

%Na was calculated using equation (Wilcox, 1955) as:

$$\%Na = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} X100$$

All the ions are expressed in meq/l

PI was calculated using equation (Doneen, 1964) as:

$$PI = \frac{(Na^{+} + \sqrt{HCO^{3}})\ X\ 100}{Ca^{2+} + Mg^{2+} + Na^{+}}$$

All the ions are expressed in meq/l

KR was calculated using formula (Kelley *et al.*,1940) as:

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$$

All the ions are expressed in meq/l

RSC was calculated using equation (Eaton, 1950) as:

$$RSC = (CO_3^{\ 2-} + HCO_3) - (Ca^{2+} + Mg^{2+})$$

All the ions are expressed in meq/l

RESULTS AND DISCUSSION

Groundwater is one of the earth's most broadly distributed and important natural resources for municipal, agriculture, and industrial purposes, as well as environmental aspects. Due to urbanization and industrialization, water is increasingly laced with pollutants from industries, municipal sewers and agricultural fields that are treated with fertilizers and pesticides. As a result, water has become a cocktail of various pollutants like nitrates, chlorides and pesticides etc. Indeed, differences in the concentrations of dissolved ions in groundwater are also governed by lithology, groundwater flow, geochemical reactions and soluble salts (Bhat *et al.*, 1996; Karanth, 1997). This was depicted from the analysis of physico-chemical parameters of groundwater (Table 1).

Variations in natural and human activities are reflected in the hydro-chemical parameters of the groundwater. The fluctuation of pH in the study area during different months varied from a mean value of 6.8 to 7.2. This alkaline behavior of pH may be due to limestone rich lithology of the valley, liberating Ca, Mg, and almuno-silicates into the solution while as slightly acidic behavior can be attributed to the formation of carbonic acid by the dissolution of carbon dioxide in water (Tijani, 1994 and Yongjun, 2006).

The conductivity at the study sites varied from a mean value of 303 to 1161µS. High values of conductivity at site II, V and VI can be attributed to the prevailing lithology of the region (Ravindra and Garg, 2007), besides anthropogenic activities can also be the cause of this increase (Khodapanah, 2009). Also, concentration of total dissolved solids (TDS) varied from a mean value of 205 to 746mg/l. The values of TDS were in accordance with the values of conductivity and were high at site II, V and VI which can be attributed to the hydrogeological properties of rocks that will have a strong influence on the extent of water /rock reaction (Langmuir, 1997).

In the present study alkalinity was represented by bicarbonate alkalinity and was ranging from a mean value of 25 to 313mg/l. Relatively higher concentration at certain sites can be attributed to the dissolution of carbonates due to carbonic acid formed as a result of infiltrating carbon dioxide (Tijani, 1994 and Kumar *et al.*, 2006).

The high calcium concentration is a direct attribute of calcium rich rocks as suggested by the findings of Hynes (1970). Calcium value varied from a mean range of 25 to 108mg/l. However, at majority of the sites calcium was dominating over magnesium mostly because of its abundance in the rock types and its solubility. Magnesium was found to be ranging from a mean value of 15 to 40mg/l.

Sodium ranged from a mean value of 4 to 48 mg/l.

Low sodium value in the present study was due to carbonaceous or lime rich bed rock of the valley (Kaul *et al*., 1978; Zutshi *et al*., 1980; Pandit, 1999). While as high values at site V and VI may be due to anthropogenic sources. Also potassium ranged from a mean value of 1 to 48mg/l. The low value of Potassium in groundwater is due to highly stable nature of alumino-silicate minerals constituting this substance and subsequent fixation in clay minerals if formed due to weathering or use in biological systems (Hem, 1985). Whereas high value at site VI may be due to anthropogenic stress.

Irrigational quality

Groundwater is a very important source of irrigational water in addition to other freshwater sources. The quality of water to be used in agriculture is recommended by Food and Agriculture Organization (FAO) of the United Nations (Ayers and Westcot, 1985). Good quality of waters for irrigation is characterized by acceptable range of sodium adsorption ratio and percent sodium. Factors like water quality, type of soil along with its drainage, salt tolerance range of plants, and climate of region are important factors which determine the suitability of groundwater for irrigation (Michael, 1990). The results obtained from calculation of various irrigational parameters are shown in table 2.

Alkalinity Hazard

Sodium is a very important cation which if present in excess can depreciate the structure of the soil and decline crop yield (Narsimha *et al*., 2012 and Narsimha *et al*., 2013). Its high concentration in irrigational waters result in its absorption by clay and thus replacing magnesium and calcium which in turn has effect on soil drainage. Sodium adsorption ratio is of a great significance to assess the irrigational status of groundwater as it is a measure of alkali/ sodium hazard to the crops (Subramani *et al*., 2005). The samples showed a mean value of SAR ranging from 0.13meq/l to 1.38meq/l. Thus, all the samples were falling in excellent category (Table 3), suggesting that these groundwater sources are suitable for irrigation purposes with no risk of exchangeable sodium. %Na ranged from a mean value of 4% to 32% and thus groundwater at site I, II III, IV and VII was categorized as excellent and at site V and VI as good for irrigation (Table 3). High value of SSP will adversely affect plant growth and permeability of soil (Joshi *et al*., 2009). On the basis of the observed values it was found that the mean values of SSP were in the range of 0.15% to 31.1% and thus all the samples fall in the excellent category (Table 3).

Salinity Hazard

By plotting Electrical conductance against %Na on Wilcox diagram (Fig. 3) as sodium has a significant effect on the soil and reduces its permeability (Todd, 1980), it was found that all of the sites belonged to excellent category while as one site was belonging to good category thus indicating the suitability of water for use in agriculture. The US salinity Diagram (U.S. Salinity Laboratory Staff, 1954) was plotted using EC and SAR (Fig.4) for determining the suitability of water for irrigational purposes. In this diagram EC measures salinity hazard while as SAR measures alkalinity hazard. In the present study it was found that most of the sites fall in C2S1 category, indicating medium salinity and low alkalinity. Other sites were falling in C3S1 category, indicating high salinity and low alkalinity, thus the groundwater at these sites can be used for irrigation with little danger of exchangeable sodium.

Bicarbonate Hazard

Bicarbonate and carbonate also determine the suitability of water for irrigation and RSC is an index to determine bicarbonate hazard. High value of RSC in water means high pH and thus unsuitability for irrigation due to deposition of sodium carbonate (Eaton, 1950). The lesser its value the better it is for irrigation. In the present study the RSC values were ranging from a mean value of 1.5meq/l to 8meq/l. Thus, groundwater of site III and IV comes under doubtful category, that of site I, II, V, VI and VII were unsuitable for irrigational purpose (Table 3). Magnesium content is a very important criteria for determining the irrigation quality of waters as increased level of magnesium in irrigational waters will have harmful effect on crop yieldas salinity of soil will increases (Doneen, 1964). The samples showed a mean value of MAR in the range of 20.2 % to 78.9 %. %. Site II, III, IV and VI with MAR values less than 50 will be suitable for soil, while as site I, V and VII having MAR value more than 50 (Table 3) will be considered unsuitable for irrigation.

Ions like Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^{-} can affect the soil permeability if present in irrigational water for long (Raju, 2007). In the present study the mean values of PI were ranging from 21.8% to 51.4% and thus all the groundwater samples fall in class I signifying good quality of water for irrigation purposes (Table 3). On the other hand all the samples had Kelley's ratio in the mean range of 0.04meq/l to 0.24meq/l and thus were categorized as safe and hence suitable for irrigation (Table 3).

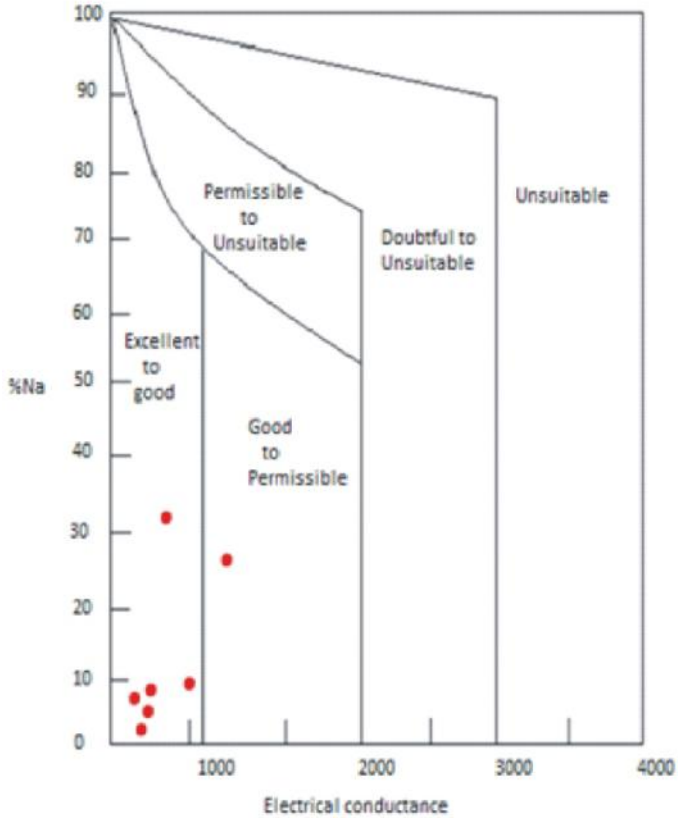

Fig.3. Wilcox's diagram for classification of groundwater quality around Dal Lake, Kashmir

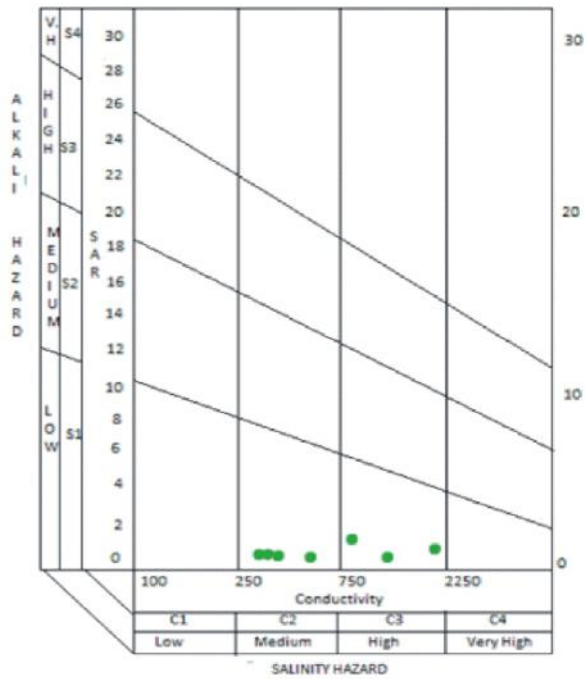

Fig.4. USSL salinity diagram for classification of groundwater quality around Dal Lake, Kashmir

Table 1. Mean values of various physicochemical parameters of study sites

Parameters	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
pH	7.2	6.8	6.9	6.8	6.9	7	6.8
Conductivity	306	982	303	399	776	1161	330
T.D.S	205	654	204	270	504	746	217
Alkalinity	25	313	106	143	114	111	54
Calcium	25	147	39	45	39	108	29
Magnesium	28	26	15	28	33	33	40
Sodium	4	24	8	8	48	44	11
Potassium		2.2			1	48	2.2

Table 2. Mean values of irrigational parameters of study sites

	EC	**SAR (meq/l)**	**SSP (%)**	**%Na (%)**	**PI (%)**	**KR (meq/l)**	**RSC (meq/l)**	**MAR(%)**
Site I	306	0.13	4.6	4	21.8	0.04	3.1	65.6
Site II	982	0.48	10	10	32	0.12	4.1	20.2
Site III	303	0.24	8.7	8	46.3	0.09	1.5	38.4
Site IV	399	0.23	0.15	6	37.8	0.07	2.2	50.9
Site V	776	1.38	31.1	32	51.4	0.46	2.8	58.4
Site VI	1161	0.95	19	27	22.1	0.24	8	33.6
Site VII	330	0.31	9	9	25.7	0.09	3.9	78.9

Table 3. Classification of groundwater in the study area

Water class	**Range**	**Category**	**Sites**	**%age of samples**
EC	0 – 25	Low		
	251- 750	Medium	I, III, IV, VII	57%
	751 – 2250	High	II, V, VI	42%
	2251-6000	Very high		
SAR	< 10	Excellent	I, II, III, IV, V, VI, VII	100%
	10 to 18	Good		
	18 to 26	Permissible		
	>26	Unsuitable		
RSC	**RSC**			
	<1.25	Safe		
	1.25-2.5	Marginal	III, IV	28%
	>2.5	Unsuitable	I, II, V, VI, VII	71%
KR	<1	Safe	I, II, III, IV, V,VI, VIII	100%
	>1	Unsuitable		
	< 20	Excellent	I, II, III, IV, VII	71%
	20-40	Good	V, VI	28%
%Na	40-60	Permissible		
	60-80	Doubtful		
	> 80	Unsuitable		
SSP	<50	Good	I, II,III,IV,V,VI,VII	100%
	>50	Bad		
PI	>75	Class I	I, II, III,IV,V,VI,VII	100%
	25-75	Class II		
MAR	<50	Suitable	II, III, IV, VI	57%
	>50	Unsuitable	I, V, VII	42%

CONCLUSION

The irrigational parameters are very important in knowing about the quality of the water and its use in agriculture. The results were compared with prescribed norms meant for the purpose.

On the basis of the analysis done it was found that the groundwater in the study area can be classified as excellent to good in case of SAR, SSP, % Na, PI and KR values. Electrical conductivity was slightly high at few sites and was falling in medium to high range while as MAR value at few sites was also found to be slightly high thus classified as unsuitable posing threat to soil, other sites had MAR values within the suitable range. Also, RSC was showing an increase at most of the sites and thus water was classified as doubtful and unsuitable which indicates risk of bicarbonate hazard to soil. Overall the groundwater in the study area had no risk of alkali hazard but some of the sites had medium to high salinity which was indication of salinity hazard.

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Watershed Prioritization Using Sediment Yield Index Model for Vishav Watershed of Jammu and Kashmir State (India)

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ABSTRACT

Assessment of soil loss through Sediment Yield Index (SYI) is important for watershed planning, prioritization and development. In the absence of measured sediment data, SYI expressing the relative sediment yield from different micro-watersheds works out ideally for prioritizing watersheds for erosion control measures. An attempt has been made in this paper to evaluate SYI on a wider scale by using cost-effective tools like remote sensing and geographical information system (GIS). SYI was estimated for twenty one micro-watersheds (33^0 39 to 33^0 65 N latitude and 74^0 35 to 75^0 11 E longitude) and were statistically classified into three priority classes on the basis of soil and altitudinal zonation maps. Aerial extent of the catchment is 106291 hectares and micro-watersheds varies between 10923 ha to 2058 ha. This lies in temperate climate region and is mainly forest covered mountainous catchment. IRS P6 LISS III 2010, digital data were used to obtain land use and land cover map. The data are digitally processed by sequential clustering technique in Arc view 3.2a, Eridas 9.0 and themes were color coded in geographic information system (GIS). Erosion intensity mapping units (EIMU) were extracted by using standard image interpretation techniques and adequately complemented by collateral data and maps. Various operations of map overlay, classification and reclassification were used. The prioritization was carried out by estimating SYI for the individual micro-watersheds. This became the basis for assigning relative priority for each individual micro-watershed. The study revealed that the seven micro-watersheds fall in high, eight in medium and six in low priority classes. The micro-watershed 1EIC9a13 has the highest priority while the micro-watershed 1EIC9a21 has the lowest priority. The prioritized watersheds are in dire need of management and planning so that the problem of environmental degradation in them can be arrested.

Key words: *Vishaw watershed, Prioritization, Soil loss, Sediment yield index, Erosion intensity mapping units, Soil map, Altitudinal zonation map, Geographic information systems.*

INTRODUCTION

Soil erosion is a continuous process, and it removes upper layer of soil rich in nutrients for plant growth, consequently, bringing down productivity of soil. It has been estimated that about 113.3 million ha. of land is subjected to soil erosion due to water and about 5,334 mt of soil is being detached annually due to various reasons in India (Narayan and Babu 1983). The problem of erosion may also be exacerbated in the future in many parts of the world because of climatic change towards a more vigorous hydrologic cycle (Amore *et al.*, 2004). Eroded soil in the form of sediment gets deposited in the reservoirs, eventually reducing designed storage capacity (Vito, 1975). Planning, conservation, and management of watersheds are important for the soil to prevent further damage from erosion. Therefore, an attempt to assess the erosion hazard and prioritization of watersheds for treatment would aid in better planning to combat this menace. Thus, watershed prioritization is ranking of different areas of a watershed according to the order in which they have to be selected for adopting suitable soil conservation measures. The watershed prioritization and formulation of proper watershed management programs for sustainable development require information on watershed sediment yield (Pandey *et al.,* 2007). Sediment load (SL) from a micro-watershed or catchment is the total quantity of sediment moving out of the watershed in a given time interval, while sediment yield is the total quantity of sediment from a watershed relative to the watershed area. Sediment load should include bed load as well as suspended load, but usually only suspended load is measured due to the difficulty of measuring bed load. Bed load is often assumed to be of minor importance even though in extreme cases it can reach 60% (Lane and Borland, 1951). The estimation for sediment yield is not straightforward for a large river basin consisting of a series of hierarchical micro-watersheds. The resource development programme can be applied scientifically on watershed basis and thus prioritization is essential for proper planning and management of natural resources for sustainable development. Therefore, the concept of prioritization plays a key role in identifying areas which need more focus or attention (Kanth, and Hassan, 2010). In this context of watershed management, prioritization has achieved more in terms of natural resource management (Biswas, *et al.,* 1999; Chakraborti, 1991; Nooka, *et al.,* 2005).

STUDY AREA

The Vishav drainage basin covering an area of 1062.91 km^2 (10 % of the Jhelum drainage basin) occupies the southeastern part of the Kashmir valley Fig. 1.1 and is positioned between 33^0 39 to 33^0 65 N latitude and 74^0 35 to 75^0 11 E longitudes with its major part (80 percent) in the Kulgam and Shopian districts of state. The Vishav watershed is a significant left bank permanent tributary of the Jhelum stream. Having its origin from Kounsarnag (3,840 m.a.s.l.) lying on the gentler northern countenance of the Pir Panjal range of Kashmir Himalayas, Vishav watershed appears to stem from a glacier fed stream near the base of Kounsarnag called Teri, which afterward joins the underground stream assumed to start off from Kounsarnag 2 km downstream at Mahinag, falling steeply north-northeast to arrive at the main strike valley till it amalgamates with Jhelum at Niayun (Raza *et al.,* 1978). The maximum discharge recorded in the month of July and minimum in the month of January. The discharge of the stream varies from 78.6 m^3s^{-1} to 0.4 m^3s^{-1}.

The stream occupies a wide sandy bed and gets bifurcated into a number of channels among which the Reshinagar water channel, Sunaman Kol, the Kawal Kol and the Mau Kol are important. The Sunaman Kol and the Mau Kol reunite and merge with the Rembiara near Niayun.

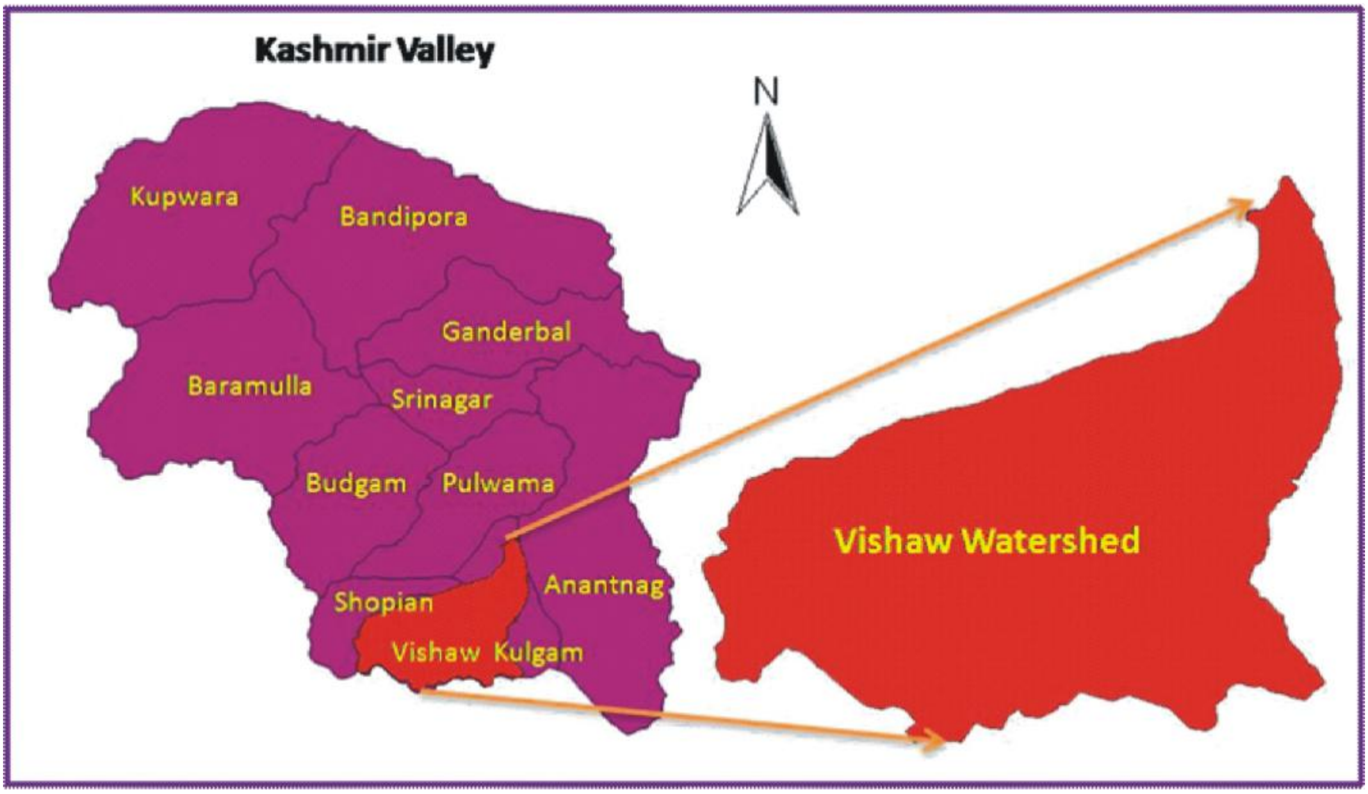

Fig. 1.1. Location map of study area

MATERIALS AND METHODS

A multi tier methodology was adopted to meet the objectives of the present study. For soil erosion purposes, soil and altitudinal zonation maps were employed to delineate Erosion intensity mapping units. Weightage value and delivery ratio were used to estimate the sediment yield index, which became the basis for prioritization. Twenty one micro-watersheds of 106091 ha. of area were classified as, high, medium and low priority zones. The soil and altitudinal zonation maps of the area were classified into three types as per standard practices (National Remote Sensing Agency 1994). The three types with their percentage of slope are: nearly level (1-5%), gently sloping, (5-10%), moderately sloping and (10-15%), strongly sloping. This micro level study provides accurate results in the context of Sediment Yield Index.

The sediment yield index has been estimated using the following equation (All India Survey and Land Use Survey Ministry of Agriculture, 2002).

$$SYI = \sum_{I=1}^{i=n} \frac{(AeI \times WeI \times DeI)}{Aw} \times 100 \quad \text{OR} \quad SYI = \frac{(\text{Area} \times \text{Weightage} \times \text{Delivery ratio})}{\text{Area of the micro-watershed}} \times 100$$

Where

SYI = Sediment Yield Index

AeI = Area of ith Erosion Intensity Mapping Unit

WeI = Weightage value of ith Erosion Intensity Mapping Unit

DeI = Delivery Ratio of ith Erosion Intensity Mapping Unit

Aw = Total Area of micro-watersheds

The sediment yield weightage is a function of climate, physiography, slope, soil, land use and management practices. However, the above equation requires a number of parameters to be taken in to consideration with special emphasis on soil and altitudinal zonation maps. The delivery ratio is defined as the proportion of the detached soil material from the source area reaching the sink area through surface flow or travelling through drainage. The maps generated namely the land use; the soil and the slope have been used as the vital input to obtain the erosivity (weightage) and the delivery ratio.

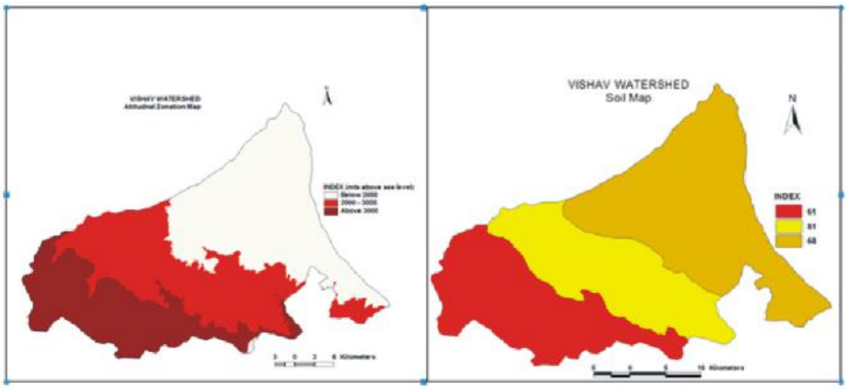

Fig. 1.2. Altitudinal zonation and soil maps of Vishav watershed
Source: Generated from SOI toposheets, 1971 and ICAR, 1992.

RESULTS AND DISCUSSION

Soil characteristics were interpreted for each of the physiographic units delineated on LISS- 1 and LISS-III data. The LISS-I data enabled to delineate a physiographic unit (Fig 1.2) while twenty one units could be delineated on SOI toposheets 1971. Weightage value and delivery ratio were assigned to each of the physiographic units based on the factors like slope erosion, soil depth, texture and management practices. The weightages values successively ranged from 13 (Valley Fill) to 17 (Hill). Similarly, the delivery ratio successively ranged from 0.58 (Valley Fill) to 0.72 (Hill). The loss of weightage value and delivery ratio due to omission of existing features is supposed to be compensated by inclusion of certain soil features. The finding of the study gives a scope of using a low-resolution satellite data for the purpose of determining SYI in time and cost effective manner. Watershed prioritization plays a key role in planning and management of sustainable development programmes. The study area, Vishav watershed, is located in Jhelum valley which is prone to high erosion. These micro-watersheds demand immediate attention in terms of management and planning perspective. This micro level study provides accurate results in the context of micro-watershed wise erosion intensity mapping units, their weightage value, delivery ratio and sediment yield index given below Table 1.1.

The prioritization indicators as listed in Table 1.1 have been used to work out the relative priority table 1.2 for ranking the micro-watersheds in order to prioritize them. The micro-watershed IEIC9a13 has attained the highest relative priority 01 and sediment yield index is 276 which means that it demands highest relative priority while the micro-watershed IEIC9a21 has attained the lowest relative priority 20 and sediment yield index is 63 which means that it needs lowest relative priority.

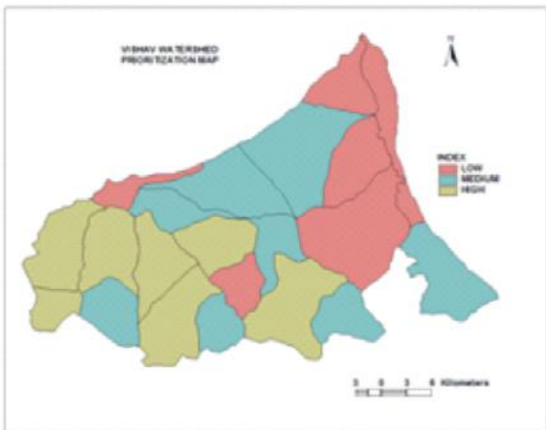

Fig. 1.3. Prioritization map of study area.
Source: Generated from SOI toposheets, 1971.

Table 1.1. Micro-watershed wise Erosion Intensity Mapping Units, Weightage Value, Delivery Ratio and Sediment Yield Index.

Hydrological Unit	Erosion Intensity Mapping Units	Area in Hectare	Weight-age Value	Weight-age Product	Delivery Ratio	Relative Sediment Yield Index	Sediment Yield Index	Relative Priority
IEIC9a1		2857	17	48569	0.72	34970	111	12
IEIC9a2		6432	17	109344	0.72	78728	249	2
IEIC9a3		4887	17	83079	0.72	59817	189	5
IEIC9a4	**Mountainous**	5451	17	92667	0.72	66720	211	4
IEIC9a5		3987	17	67779	0.72	48801	154	9
IEIC9a6		2274	17	38658	0.72	27834	88	16
IEIC9a7		5757	17	97869	0.72	70466	223	3
		31645						
IEIC9a8		2058	15	30870	0.64	19757	72	18
IEIC9a9		3137	15	47055	0.64	30115	110	13
IEIC9a10		4590	15	68850	0.64	44064	161	7
IEIC9a11	**Karewa**	3257	15	48855	0.64	31267	114	11
IEIC9a12		2770	15	41550	0.64	26592	97	15
IEIC9a13		7862	15	117930	0.64	75475	276	1
IEIC9a14		3681	15	55215	0.64	35338	129	10
		27355						
IEIC9a15		6946	13	90298	0.58	52373	111	12
IEIC9a16		9791	13	127283	0.58	73824	156	8
IEIC9a17		5125	13	66625	0.58	38643	82	17
IEIC9a18	**Alluvial**	10923	13	141999	0.58	82359	174	6
IEIC9a19		6420	13	83460	0.58	48407	102	14
IEIC9a20		4147	13	53911	0.58	31268	66	19
IEIC9a21		3939	13	51207	0.58	29700	63	20
		47291						

Source: All India Soil and Land Use Survey, 2002.

Table 1.2. Ranks of prioritization indicators for different micro-watersheds of Vishav watershed

S.NO	Hydrological Unit	Area in Hectare	Sediment Yield Index	Relative Priority
1	IEIC9a13	7862	276	1
2	IEIC9a2	6432	249	2
3	IEIC9a7	5757	223	3
4	IEIC9a4	5451	211	4
5	IEIC9a3	4887	189	5
6	IEIC9a18	10923	174	6
7	IEIC9a10	4590	161	7
8	IEIC9a16	9791	156	8
9	IEIC9a5	3987	154	9
10	IEIC9a14	3681	129	10
11	IEIC9a11	3257	114	11
12	IEIC9a1	2857	111	12
13	IEIC9a15	6946	111	12
14	IEIC9a9	3137	110	13
15	IEIC9a19	6420	102	14
16	IEIC9a12	2770	97	15
17	IEIC9a6	2274	88	16
18	IEIC9a17	5125	82	17
19	IEIC9a8	2058	72	18
20	IEIC9a20	4147	66	19
21	IEIC9a21	3939	63	20

Source: All India Soil and Land Use Survey, 2002.

The SYI pertaining to all micro-watersheds of Vishav watershed were estimated. The micro-watersheds were arranged with respect to the decreasing order of their SYI and graded into three categories such as, high, medium and low using the range in SYI given below Table 1.3.

Table 1.3. Priority Category

S. No.	Priority category	Range in Sediment Yield Index
1	High	> 160
2	Medium	121-160
3	Low	81-120

Source : All In dia Soil and Land Use Survey 2002.

After computing the sediment yield indices for each micro-watersheds priority ratings were assigned Table 1.2. Based on the SYI values, a total of twenty one micro-watersheds were grouped into high, medium and low classes shown in table 1.3. The SYI values and corresponding priority classes are presented in Figs. 1.3 respectively. Vishav watershed area has been subdivided into twenty one micro-watersheds following the delineation and codification method of Watershed Atlas of India (WAI). Out of 106291 ha. surveyed area, 45902 ha. (43%) spread over seven micro-watersheds have been categorized under high priority classes, 40076 (38%) spread over eight micro-watersheds have been categorized under medium priority classes and 20323 (19%) spread over six micro-watersheds have been categorized under low priority classes given below Table 1.4.

Table 1.4. Priority Categorization

S. No.	Priority category	No. of Microwatersheds	Area in hectares	Percentage
1	High (>160)	7	45902	43
2	Medium (121 -160)	8	40076	38
3	Low (81-120)	6	20323	19
Total		**21**	**106291**	**100**

Source: All India Soil and Land Use Survey, 2002.

High priority zone: Out of the total twenty one micro-watersheds, only seven micro-watersheds (IEIC9a13, IEIC9a2, IEIC9a7, IEIC9a4, IEIC9a3, IEIC9a18 and IEIC9a10,) came under in the high priority category, with a higher SYI value (>160) and cover of 45902 ha (43%) of Vishav watershed. Geomorphologically, these watersheds have high slopes and high stream density as compared to the other micro-watersheds. Hence, these micro-watersheds have higher erosivity. With limited vegetation cover, the barren surfaces have very little colluviums accumulation. Hence, these micro-watersheds possess hazards caused to the terrain, thus needing immediate attention. By adopting suitable land treatment practices, e.g., contour bunding, contour vegetative barriers, field bunding, gully reclamation, etc., so that soil conservation and resulting land productivity can be increased to achieve sustainable crop production.

Medium priority zone: Eight micro-watersheds (IEIC9a16, IEIC9a5, IEIC9a14, IEIC9a11, IEIC9a1, IEIC9a15, IEIC9a9 and IEIC9a19) fall under medium category with a higher SYI value (121-160) and cover 40076 ha and 38% of the study area. These micro-watersheds are well distributed among twenty one micro-watersheds. A majority are located in the perimeter of the Vishav watershed. In these micro-watersheds, low slopes were identified. Erosivity values are high, but the delivery ratio is comparatively less because of long distance from the outlet of Vishav micro-watershed. Therefore, these eight micro-watersheds do not suffer from any significant hazards and need no immediate attention.

1.4.3. Low priority zone: Six micro-watersheds (IEIC9a12, IEIC9a6, IEIC9a17, IEIC9a8, IEIC9a20 and IEIC9a21) have been placed under low priority category with a higher SYI value (80-120) covering an area of 20313 ha (19%) of the Vishav micro-watersheds area. These have very low drainage integration and low sediment erosivity value. The topography is dominated by flat gentle slope plains.

CONCLUSION

Soil loss is one of the hazards that reveals the negative impacts and is an major impediment for sustainable development. The Vishav watershed is undergoing significant changes in land use/land cover which have seriously threatened its sustainability. This ultimately lays emphasis on prioritization of micro-watersheds for soil and water conservation measures. The ever increasing human impact and depleting natural resources have necessitated proper management strategies for conservation purposes. In order to initiate such measures prioritization is a pre-requisite. The seven micro-watersheds fall in high, eight in medium and six in low priority classes possessing yield indices >160, 121-160 and 80-120 respectively. Its higher susceptibility to erosion due to its high slope and absence of vegetation, the micro-watersheds of the upper part of the catchment falling in high priority classes are in immediate need of erosion control measures. The medium priority classes occur in the alluvium, shale/sandstone and basalt geological region. In low priority classes soil conservation measures need to be adopted in areas especially under open land, agriculture and river banks. The prioritization of micro-watersheds envisages a sustainable planning to address socio economic problems in general and environmental degradation in particular.

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Immunomodulatory Activity of Methanolic Extract of *Gentiana kurroo* Royle on Balb/C mice

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ABSTRACT

In the present study immunomodulatory activity of methanolic extract of *Gentiana kurroo* root extract was investigated against Balb/c mice models. The study revealed that *G. kurroo* root extract possesses a potent immunosuppressive action. The inhibition of the humoral response against SRBCs in Balb/c mice by *G. kurroo* root extract was evidenced by the decrease in both primary and secondary antibody titre, DTH response as reflected by the decreased footpad thickness compared to the control group. We found that *G. kurroo* root extract inhibited LPS and Con-A induced spleenocyte proliferation, indicating its role in inhibiting T-cell activation. Further *G. kurroo* root extract was found to interfere with macrophage activation induced with LPS. These findings indicate that *G. kurroo* root extract inhibits LPS induced macrophage activation by inhibiting the pro-inflammatory cytokines release.

Key Words: Gentiana kurroo Royle, Delayed type hypersensitivity, Immunomodulation, Hemagglutination, Macrophage, Cytokines

INTRODUCTION

The human immune system plays an indispensible role in protecting the body against the numerous pathogenic invasions. It is able to produce an enormous variety of cells and molecules capable of specifically recognizing and eliminating an apparently limitless variety of foreign invaders (Richard *et al.,* 2003). Leukocytes (WBC) is one the important player of immune system which is derived from precursor cells in the bone marrow and develop under the influence of various cytokines and growth factors. The immune-committed cells recognize antigens trapped in the peripheral lymphoid tissues and are then activated. Plasma cells produce antibodies (Abs) that serves as receptor for binding to antigenic determinants on pathogens to prevent or neutralize infection. Towards the other extremity, T cells recognize antigen displayed on the surface of antigen-presenting cells (APCs) via with the help of major histocompactibility complex (MHC) e.g., dendritic cells (DCs) and secrete cytokines which subsequently ensues in the differentiation of T helper (TH) cells and B lymphocytes (Konig and Zhou, 2004). The TH response involves the activation of macrophages and T-cells and also affects B cell differentiation in to plasma cells which secrete antibodies and therefore helps in humoral immunity (McHeyzer *et al.,* 2003). The TH response involves the activation of macrophages and T-cells and also affects B cell differentiation in to plasma cells which secrete antibodies and therefore helps in humoral immunity (McHeyzer *et al.,* 2003). TH cells after recognizing the antigen (Ag) proliferate and differentiate to specific lineages according to the local cytokine environment and differentiate either in TH1 or TH2 cells, each of which secrete specific cytokines. TH1 cells secrete interleukin (IL)-

2, interferon (IFN)-γ and tumour necrosis factor (TNF)-α which helps in the activation of cytotoxic lymphocytes (CTLs) whereas TH2 lymphocytes secrete IL-4, IL-5 and IL-10 which helps in activation of B cell response. IL-10 is one of the renowned immune-suppressant. So TH1 and TH2 cells work antagonistic to each other.

Immunomodulation is requisite when host defense mechanism has to be activated under the conditions of impaired immune response or when a selective immunosuppression is desired in conditions like autoimmune disorders. Immunomodulatory medicinal plants are relatively a modern concept in phytomedicine. Immunomodulation using medicinal plants can provide an alternative approach to conventional chemotherapy for a variety of diseases. The use of medicinal plant products as immunomodulators as possible therapeutic measure is becoming a new subject of scientific investigations (Sahu *et al.,* 2010). Immunomodulation is a process that alters the immune system of an organism by interfering with its function either by immunosuppression or immune-stimulation. Immunomodulaion is any change in immune response of body involving induction, expression, amplification, or suppression. An immunomodulator is an agent that helps to regulate immune system. Immuno-modulators are becoming very popular in the worldwide natural health care system.

The Immune System is the most complex biological systems in the body. At the time of infection immune system go under the attack of a large number of viruses, bacteria and fungi. The immune system is a part of body to detect the pathogen by using a specific receptor to produce immediately response by the activation of immune components cells, cytokines, chemokines and also release of inflammatory mediators. They modulate and potentiate the immune system. Immuno-stimulators are known to enhance body's resistance against a number of infections, allergies and cancers serving as immune potentiators in healthy persons and immunotherapeutic agents in case of persons with impaired immunity.

An immunosuppressant is an agent that causes suppression of immune system. Immuno-suppressants are mainly used to prevent the rejection of transplanted organs and tissues (e.g. bone marrow, heart, kidney, liver), to treat autoimmune diseases or diseases that are most likely of autoimmune origin (e.g. rheumatoid arthritis, multiple sclerosis, myasthenia gravis, systemic lupus erythematosus, Crohn's disease and ulcerative colitis), and can be used to treat other non-autoimmune inflammatory diseases (El-Hashim *et al.,* 2010). The majority of synthetic immunosuppressants act non-selectively. Allopathic immune-suppressive agents have side-effects, such as hypertension, dyslipidemia, hyperglycemia, peptic ulcers, liver and kidney injury. Also, prolonged use of allopathic immunosuppressants increases the risk of cancer (Gruber, 1996). At present, research in field of immunosuppressive herbs is in a stage of rapid growth and development. Herbs being used as immunosuppressive agents are known as antirejection herbs. They are as effective as allopathic drugs and have fewer side effects (Dorsher and Peng, 2007). Many herbs of Indian and Chinese traditional medicine origin are having immunosuppressive activity. Herbs of Indian traditional medicine having immunosuppressive activity include *Tylophoraindica, Hemidesmus-indicus Aphanamixis polystachya* etc. Herbs of Chinese traditional medicine having immuno-

Chinese traditional medicine having immuno-suppressive activity include *Tripterygium wilfordii*, *Artemisia annua*, *Rehmannia glutinosa*, *Saussurea medusa* etc. Pre-clinical studies indicate that herbs or their constituents have potential immunosuppressant activity.

METHODOLOGY

Sample preparation and experimental animals

For *in vivo* studies, *G. kurroo* root extract was dissolved in 1% (w/v) gum acacia and serially diluted with 1% gum acacia to obtain desired concentrations. Male Balb/C mice (*Mus musculus*) 810 weeks old, weighing 1822 g and grouped into five groups of six animals each were used for the study. The protocol for acute toxicity and *ex vivo* studies on immunomodulatory activity was approved by Institutional Animal Ethics Committee (IAEC) of Indian Institute of Integrative Medicine (CSIR), Canal Road Jammu (CPCSEA registration No. 67/ CPCSEA/99). The animals were bred and maintained under standard laboratory conditions: temperature (25±2°C) and a photoperiod of 12h fed with standard pellet diet and received water *ad libitum.*

General behaviour and acute toxicity test

Acute oral toxicity studies were carried out following OECD guidelines no. 423 after approval from the Institutional Animal Ethics Committee (IAEC). Graded doses of *G. kurroo* root extract up to 500 mg/Kg were separately administered to the animals in each of the groups. All the animals were having free access to food and water. The animals were observed individually after dosing at least once during the first 30 min and periodically during the first 24 h with special attention given during the first 4 h and daily thereafter for 14 days. At the same time general behavior and any toxic symptoms produced by the plant extract were observed for 14 days for routine pharmacological parameters such as convulsions, tremors, cyanosis, ataxia, body tone, muscle tone, pilo-erection, salivation, tail flick, drowsiness, alertness, spontaneity, diarrhoea, pupil size, ptosis, breathing rate, urination etc.

Immunization Schedule

SRBC (Sheep Red Blood Cells) collected in Alsever's solution, were washed three times in large volumes of pyrogen-free 0.9% normal saline and adjusted to a concentration of 5×10^9 cells/ml for immunization and challenge. The animals were divided into five groups of six animals each. Group I (control) received 1% gum acacia; Group II received β-methasone (BMS), a standard immunosuppressor (0.05 mg/Kg b.w); Group III received *G. kurroo* root extract (25 mg/Kg b.w); (Group IV) received *G. kurroo* root extract (50 mg/Kg b.w) and Group V received *G. kurroo* root extract (100 mg/Kg b.w). Extract was dissolved in 1% gum acacia and was administered orally for 14 days. The dose volume was 0.2 ml.

Anti-SRBC Antibody Titre

Mice were immunized by injecting 0.2 ml of 10% of fresh SRBC suspension intraperitoneally on day 0. Blood samples were collected in micro centrifuge tubes from individual animals by retro-orbital plexus on day 7 for primary antibody titre and day 14 for secondary antibody titre. Serum was separated and antibody levels were determined by the haemagglutination technique. Briefly, equal volumes of individual serum samples of each group were pooled. Two fold dilutions of pooled serum samples were made in 25µl volumes of normal saline in a micro titration plate to which were added 25µl of 1% suspension of SRBC in saline. After mixing, the plates were incubated at room temperature for 1h and examined for haemagglutination under the microscope. The reciprocal of the highest dilution of the test serum giving agglutination was taken as the antibody titre.

Delayed Type Hypersensitivity (DTH)

This method is based upon the ability of test drug to inhibit the edema produced in the hind paw of mice after injection of SRBC antigen (Doherty, 1981). *G. kurroo* root extract dissolved in 1% gum acacia was administered 2h after SRBC injection and once daily on consecutive days; six days later, the thickness of the left hind footpad was measured with a spheromicrometer (pitch, 0.01 mm) and was considered as the control. The mice were then challenged by injecting 20 µl of 5 × 10^9 SRBC/ml intradermally into the left hind footpad. The foot thickness was measured again after 24 and 48h (Bafna and Mishra, 2006).

Spleenocyte Proliferation Assay

Spleen collected under aseptic conditions in HBSS, was minced using a pair of scissors and passed through a fine steel mesh to obtain a homogeneous cell suspension and the erythrocytes were lysed with ammonium chloride (0.8% w/v). After centrifugation (380 × g at 4°C for 10 min), the pelleted cells were washed three times with PBS and resuspended in complete medium [RPMI 1640 supplemented with 12 mM HEPES (pH 7.1), 0.05 mM 2-mercapto ethanol, 100 IU/ml penicillin, 100 µg/ml streptomycin and 10% FCS]. The cell number was counted with a haemocytometer by the trypan blue dye exclusion technique (Wang *et al.,* 2002). Cell viability should exceed 95%. To evaluate the effect of plant extract on the proliferation of splenic lymphocytes, the spleen cell suspension (1 x 10^7 cell/ml) was pipetted into 96-well plates (200 µl/well) and cultured at 37 °C for 72 h in a humid saturated atmosphere containing 5% CO_2 in the presence of Con-A (5µg/ml) and LPS (10µg/ml). After 72 h, 20 µl of MTT solution (5mg/ ml) was added to each well and incubated for 4 h. The plates were centrifuged (1400 x g for 5 min) and the untransformed MTT was removed carefully. To each well, 100µl of a DMSO working solution (192µl DMSO with 8µl 1M HCl) was added and the absorbance was measured on ELISA reader at 570 nm after 15 min.

IL6 and TNF-α assay

Male Balb/C mice were given sodium thioglycolate media (Himedia) 1ml per mice. After 24 hours peritoneal macrophages were collected by injecting 10 ml of RPMI-1640 medium in peritoneal cavity. After 5 min, the medium was taken out and centrifuged (1800 × g at 4°C for 10 min). The cell pellets were re-suspended in RPMI 1640 medium. Macrophages (3 ×10^6) were seeded in 24-well culture plate in a CO_2 incubator for 3 hrs. At the end of incubation period, non-adherent cells were removed and plates were further incubated for 48 h in the presence of 1µg/ml LPS (Lipopolysacharide) for control BMS (β-methasone) with LPS for positive control and increasing dose of plant extract (25-100 µg/ml). The plates were cultured at 37°C and in a humid saturated atmosphere containing 5% CO_2 for 24 hours. After 24 hours of incubation supernatant was collected for determination of TNF-α and lL6. Pro-inflammatory cytokines (IL-6 and TNF-α) in macrophages stimulated with LPS and variable doses of plant extract were evaluated by ELISA assay using commercial kits.

Statistical Analysis

Data are expressed as mean ± S.D and statistical analysis was carried out using one-way ANOVA followed by Dunnett's test to analyze the different variables in the same subject and *Pvalne* less than 0.05 was taken as statistically significant.

RESULTS AND DISCUSSION

Modulation of immune response through stimulation or suppression to alleviate disease has been of great interest for long time. A handsome number of plants used in traditional system of medicines have been shown to stimulate or inhibit immune responses, with several active principles have been isolated and characterized from plants (Agarwal and Singh, 1999). *G. kurroo* extracts have not yet been investigated for immunomodulatory activity, so we carried the present study to identify clinically useful and safe products from medicinal plants that could modulate immune response and may have future in clinic. To scrutinize the possible immunomodulatory effect of *G. kurroo* root extract, a number of assays were performed in different immune response cells. Standard immune-suppressive drug Betam-ethasone (BMS) was used as positive control (0.05 mg/Kg, p.o). The preliminary experiments showed that *G.kurroo* root extract was found to induce significant immuno-suppressive effect. Further test models were used for determining the possible immunosuppressive activity against LPS induced macrophage activation and production of pro-inflammatory cytokines.

No undesirable effect on behaviour or mortality was observed by the administration of plant extract up to 500 mg/kg oral dose on animals. Male Balb/C mice challenged with SRBC antigen and fed with *G. kurroo* root extract, at all selected doses (25, 50 and 100 mg/kg b.w) produced significant (*$P<$ 0.05) and dose dependent decrease in both primary and secondary antibody formation compared with β-methasone, a standard immunosuppressant drug (Fig.1). The maximum inhibition in primary and secondary antibody formation was observed at the dose level of 100 mg/kg. Administration of β-methasone (0.05 mg/kg) resulted in a significant decrease in the humoral antibody titre compared with the control animals. The results clearly reveal that *G. kurroo* root extract is playing a role in humoral immunity. Antibody molecules, a product of B lymphocytes and plasma cells, are central to humoral immune responses; IgG and IgM are the major immunoglobulins which are involved in the complement activation, opsonization, neutralization of toxins, etc (Miller *et al.,* 1991).

Delayed type hypersensitivity (DTH) reaction is an expression of cell-mediated immunity (CMI) and plays a role in many inflammatory disorders. In the present study, male Balb/C mice were challenged with SRBC antigen into the sub-plantar side of left hind paw and were fed with different doses of *G. kurroo* root extract (25-100 mg/kg).The results clearly demonstrate that there was a dose dependent decrease in DTH response as evident by the decrease in footpad thickness at 24 and 48 hours (Fig. 2). Maximum decrease was observed at 200 mg/Kg body weight (*$P<0.05$). The DTH response, which is a direct correlate of cell mediated immunity (CMI), which involves effector mechanisms carried out by T lymphocytes and their products (lymphokines). CMI responses are critical to defenceagainst infectious organisms, infection of foreign grafts and tumour immunity (Miller *et al.,* 1991).

To corroborate the effect of *G.kurroo* root extract on the cellular immune response, the proliferation of spleenocytes in response to LPS and Con A was evaluated. *G. kurroo* root extract caused the dose dependent decrease in the proliferation of B and T cells. *G.kurroo* root extract exhibited a significant inhibition (*P<0.05) of LPS-induced B cell and Con-A induced T cell proliferation. Maximum inhibition was observed at the dose level of 100 mg/Kg (Fig.3). The results demonstrate that the plant extract is more effective against LPS induced B cell proliferation than Con-A induced T cell proliferation.

G.kurroo root extract has shown inhibition of LPS-induced pro-inflammatory cytokine (TNF-α and IL-6) production in peritoneal macrophages. Our results indicate that *G.kurroo* root extract inhibited TNF-α and IL-6 release in a dose-related manner. At a dose of 100 mg/Kg, inhibition in TNF-α (Fig. 4) and IL-6 (Fig.5) production was found to be the most significant. Lipopolysaccharide (LPS) is a group of bacterial endotoxins that causes polyclonal activation of B cells and stimulation of macrophages to produce the proinflammatory cytokines TNF-α and IL-6, which in turn are the principal initiators of the endotoxin shock syndrome (Akira and Takeda, 2004). LPS also induces strong stimulation of T cells under in vivo conditions. We observed a significant decrease inendotoxin-induced proinflammatory cytokines production.

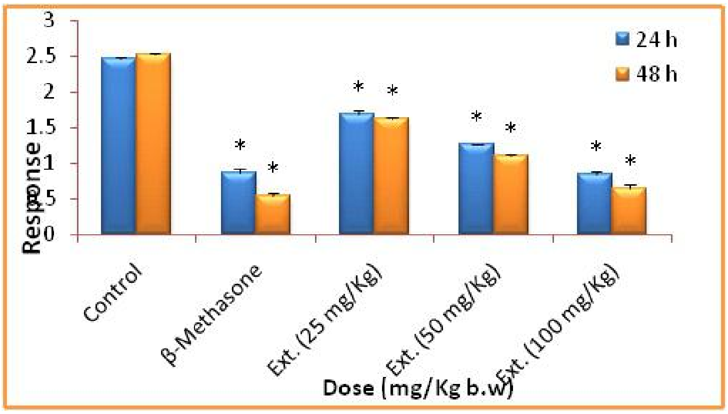

Fig.2 Effect of *G. kurroo* root extract on Delayed Type Hypersensitivity (DTH)

*Values are means ± S.D (n = 6). Data were analyzed by one-way ANOVA followed by Dunnett's test; *P < 0.05 (control vs. treated groups) was considered as statistically significant.*

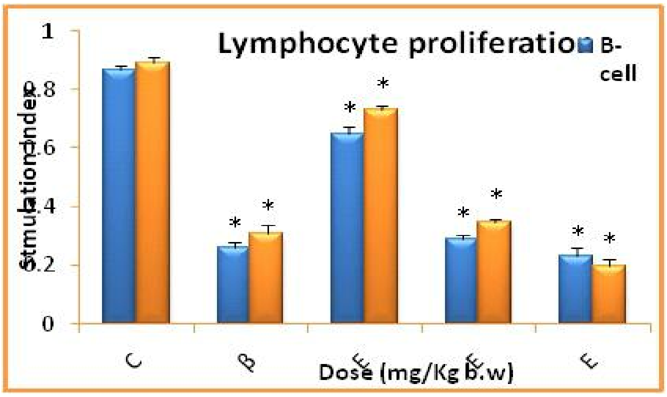

Fig.3 Effect of *G. kurroo* root extract on splenocyte proliferation
*Splenocytes were isolated and stimulated with LPS and Con A for B and T cell proliferation respectively. Data were analyzed by one-way ANOVA followed by Dunnett's test; *P < 0.05 (control vs. treated groups) was considered as statistically significant.*

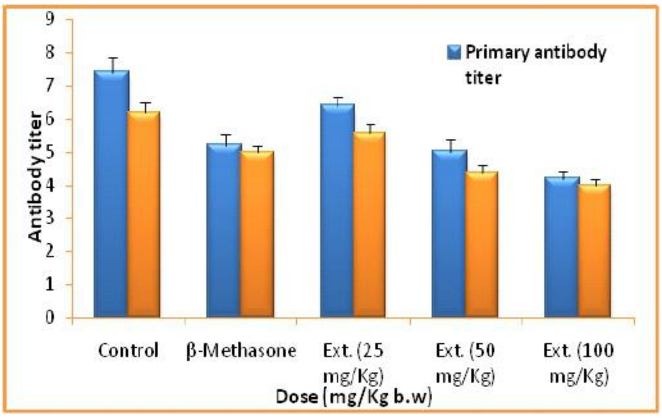

Fig.1 Represents the dose dependent decrease in antibody titre by methanolic root extract of *G. kurroo*
*Values are means ± S.D (n = 6). Data were analyzed by one-way ANOVA followed by Dunnett's test; *P < 0.05 (control vs. treated groups) was considered as statistically significant.*

LPS administration resulted in an acute elevation of TNF-α and IL-6 in plasma. TNF-α and IL6 was significantly reduced in mice pre-treated with *G. kurroo* root extract compared to LPS only. TNF-α plays a major role in regulating inflammation, mostly through the induction of inflammatory cytokines including

IL-1β, IL-6, macrophage inflammatory protein 2, granulocyte-macrophage colony-stimulating factor and various adhesion molecules (1b, 21b). Nuclear factor kappa B (NF-κB) has been shown to play an important role in regulating the expression of many genes involved in cell survival, immunity and in the inflammatory processes. NF-κB activation upregulates inducible nitric oxide synthatase leading to enhanced nitric oxide production as well

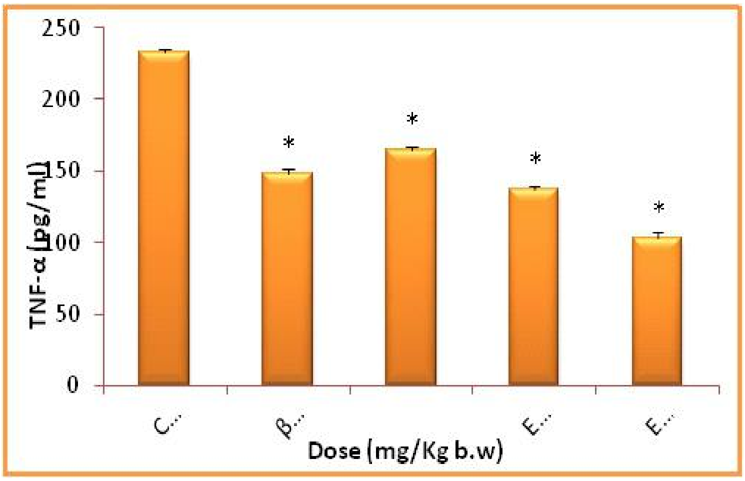

Fig.4 Represents the inhibitory effect of *G. kurroo* root extract on production of TNF-α in mouse peritoneal macrophages
*Data were analyzed by one-way ANOVA followed by Dunnett's test; *P < 0.05 (control vs. treated groups) was considered as statistically significant.*

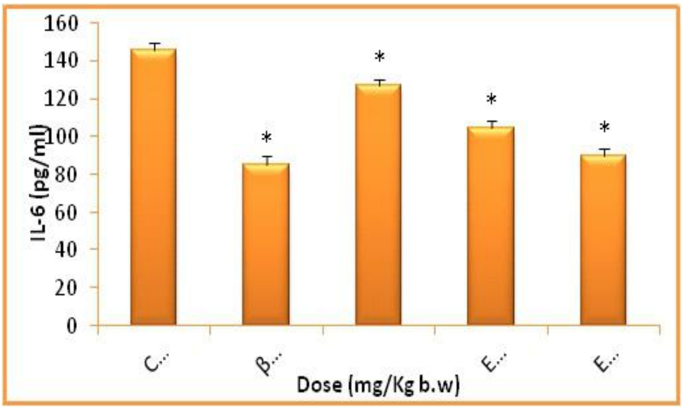

Fig.5 Represents the inhibitory effect *G. kurroo* root extract on IL-6 expression on mouse peritoneal macrophages
*Data were analyzed by one-way ANOVA followed by Dunnett's test; *P < 0.05 (control vs. treated groups) was considered as statistically significant.*

as increase in expression of TNF-α and IL-6 cytokine genes. Satnam *et al.,* 2012 have reported the immune-stimulatory action of extracts of *Gentiana olivieri*, a related species belonging to same genus gentian. However our study demonstrated that *G. kurroo* root extract possesses a potent immunosuppressive action. The inhibition of the humoral response against SRBCs in Balb/c mice by *G. kurroo* root extract was evidenced by the decrease in both primary and secondary antibody titre. Treatment with *G.kurroo* root extract inhibited the DTH reaction, as reflected by the decreased footpad thickness compared to the control group. We found that *G. kurroo* root extract inhibited LPS and Con-A induced spleenocyte proliferation, indicating its role in inhibiting T-cell activation. In further studies, *G. kurroo* root extract was found to interfere with macrophage activation induced with LPS. This finding indicates that *G. kurroo* root extract inhibits LPS induced macrophage activation by inhibiting the pro-inflammatory cytokines release.

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Determination of the Topographic Wetness Index for the Analysis of Spatial Wetness Patterns in the Immediate Catchment of Wular Using Geo-spatial Tools

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ABSTRACT

The spatial distribution of soil moisture and surface saturation within a watershed is mostly determined by topography-related geographical processes and hydrological models. The present study is aimed to use Topographic Wetness Index to determine the spatial distribution of soil moisture in the various sub-watersheds of Wular catchment on the basis of the topography. The Wular catchment in Kashmir Himalaya lies between 34^0 12 67 and 34^0 36 26 N latitude and its longitudinal extent is between 74^0 26 42 and 74^0 56 90 E. The altitudinal range of the study area is from 1570 meters near Wular Lake to 5148 meters above mean sea level. The sub-watersheds 1EE2a, 1EM1a and 1EE1b with low topographic wetness index have low water retention capability and are susceptible to soil erosion.

Key words: *Topographic Wetness Index; Watershed; Wular Catchment; GIS; ASTER*

INTRODUCTION

The topographic wetness index is assumed to control the soil wetness pattern (Wilson and Gallant, 2000). It is an important secondary topographic attribute for hydrological research. The topographic wetness index frequently used in approximately characterizing the spatial distribution of soil moisture and surface saturation within a watershed, has been widely applied in topography-related geographical processes and hydrological models. The topographic wetness index originally defined in TOPMODEL (Beven and Kirkby 1979) to approximate the spatial distribution of variable source areas (Quinn *et al.* 1995) and predict local variations in water table depths (Brasington and Richards 1998) within a watershed, has been widely used to study the effects of topography on hydrologic processes at a basin scale (Beven *et al.* 1984; Ambroise *et al.* 1996; Beven 1997). The TWI concept, owing to its simple but physically-based nature as well as its potential to couple with groundwater variability in time and space, has been implemented to several ecological atmosphere models and some topography-based land-surface process schemes used in regional climate models (RCMs) or global climate models (GCMs) (Famiglietti and Wood 1994; Stieglitz *et al.* 1997; Koster *et al.* 2000; Chen and Kumar 2001; Niu and Yang 2003; Niu *et al.* 2005). “Nowadays” TWI is normally regarded as one key index for modeling the topography-based geographical processes and hydrological cycle from catchment scale to regional or global scale. Sorensen et al, 2005 obtained the topographic wetness index, to quantify topographic control on hydrological processes for two separate boreal forest sites in northern. The spatial wetness pattern will provide us with a preliminary knowledge about the distribution and species richness based on the soil moisture patterns. It is extremely useful for drawing the broad contours for soil and water management in a sub-watershed.

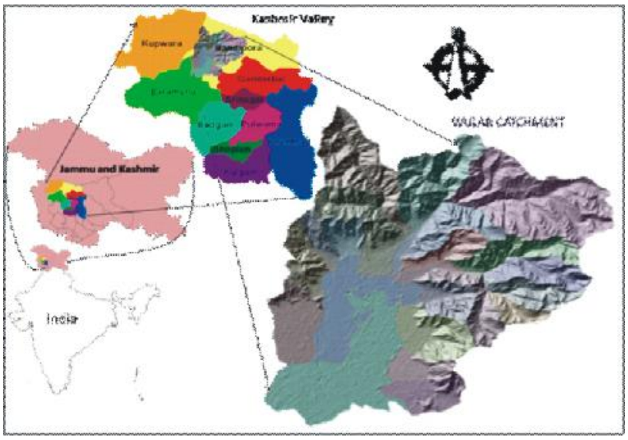
STUDY AREA

The study area falls in three districts of Jammu and

Kashmir namely Baramulla Bandipora and Ganderbal. The Wular catchment lies between 34⁰ 12'67" and 34⁰36' 26" N latitude and its longitudinal extent is between 74⁰ 26' 42" and 74⁰ 56' 90" E Fig 1.1. The altitudinal range of the study area is from 1570 meters near Wular Lake to 5148 meters above mean sea level in the Harmukh range. It has an area of 1200.36 km^2 and accounts for 7.6% of the total area of Kashmir valley.

In the present research work the study area has been divided in to nineteen watersheds, Wular Lake and an adjoining riparian zone Wular

Fig. 1.1: Location Map of Study Area.



Periphery on the basis of its proximity to the Wular Lake. The landscape is mountainous and rugged on the north-eastern side, while it is mostly plain on the south-south western side of the study area. The study area has got vast reserves of water in form of rivers, lakes, wetlands, springs, glaciers and sars. Apart from river Jhelum, the two important tributaries draining the catchment are Madhmatti and Erin. The world famous picturesque lakes namely Wular Lake and Manasbal Lake are located in the study area. The Wular catchment has got a high drainage density of the order of 2.41 km/km^2 (Kanth and Hassan 2012). The total population of the study area in 2011 is **389741** (Census of India 2011). The population density of the study area is 324.7 persons per km^2.

METHODOLOGY

The topographic wetness index relates upslope area as a measure of water flowing towards a certain point, to the local slope, which is a measure of subsurface lateral transmissivity (Beven and Kirkby, 1979). The database used to evaluate the Topographic Wetness Index parameters is the ASTER DEM. The raster calculator function of spatial analyst module of Arc GIS 9.3 has been used to run the functions for topographic wetness index.

TWI = log (*A*s /tan b) -**(Beven and Kirkby, 1979);**

Where *A*s is contour length, and tan b is the slope of the ground surface at the location

Arc GIS 9.3: Spatial Analyst -Raster Calculator

L("facc_dem" + 0.001) /

(("slope_dem" / 100) + 0.001))

This equation assumes steady-state conditions and describes the spatial distribution wetness indices and extent of zones of saturation (i.e., variable source areas) for runoff generation asa function of upslope contributing area, soil transmissivity, and slope gradient.

RESULTS AND DISCUSSION

The topographic wetness index is given in Fig 1.2, while as the watershed wise area under the various categories is given in "T" 1. The statistics have been depicted in Fig. 1.3 and Fig. 1.4. The topographic wetness index (TWI) has been divided into five categories.

Very Low

The topographic wetness index in this category ranges from -4.141 to 0.108. It covers the least area in the Wular catchment (7.23 km^2) covering only 0.60% of the total area. Almost all watersheds have a low percentage share in this category, the highest being in 1EE2b (1.78%) and lowest in 1EE1b (0.24%). This clearly indicates that absence of soil moisture is a rare case in the study area.

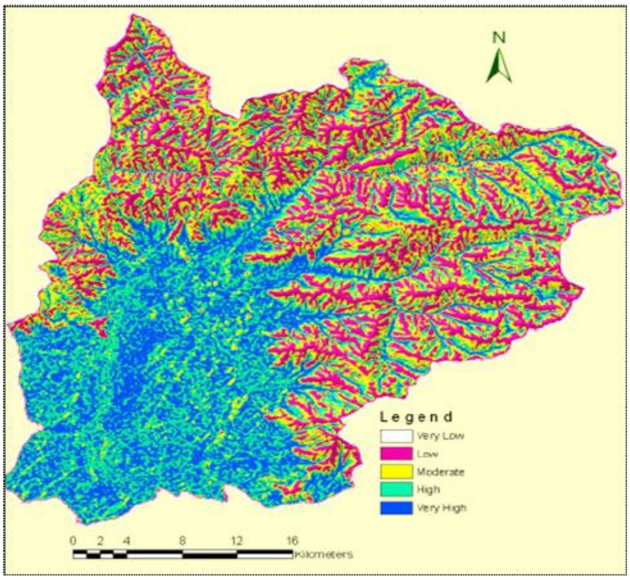
Low

This category has a significant percent share in the Wular catchment (24.44%) covering an area of 293.32 km^2. It ranges from 0.108000001 to 2.184 and exhibits a significant percentage contribution in many watersheds like 1EE2a (44.38%), 1EM1a (41.98%) and 1EE1b (40.13%) etc. These watersheds are characterized by low moisture content, mostly on steep slopes with barren and rocky surfaces.

Moderate

This category covers the second highest area in the Wular catchment (304.68 km^2) constituting 25.38% of the total. The topographic wetness index ranges from 2.184000001 to 3.221 in this category. The watersheds 1EW1b and 1EE2b are predominantly covered by moderate range of topographic wetness index with a percentage share of 42.80% and 38.98% respectively. The watersheds with high percentage share of moderate TWI have high moisture retain ability due to moderate slope gradients and good vegetal cover.

Fig. 1.2: Topographic Wetness Index - Wular Catchment



Source: Generated from DEM (ASTER)

Fig. 1.3: Watershed wise Proportion of Topographic Wetness Index in Wular Catchment

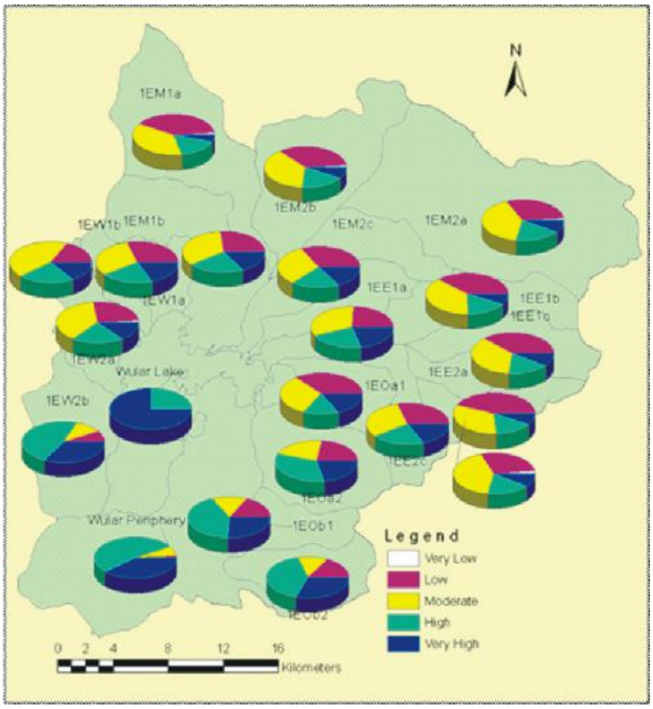
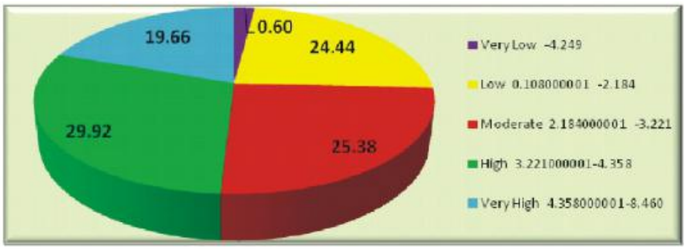


Fig. 1.4: Proportion of Topographic Wetness Index in Wular Catchment



High

The High category of topographic wetness index covers the highest area in the Wular Catchment (359.13km^2) with the percentage share of 29.92. The topographic wetness index in this category has a range of 3.221000001 to 4.358. The highest percentage share is by 1EW2b (47.04%). Wular Periphery and Wular Lake constituting the base level of the catchment have a percentage share of 51.83 and 45.58 respectively in the high category of TWI. This range of TWI is dominant in watersheds with moderate to gentle slopes and dense vegetation.

Table 1: Watershed wise Topographic Wetness Index in Wular Catchment

S. No.	Watershed Code	Very Low (-4.141-0.108)	Low (0.108000001 - 2.184)	Moderate (2.184000001 - 3.221)	High (3.221000001-4.358)	Very High (4.358000001-8.460)
1	1EW1a	-	7.5 (30.56)	6.6 (26.90)	6.25 (25.47)	4.19 (17.07)
2	1EW1b	0.1 (0.65)	2.49 (16.15)	6.6 (42.80)	4.2 (27.24)	2.03 (13.16)
3	1EW2a	0.51 (1.36)	9.74 (26.06)	12.99 (34.76)	9.55 (25.55)	4.58 (12.27)
4	1EW2b	0.23 (0.39)	3.77 (6.43)	6.56 (11.20)	27.56 (47.04)	20.47 (34.94)
5	1EM1a	1.13 (1.35)	35.26 (41.98)	30.43 (36.23)	14.06 (16.74)	3.11 (3.70)
6	1EM1b	0.2 (0.27)	19.59 (26.76)	22.94 (31.34)	19.43 (26.55)	11.04 (15.08)
7	1EM2a	1.75 (1.06)	53.74 (32.61)	61.88 (37.55)	35.17 (21.34)	12.24 (7.44)
8	1EM2b	0.9 (1.13)	29.98 (37.50)	27.69 (34.63)	15.85 (19.82)	5.54 (6.92)
9	1EM2c	(0.0)	18.68 (34.34)	14.75 (27.11)	13.15 (24.17)	7.82 (14.38)
10	1EE1a	-	7.28 (24.05)	9.45 (31.23)	7.4 (24.45)	6.13 (20.27)
11	1EE1b	0.11 (0.24)	18.42 (40.13)	16.02 (34.90)	8.52 (18.56)	2.84 (6.17)
12	1EE1c	0.37 (0.91)	15.97 (39.31)	13.46 (33.13)	7.62 (18.76)	3.2 (7.89)
13	1EE2a	0.32 (0.96)	14.85 (44.38)	10.41 (31.11)	5.61 (16.77)	2.27 (6.78)
14	1EE2b	0.32 (1.78)	5.48 (30.47)	7.01 (38.98)	3.69 (20.52)	1.48 (8.25)
15	1EE2c	0.24 (0.54)	13.45 (30.33)	12.16 (27.43)	11.15 (25.15)	7.34 (16.55)
16	1EOa1	-	13.13 (37.94)	9.52 (27.51)	6.65 (19.21)	5.31 (15.34)
17	1EOa2	0.21 (0.37)	12.18 (21.56)	13.69 (24.23)	18.85 (33.36)	11.58 (20.48)
18	1EOb1	0.1 (0.35)	4.23 (15.76)	4.89 (18.22)	10.72 (39.95)	6.9 (25.72)
19	1EOb2	0.24 (0.62)	5.58 (14.30)	6.07 (15.56)	15.1 (38.70)	12.03 (30.82)
20	Wular periphery	0.5 (0.32)	1.95 (1.23)	9.07 (5.74)	81.87 (51.83)	64.58 (40.88)
21	Wular Lake	-	0.06 (0.07)	2.49 (3.09)	36.73 (45.58)	41.31 (51.26)
22	Wular Catchment	7.23 (0.60)	293.32 (24.44)	304.68 (25.38)	359.13 (29.92)	236 (19.66)

Source: Computed from DEM (ASTER) {the figure in the parenthesis represents percentage share of area in the respective Watershed}

Very High

This category ranges from 4.358000001 to 8.460 and covers an area of 236 km^2 constituting 19.70% of the total Catchment. The watersheds which have predominantly gentle slope have highest soil wetness which include 1EW2b (34.94%), 1EOb2 (30.82%) etc. Wular Lake and Wular Periphery due their location in <1600 meters altitudinal zone contribute 51.26% and 40.88% respectively in the very high category of topographic wetness index.

Conclusion

The topographic wetness index has clearly indicated the dominant control of local topography on hydrological processes. The watersheds which have highest share in Low topographic wetness index are 1EE2a, 1EM1a and 1EE1b with a percentage share varying from 40 to 44 percent. These watersheds are characterized by low moisture content, mostly on steep slopes with barren and rocky surfaces. The watersheds which have predominantly gentle slope have highest soil wetness which include 1EW2b, 1EOb2 etc. The sub-watersheds with low TWI have low water retention capability and are susceptible to soil erosion. Thus, there is an urgent need to prioritize these sub-watersheds for soil and water management.

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Study on Different Fishing Methods (Gear & Craft) used in Manasbal Lake of Kashmir Himalaya

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ABSTRACT

The present investigation deals with the various fishing crafts and gears adopted for fishery in the Manasbal lake. The fishing craft and gears operated in the lake were simple tools used by local fishermen for commercial catches of fish production. The data were gathered through interview of fishers using a semi structured interview schedule, personal lake survey and study of gear & craft. During the present investigation one type craft and six types of gears were observed in the lake. The craft was plank built wooden boat, while the gears were Long line, Cast net, Narchoo, Scoop net, Gillnet, and Rod & Line. The fishers use indigenous materials and methods for construction, fabrication and maintenance of fishing gears and crafts. However, the operation of the gears in the lake varied during different seasons. Rod and Line netting was found seasonal and was operated during summer months (May to August). Narchoo was exclusively used during the winter months most probably due low depth and high transparency. Rod and line is mostly used during summer months. Gill nets were mostly used during the winter and spring months towards the outflow channel probably due to movement of fishes from the lake to River Jhelum and vice-versa.

Keywords: *Fishing gear, Fishing craft, Cast net, Narchoo, Long line, Manasbal Lake*

INTRODUCTION

The valley has the distinction of having the different natural water resource which includes the river Jhelum, the largest fresh water lake of Asia i.e., Wular Lake, Dal lake, Manasbal lake, Anchar lake and Nigeen lake etc. The Manasbal lake situated between districts of Ganderbal and Bandipora of Kashmir valley (Latitude $34^{0}15^{I}$ N and Longitude $74^{0}40^{I}$ E). The lake is encircled by three villages viz. Jarokabal, Kondabal and Sumbal and is stated to be the deepest lake (13 m or 43 ft depth) of Kashmir. The drainage basin for the lake, covering an area of 33 km^2 has no major inlet channels and is mainly fed by precipitation (rain and snow fall) and springs (more than 1200 springs). The lake water outflows to the Jhelum River through a regulated outflow channel. It has good potential resources for capture fisheries, Nadroo and extraction of grass and forms the life line for rural economy and environment of the area. Low-lying area is used for a variety of human activities including agriculture, horti-culture, and irrigation. It has a great recreational value and it also supports tourism. Despite being the deepest lake of the valley, it has suffered adversely due to excessive growth of weeds, pollution and encroachment. The Manasbal lake harbours a variety of fish species especially *Schizothorax* species (*Schizothorax niger*, *Schizothorax esocinus, Schizothorax curvifrons*), *Botia birdi, Triplophysa* sp. and exotic fishes like *Cyprinus carpio* var. *communis*, *C. C.* var. *specularis*, *Carassius carassius*, *Puntius conchonius*. The exotics contribute to a great extent to the total fish production in the lake as in other lakes of the Kashmir valley. However, the endemic species (Schizothoracids) are fast declining as these fishes cannot thrive well in polluted water and due to introduction of exotic carps (Bhat and Yousuf, 2004; Balkhi, 2007)

Fishing method means the manner in which the fishes are captured (Sreekrishna and Shenoy, 2001). Fishing gear is the implement used for capturing the fish. The knowledge of the fish behavior in relation to fishing gear has become one of the most important tools of modern gear development (Anon., 1999). The choice of material has become very important since it was found that efficiency of a gear could be increased many fold by using suitable materials like the synthetic yarn, in place of natural fibres (Ramaroa *et al.,* 2002; Thomas and Hridayanathan, 2006). The fishing technology is an integral part of the fishery science. Thus studies in fishing gears and methods provide the essential background for proper exploitation of fishery and for maintaining sustainability.

Capture fishery in lentic environment constitutes the single largest resource in the country, both in terms of resource size and productivity potential (Sagunan, 1995). These resources are distributed under divergent geoclimatic, morphometric and edaphic environment and fish production. The present low levels of production from Kashmir lake fishery is on account of many reasons such as low primary productivity of resources, slow growth rate of fish, inefficient fishing practices and inaccessibility of fishing sites, lack of fish seed stocking, poor landing and marketing channels, absence of closed season (Bhat *et al*., 2013; Qureshi *et al*., 2013). The information gathered in recent past indicated alarming downward swing in quality and average size of indigenous snow trouts, other carps and exotic trouts (Yousuf, 1996; Bhat, 2003).

However, the fishing methods operated in the Manasbal lake have never being documented. The present report is an attempt to document the various fishing craft and gears of the Manasbal lake. Keeping in view the documentary of the present study and qualitative nature of the data involved, exploratory survey research design was employed. Data were collected from the field by measuring, viewing and direct conversation with the fishermen. The respondents were contacted either at the fisheries cooperative society, home or at the landing centre. The materials used during the survey included measuring taps, measuring scales, one still camera, fish identification field book and drawing.

RESULTS AND DISCUSSION

Fishing Craft:

The one of the most important fishing equipment is Plank built boat. It is one and only fishing craft operated in Manasbal lake. A plank built boat is a wooden, non-motorised, manually operated boat. The wooden boat is locally manufactured commonly called as *"Naav".* The length of boat is about 7-11 meters and width ranges upto 2 meters (Figure 1, Table 1). The boats were painted inside by synthetic paints while outside they are coated with dammar for protection against water. The average age of plank boat is nearly 10 years.

Fishing Gears:

The following gears were recorded from the Manasbal lake during the present study;

1. Longline (*Waelraz*)

It is made of nylon line with length ranges between 300-500 m to which hooks are attached at regular intervals. Trash fish, maize flour mixed with candy or small fish are grinded and balls are prepared. These balls are used as bait. Long lines are set usually in the evening and the catches are collected in the morning next day. The line fishing is mainly done from May to August months in the lake.

2. Rod and Line

The Rod and Line is one of the oldest and famous methods of fishing all over the world. A metal hook is tied with one end of nylon thread and the other end of nylon thread is tied with a bamboo stick. Earth worm, fingerlings are tied to the hook as bait. The nylon rope with hook is placed into the lake for 1-2 hours. This is not a commercial fishing method and mostly the fish caught are consumed by the fishers of Manasbal Lake. It is a seasonal fishing and is operated in the months of May, June, July and August months. The reason for this kind of gear during summer months may be due to activeness of the fishes and their search for more food and therefore falling the prey of the gear.

3. Narchoo

It is traditional gear used for fishing in the lake (having a wooden pole to which double head spear or multi head spears are fixed at one end). This is shot at a fish at the time it is sighted and is used to capture bigger fishes in the shallow clear waters, where movement of the fish is seen (Figure 2). This type of fishing gear was mostly operated during November to January month most probably due to low depth and more visibility.

4. Cast net

The cast net is the main type of fishing gear used throughout the valley and is almost dominant gear used for lacustrine fishery and in the lake also. The cast net as the name implies, simply cast from a craft over the water surface. The cast net is a small meshed, nylon, conical net with a long line attached to the vertex. The circular open end is weighted with lead or iron. It requires considerable strength balance and skill to cast the net in such a way that it forms a flat circular shape just on reaching the water surface. As soon as the net touches the surface it sinks down fast because of the weights. Fish directly gets enclosed in the net. On hauling the net with the rope at the vertex, it closes onto the fish and their gills get entangled (Figure 3).

Depending upon the number of meshes the cast net is known by different names as mentioned below:

I. Guran jal (1200 meshes) used for small fish commonly called as guran.
II. Thapthal Jal (1100 meshes)
III. Daljal (1100 meshes)
IV. Naushoth Jal (900 meshes) name has been derived depending upon number of meshes.
V. Nuchkul Jal (800 meshes)
VI. Pouchkul jal (500 meshes)
VII. Arajal (400 meshes). This jal has derived its name from the water where it is used locally as 'Aras' which are small streams.

5. Scoop Net

The scoop net is very useful fishing equipment used in the Manasbal lake. This is a circular net having a long handle. This is mainly used from the boat or from bank of lake especially near outgoing canal of lake to catch mainly carps (Figure 3).

6. Gillnet

Gillnet locally called *Thani*, *Shaitan Zal* are 15-35 m long and 2-3 m width. Gillnets of different mesh sizes are used by the fishermen, the mesh size shows variations and depend upon the species to be targeted. It is operated during winter and summer months viz., January, February, March and April Months when water level in the lake is low and is fixed at the outflow channel of the lake. The fixing of this gear towards outflow seems mostly due to

April Months when water level in the lake is low and is fixed at the outflow channel of the lake. The fixing of this gear towards outflow seems mostly due to an increased current of the water and movement of fishes in and out of the lake. The simple gillnet is having floats at the head rope and lead sinkers at the bottom rope. Gillnet catches comprise less economic indigenous species and are of low magnitude but more suitable for carp fishery.

For increasing fishing efficiency in reservoirs and lakes, replacement of age old fishing crafts and gears by motorised ones is being employed now a days. Most of the fishermen of Manasbal lake are still using traditional fishing craft and gears which are outdated because of their inefficiencies. However, use of mechanised fishing methods is also disastrous for these fragile ecosystems mostly due to their small size, shallowness, low depth and dense population of macrophytes. In this consideration, certain suggestive measures and recommendations have been listed below for the proper management of the ecosystem and development of fishery in the lake Manasbal.

1. For increasing the fish catch and production from the lake, introduction of appropriate technologies, modernization or modification of existing gears/crafts or introduction of new ones need to be carried under scientific guidance.

2. To save ecology and environment in the lake and other water bodies, use of any chemical for capturing fish need to be banned.

3. Fishing during the breeding seasons of fishes especially Schizothoracids needs to be banned completely.

4. Training of fishermen for overall economic development through sustainable fishing is need of the hour.

Table 1: Description of Fishing Crafts operating in the Manasbal Lake

Detail	Average (Value)
Length (OAL)	9.2 ± 0.27
Breadth	0.71 ± 0.14
Depth	0.56 ± 0.01

Fig. 1: Measuring of Fishing Craft

Fig. 2: Narchoo

Fig.3: Cast Net

Fig. 4: Scoop net

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Trace Elements and Health in Mountain Ecosystem of North Kashmir Himalayas

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ABSTRACT

The present research work was an attempt to analyze the concentration of trace elements in soils and incidence of trace element related diseases in the mountain ecosystem of North Kashmir Himalayas. The study reveals that the soils of the study area have average concentration of iodine as 1.570mg/kg with a considerable negative mean deviation of -0.030 mg/kg from control samples. Average concentration of zinc was 2.886mg/Kg with a high negative mean deviation of -0.864 mg/Kg from control samples. Average concentration of zinc shows negative deviations in all altitudinal zones with declining trend with altitude. Average concentration of copper in the soils of the study area was 5.439 mg/Kg with a negative mean deviation of -1.354mg/Kg from control samples. Average concentration of copper although shows negative deviations of -0.760 mg/kg from control sample in altitude zone A and a positive deviation of +0.240 from control samples in altitudinal zone B but again decreases with altitude with a negative deviations of 2.205 mg/Kg in altitudinal zone C, - 2.349 mg/Kg in altitudinal zone D, -0.989 mg/Kg in altitudinal zone E and -3.123 mg/Kg in altitudinal zone F. Analysis of data obtained from health care facilities reveals that a considerable number of cases were suffering from various trace element diseases like thyroid (IDD), bone and nerve degeneration (Cu DD), skin lesion (Zn DD) and diabetes (Zn and Cu DD). The number of cases suffering from various trace element diseases were 13.16 percent male thyroid cases, 12.61 percent female thyroid cases, 12.02 and percent male and 11.67 percent female cases suffering from bone and nerve degeneration, 11.38 percent male and 10.43 percent females suffering from skin lesions and 14.52 percent male and 14.19 percent female suffering from diabetes with considerable variation among different altitudinal zones. Number of cases suffering from various trace element diseases especially thyroid and diabetes increases with altitude. An attempt has been made to identify the risk areas by using composite score method.

Key words: *Trace elements, Thyroid disorders, Bone and nerve degeneration, Skin lesion , Diabetes, North Kashmir Himalayas.*

INTRODUCTION

Trace elements are increasingly becoming recognized as vital to human health. Each trace element has a standard requirement adequate for human health recommended by W.H.O (Fishbein, 1986). All essential trace elements either in imbalance states (Warren, 1991) or in deficiency states (Pyle, 1979) are known to create serious health problems particularly in the areas where these are regionally deficit (Learmonth, 1988 and Akhtar, 1991). Diseases due to trace element deficiencies as well as excess are known for iodine, copper, zinc, selenium, molybdenum, manganese iron , calcium, arsenic and cadmium (Lindh, 2005) and radon (Warren, 1991). Endemicity of many chronic or mild disorders such as goiter, dental fluorosis (*Dissanayake,* 1990) cancers (Akhtar, 1998), skin disorders, etc. is quite prevalent across

India because of the variable concentrations of certain trace elements such as arsenic, fluoride, iodine, cerium, etc. (Dissanayake *et al.*, 2010).

The distribution of iodine is uneven in the biosphere. Both natural process such as leaching (Jeelani, 2010) , volcanism (Selinus *et al.,* 2007) and human activities such as mining and smelting (Keller, 1999) are responsible for redistribution of trace elements in the soils and water and organic environments (plants, animals and humans) through a network of pathways called as biogeochemical cycles (Furely and Newey, 1982). Its deficiency does not cause a mere enlargement of thyroid gland (endemic goiter), it can cause a variety of disorders called as iodine deficiency disorders (IDDs) or thyroid disorders consisting hypothyroidism, endemic cretinism, still-births, mental retardation, defects in vision, hearing and speech, and neuromuscular weakness. These disorders are mainly found in those people who live in mountainous areas, previously glaciated areas. Even people living in coastal areas and on islands suffer from IDDs because sea salt does not contain iodine content as much as required by the people and due to their unsuitable habits (UNICEF, 2002).

People living in hilly areas are more prone to thyroid disorders as iodine from the soil is washed away leaving behind iodine deficient soils which ultimately effects human as well as animal health (Akhtar, 1978). Near about 70 percent of the world populations living in mountainous soils are at risk of iodine deficiency with endemic goiter. W.H.O. estimated that about 20 to 60 % of the world's population is iodine deficient (Zimmermann *et al.,* 2009) with most of the burden in developing countries. In India about 41% of the population suffers from iodine deficiency and in the state of Jammu & Kashmir nearly 33% of the population suffers from iodine deficiency (Zargar *et al.,* 1996). According to a recent research conducted in 2013 on school children of Kulgam district, it was found that 18.9 % suffer from Total Goiter Rate (TGR); 21.2 % boys and 16.7 % girls (Khan *et al.,* 2014).

Study area

North Kashmir Himalayas is a part of Great Kashmir Himalayas and lies between 34°16”15”.09 34° 12'41.35” North Latitude and 74°48'00.00” 75°05'09.58” East Longitude. The mountainous range has an average altitude of 2324 meters and stretches over an area of 5110.60 sq. Kms. It is at a point near Zojila that Great Kashmir Himalayas takes a blend towards the south west and is described as the North Kashmir range . North Kashmir Range acts as a water divide between Jhelum in Kashmir valley and Kishanganga of Gurez valley. The area experiences temperate climate with an average annual rainfall of about 1,230 mm (Raza, *et al.,* 1978). Paleozoic sedimentary rocks, Triassic limestone, Karewa and Alluvium are the predominant geological formations of the area with limestone, shale, sandstone and unconsolidated sediments as the dominant lithology The soils of the concerned area vary in origin from alluvial to lacustrine and glacial.

MATERIAL AND METHODS

A comprehensive methodological framework has been adopted for the present research.

Data Base

The present research work is based mainly on primary data and partly on secondary sources of data. The primary data include the Survey of India toposheets on 1:50,000 scale of 1971 year, the data regarding concentration of essential trace element iodine in soils was obtained from analysis element iodine in soils was obtained from analysis of soil samples collected from 32 sample sites and 4 control samples. Data regarding the incidence of trace element related diseases was obtained from different health care facilities. Data regarding socio-economic aspects like the dependence of people on local foods, use of iodized salt, use and methods of purification of drinking water was obtained by conducting household survey through a well structures schedule/ Questionnaire. Secondary data were collected from government departments, reports, manuals, research articles, etc.). The Soil map of the area was taken from the Soil Map of Jammu and Kashmir prepared by Indian Council of Agricultural Research (ICAR), Nagpur-2010.

Methods used

The methodology has been divided into many steps based on the materials and techniques used and described under the following headings.

The area under study is fairly large characterized by large altitudinal variations; it was divided into seven altitudinal zones using SOI toposheets of 1:50000 scale (Table.1.1).

Selection of sample villages, sample households and sample sites

Stratified random sampling technique was used for selection of around 15% of sample villages (32) and 20% of sample households (4000) in proportion to total number of villages and households from each altitudinal zone. From each sample village soil sample site was selected from major agricultural field, (Table 1.2).

Table 1.1. Sample frame with altitudinal zones

Altitude Zone	Altitude (meters)	Area (Sq. Kms)	Revenue villages			Number of households				
			Total	Sample	Sample (% age)	Total households	Sample	Sample (% age)	Soil	Control Samples
A	1600-1750	499.18	32	4	12.5	3246	546	16.82	4	Soil = 4
B	1750- 1900	308.43	43	5	11.63	3422	678	19.81	5	
C	1900- 2050	269.87	51	8	15.68	5056	1026	20.3	8	
D	2050- 2200	286.23	42	6	14.28	3171	638	20.12	6	
E	2200- 2350	275.5	31	6	19.35	3534	782	22.13	6	
F	2350- 2500	293.19	18	3	16.67	1540	330	21.43	3	
G	2500-6000	3178.2								
Total		**5110.6**	**217**	**32**	**14.74**	**19989**	**4000**	**20.01**	**32**	**4**

Sample collection and sample codification

An intensive and multi-faceted field work was undertaken to collect the soil water and staple food both cereals and vegetable samples . One soil sample was collected from each sample village making a total of thirty two (32) and one soil sample was collected from 4 control sites of Bandipora, Ganderbal, Kupwara and Baramulla having high agricultural productivity, good crop health and good human health status to make standard for comparative analysis. Soil samples were collected in clean unused polythene bags and were labeled properly. Soil samples were taken only from surface soil (depth of 0-30 cm) for the reason that these soils are under the cultivation of paddy, vegetables and maize and this is the major zone of root development of crops (Brady, 1991). All the samples were properly packed, coded properly and reached to the lab for trace element-iodine, copper and zinc analysis.

Proper codification scheme was followed for identification of the samples.

Codes were used as:

Ist alphabet for Macro region

2nd alphabet for Geo chemical component (S= Soil)

3rd alphabet as simply S for sample in all components

4th alphabet as a numerical number of the village (1,2,3.4 etc.)

In case of control samples alphabet C for control is added.

Sample household survey

The socio-economic field survey of 4000 households was carried out through the structured schedules to study different Socio-economic aspects like dependence of people on local food items use of iodized salt and the methods of purification of drinking water. The data regarding the prevalence of trace element related diseases was obtained from different health care facilities.

Data analysis and map work

Data obtained from the analysis of soil from the RCRQA Laboratory, SKUAST-K and data obtained after tabulation of data from Questionnaire/ Schedule was statistically analyzed. Map work has been carried out under GIS environment.

RESULTS AND DISCUSSION

Concentration of Iodine, Copper and Zinc in Soils

The soils of the study area have average concentration of iodine as 1.570mg/kg with a considerable negative mean deviation of -0.030 mg/kg from control samples . The concentration decreases from an average concentration of 1.617 mg/kg in altitudinal zone A to an average concentration of 1.524 mg/kg in altitudinal zone F. Average concentration of iodine shows positive deviations of + 0.017 mg/kg from control sample in altitude zone A and decreases with altitude to a negative deviations of -0.038 in altitudinal zone B, 0.012 mg/kg in altitudinal zone C, - 0.054 mg/kg in altitudinal zone D, -0.082 mg/kg in altitudinal zone E and -0.076 mg/Kg in altitudinal zone F (Table 1.2 and Fig. 1.1). The reason could be that organic matter and pH influence the concentration of I in the soils because OM binds up I ions in the soil but the increasing slope and coarser texture cause I ions flow and translocate easily during rainfall. The study area being formed during Orogensis of Himalayas and subjected to tremendous transformation both by natural and human activities. Extensive water leaching of some acid arenaceous soils low in organic matter increases the magnitude of iodine losses and reduces the intrinsic availability of soil selenium and zinc. High soil acidity strongly potentiates crop uptake of almonium, iron and manganese (Mills, 1997).

Average concentration of Zinc in the soils of the study area was 2.886mg/Kg with a high negative mean deviation of -0.864 mg/Kg from control samples. The concentration decreases from an average concentration of 3.790 mg/Kg in altitudinal zone A to an average concentration of 1.160 mg/Kg in altitudinal zone F. Average concentration of zinc shows negative deviations in all altitudinal zones with declining trend with altitude. There was a positive deviations of +0.040 mg/kg from control sample in altitude zone A but decreases to a deviation of -0.513mg/kg from control samples in altitudinal zone B, -0.913mg/Kg in altitudinal zone C, - 1.010 mg/Kg in altitudinal zone D, - 0.196 mg/Kg in altitudinal zone E and - 2.590 mg/Kg in altitudinal zone F (Table 1.2). It is evident from the table 5.1 that the soils of the study area in all the elevations are deficient in Zn. The altitude zone A has high Zn content as compared to all other altitudinal zone because the former is characterized by relatively more total organic matter and favorable pH media than the latter. Since the soils at all the elevations are Zn deficit and the crops grown in these soils might be Zn deficient leading to its deficiency in human beings especially where people are more dependent on locally cultivated food items.

Average concentration of copper in the soils of the study area was 5.439 mg/Kg with a negative mean deviation of -1.354mg/Kg from control samples. The concentration decreases from an average concentration of 6.210 mg/Kg in altitudinal zone A to an average concentration of -3.847 mg/Kg in altitudinal zone F. Average concentration of copper although shows negative deviations of -0.760 mg/kg from control sample in altitude zone A and a positive deviation of +0.240 from control samples in altitudinal zone B but again decreases with altitude with a negative deviations of 2.205 mg/Kg in altitudinal zone C, - 2.349 mg/Kg in altitudinal zone D, -0.989 mg/Kg in altitudinal zone E and -3.123 mg/Kg in altitudinal zone F (Fig. 1.1).

The soils of the study area in all the altitudinal zones are deficient in Cu except zone B. The altitude zone B has high Cu content as compared to all other zones. The reason could be altitudinal variation of OM and pH in the soils Since the soils at all the elevations are Zn deficit and the crops grown in these soils might be Cu deficient leading to its deficiency in human beings especially where people are more dependent on locally cultivated food items.

Incidence of trace element related diseases.

Analysis of table 1.3 based on data obtained from nearest health care facilities reveals that a considerable number of cases are suffering from various trace element diseases like thyroid (IDD), bone and nerve degeneration (Cu DD), skin lesion (Zn DD) and diabetes (Zn and Cu DD).

The number of cases suffering from various trace element diseases were 13.16 percent male thyroid cases, 12.61 percent female thyroid cases, 12.02 and percent male and 11.67 percent female cases suffering from bone and nerve degeneration , 11.38 percent male and 10.43 percent females suffering from skin lesions and 14.52 percent male and 14.19 percent female suffering from diabetes, with considerable variation among different altitudinal zones (Table 1.3). Analysis of data reveals that number of cases suffering from various trace element diseases especially thyroid and diabetes increases with altitude and even number of cases attending health care facilities decreases with altitude.

Identification of high risk areas

Composite score method was used for identification of risk areas. Ranks were assigned according to order of magnitude of variables. In case of concentration of iodine, zinc and copper in soils. Ranks were assigned in increasing order from +deviation to deviation while as in case of dependency on local foods, use of non iodized salt, keeping salt box open lid and prevalence of trace element diseases like thyroid and diabetes were assigned ranks in increasing order of magnitude as 1, 2, 3 etc. In order to remove biasness of scale and with no weightage problem, deviation from mean and percentages of variables were given the ranks. Removal of tie was carried out by taking average of the ranks of the same values of different sample villages. All the ranks of various variables of each sample village were added together to get composite score for each sample village (Table 1.4). Sample villages along with altitudinal zone were then categorized into various categories of risk like very high, high, medium, low and very low (Table 1.5).

Table 1.2. Concentration of Iodine, Copper and Zinc in Soils.

Altitudinal Zone	Sample Village	Sample Site	Concentration of trace elements with deviation from the Mean of control sample * I (mg/kg)	Zn. (mg/kg)	Cu (mg/kg)	EC(mS)	pH	OM
A 1600-1750	Chatragul	GSS3	1.64 (+0.040)	2.73 (-1.020)	2.5 (-4.470)	1.4	7.38	1.5
	Ajas	BSS1	1.6 0	4 (+0.250)	4.3 (-2.670)	1.14	7.55	1.5
	Shirhama	KSS2	1.6 0	4.13 (+0.380)	8.78 (+1.810)	1.93	7.65	0.98
	Nadihu	BL SS4	1.63 (+0.030)	4.3 (+0.550)	9.27 (+2.300)	1.8	7.29	1.73
	Average	**-**	**1.617 (+0.017)**	**3.79 (+0.040)**	**6.21 (-0.760)**	**1.567**	**7.47**	**1.42**
B 1750-1900	Gund	GSS1	1.6 0	2.14 (-1.610)	5.85 (-1.120)	1.42	6.61	1.5
	Aragam	BSS2	1.64 (+0.040)	3.48 (-0.270)	5.6 (-1.370)	1.05	5.81	0.9
	Aloosa	BSS9	1.56 (-0.040)	2.73 (-1.020)	8.7 (+1.730)	7.5	6.99	0.75
	Shiltra	KSS7	1.5 (-0.100)	4.33 (+ 0.580)	10 (+3.030)	1.84	7.51	1.58
	Kalamabad	KSS4	1.51 (-0.090)	3.5 (-0.250)	5.9 (-1.070)	2.15	7	1.73
	Average	**-**	**1.562 (-0.038)**	**3.236 (-0.513)**	**7.21 (+0.240)**	**2.79**	**6.78**	**1.29**
C 1900-2050	Khanan	GSS4	1.6 0	2.2 (-1.550)	4.45 (-2.520)	1.39	6.82	1.65
	Arin	BSS5	1.65 (+0.050)	3.23 (-0.520)	4.23 (-2.740)	1.66	7.11	0.75
	Sumlar	BSS4	1.81 (+0.210)	3.46 (-0.290)	3.2 (-3.770)	3.6	7.32	1.58
	Haril	KSS6	1.56 (-0.040)	2.13 (-1.620)	5.45 -1.52	1.04	6.41	1.88
	Mawar	KSS11	1.48 (-0.120)	3.16 (-0.590)	4.45 (-2.520)	1.65	7.29	1.5
	Indedeji	KSS12	1.49 (-0.110)	3.2 (-0.550)	5.57 (-1.400)	2.2	6.83	1.58
	Potwari	KSS13	1.48 (-0.120)	2.95 (-0.800)	4 (-2.970)	3.5	6.54	1.05
	Wanpur	BLSS3	1.64 (+0.040)	2.37 (-1.380)	6.77 (-0.200)	5.98	7.13	1.13
	Average	**8**	**1.588 (-0.012)**	**2.837 (-0.913)**	**4.765 (-2.205)**	**2.63**	**6.93**	**1.39**
D 2050-2200			0	(-0.730)	(-2.030)			
	Malangam	BSS8	1.52 (-0.080)	3.02 (-0.730)	2.95 (-4.020)	12.6	7.46	0.75
	Waderbala	KSS5	1.57 (-0.030)	2.5 (-1.250)	4.6 (-2.370)	1.15	7.94	1.5
	Monbal	KSS9	1.51 (-0.090)	2.3 (-1.450)	4.77 (-2.200)	1.08	6.62	1.5
	Lache	KSS3	1.6 0	3 (-0.750)	3.3 (-3.670)	1.5	6.2	1.88
	Potus	BLSS1	1.48 (-0.120)	2.6 (-1.150)	7.17 (+0.200)	3.65	6.91	1.5
	Average	**6**	**1.546 (-0.054)**	**2.74 (-1.010)**	**4.621 (-2.349)**	**3.57**	**7.02**	**1.47**

E 2200-2350			(+0.180)	(-2.440)	(-1.470)			
	Waniarm	GSS6	1.71 (+0.110)	2.09 (-1.660)	3.6 (-3.370)	1.18	6.39	1.5
	Mukam	BSS7	1.45 (-0.060)	2.38 (-1.370)	5.4 (-1.570)	1.34	6.82	1.73
	Rishwari	KSS10	1.5 (-0.100)	2.95 (-0.800)	5.5 (-1.470)	1.4	6.77	0.9
	Kandi	KSS1	1.54 (-0.060)	3 (-0.750)	9 (+2.030)	3.24	7.46	1.73
	Walthur	BLSS2	1.66 (+0.060)	0.55 (-3.200)	6.89 (-0.080)	2.12	6.89	0.75
	Average	**6**	**1.518 (-0.082)**	**3.554 (-0.196)**	**5.981 (-0.989)**	**1.71**	**6.78**	**1.37**
F 2350-2500	Chont waliwar	GSS2	1.5 (-0.100)	0.1 (-3.650)	1.84 (-5.130)	2.3	7.85	1.65
	Kitsan	BSS6	1.55 (-0.050)	1.88 (-1.870)	4.8 (-2.170)	1.01	6.54	1.65
	Zachaldara	KSS8	1.52 (-0.080)	1.5 (-2.250)	4.9 (-2.070)	1.9	6.62	0.75
	Average	**3**	**1.524 (-0.076)**	**1.16 (-2.590)**	**3.847 (-3.123)**	**1.73**	**7**	**1.35**
G 2500 & Above	Uninhabited							
Total	**32**	**32**	**1.57 (-0.030)**	**2.886 (-0.864)**	**5.439 (-1.354)**	**2.33**	**6.99**	**1.38**

* Concentration of I, Zn and Cu in Control Soil Samples

Control Soil Sample	Con. of I (mg/kg)	Con. of Zn (mg/kg)	Con. of Cu. (mg/kg)	Ec (mS)	pH	OM
GCSS	1.550	2.810	4.400	1.10	6.86	1.73
BCSS	1.680	3.640	3.370	0.80	7.62	0.90
KCSS	1.680	4.150	9.500	1.11	7.57	1.13
BLCSS	1.490	4.420	10.630	0.80	7.34	1.05
Average	**1.600**	**3.750**	**6.970**	**0.95**	**7.34**	**1.20**

Source: Data obtained through analysis of soil samples in RCRQA Lab, SKUAST-2014

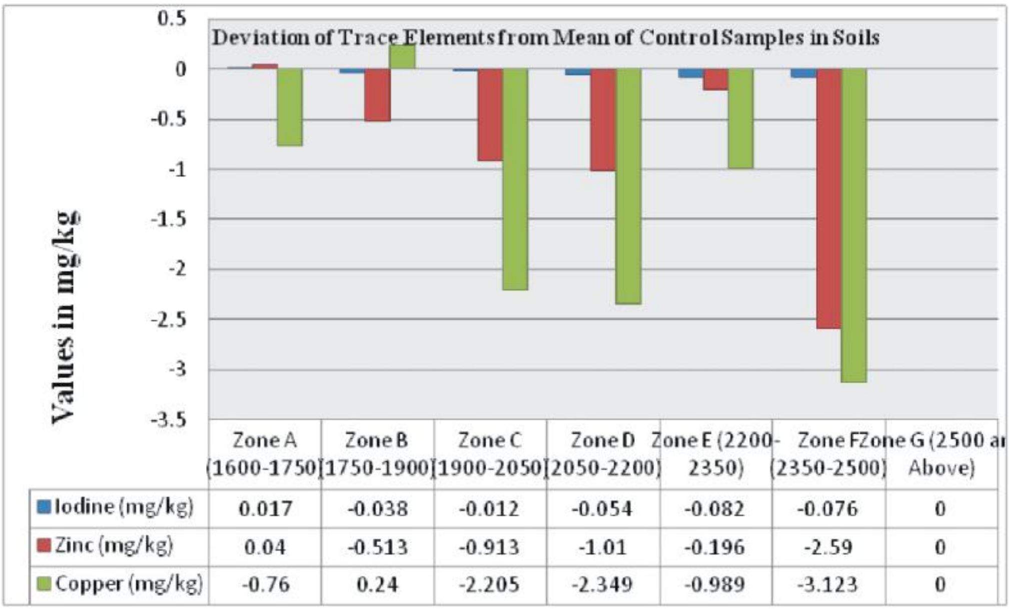

Fig. 1.1. Concentration of Iodine, Copper and Zinc in Soils

Table 1. 3. Incidence of trace element related diseases. (based on hospital record)

Altitudinal Zone. (Alt.in meters)	Sample villages	Total No of Cases	No of cases suffering from trace element diseases (% to total cases)							
			IDDs (Thyroid)		Cu DDs (Bone and nerve degeneration)		Zn DDs (Skin lesions)		Zn & Cu DDs (Diabetes)	
			Male	Female	Male	Female	Male	Female	Male	Female
Zone A (1600-1750)	4	384	48 (12.50)	41 (10.67)	54 (14.07)	45 (11.71)	47 (12.24)	45 (11.71)	51 (13.28)	53 (13.80)
Zone B (1750-1900)	5	444	56 (12.61)	54 (12.17)	57 (12.84)	52 (11.71)	51 (11.48)	53 (11.93)	60 (13.51)	61 (13.74)
Zone C (1900- 2050)	8	484	61 (12.60)	70 (14.46)	56 (11.57)	59 (12.19)	52 (10.74)	46 (9.50)	68 (14.04)	72 (14.88)
Zone D (2050-2200)	6	420	56 (13.33)	63 (15.00)	45 (10.71)	50 (11.91)	45 (10.71)	41 (9.76)	61 (14.52)	59 (14.05)
Zone E (2200-2350)	6	301	43 (14.28)	35 (11.62)	36 (11.96)	34 (11.29)	33 (11.28)	28 (9.30)	50 (16.62)	42 (13.96)
Zone F (2350-2500)	3	314	45 (14.33)	33 (10.51)	34 (10.82)	34 (10.83)	39 (12.42)	32 (10.20)	51 (16.24)	46 (14.65)
Zone G (2500&Above)	Uninhabited									
Total	**32**	**2347**	**309 (13.16)**	**296 (12.61)**	**282 (12.02)**	**274 (11.67)**	**267 (11.38)**	**245 (10.43)**	**341 (14.52)**	**333 (14.19)**

Source :- Based on data obtained from Health Care Facilities, 2013.
Note : - Figures in parenthesis represent % to total cases.

Table 1.4. Computation of composite score for identification of risk areas.

Sample Village	Conc. Of trace Elements in Soil			Dependency on local Food Products > 50 (percent)	Percentage of household using non-Iodized salt	Percentage of sample household (SHH) keeping lid of salt box open	Percentage of sample Population suffering Thyroid	Percentage of sample Population suffering Diabeties	Composite Score
	I (mg/kg)	Zn (mg/kg)	Cu (mg/kg)						
Chatragul	0.04 (7)	-0.020 (18)	-4.470 (3)	27.27 (3)	000 (7.5)	8.44 (1.5)	5.01 (5)	5.01 (7)	52
Ajas	0.00 (13.5)	+0.250 (4)	-2.670 (24)	30.00 (6)	0.00 (7.5)	8.44 (1.5)	5.34 (6.5)	5.59 (15)	78
Shirhama	0.00 (13.5)	+0.380 (3)	+1.810 (4)	25.50 (2)	0.00 (7.5)	21.57 (6)	6.22 (10)	6.36 (18)	64
Naidhu	0.030 (9)	+0.550 (2)	+2.300 (2)	21.43(1)	0.00 (7.5)	27.85 (12)	5.66 (8)	3.87 (3)	44.5
Gund	0.00 (13.5)	-1.610 (25)	-0.12 -10	31.66(9)	0.00 (7.5)	33.33 (15)	7.87 (18)	5.1 (9)	107
Aragam	0.040 (7)	-0.270 (6)	-1.370) (11)	39.39 (18)	0.00 (7.5)	30.30 (13)	3.64 (1)	4.2 (4)	67.5
Aloosa	(-0.040 (18.5)	-1.020 (17)	+1.730 (5)	29.19 (5)	0.00 (7.5)	34.78 (16)	4.70 (3)	7.11 (21)	93
Shiltra	(-0.100 (27)	+0.580) (1)	(+3.030) (1)	36.48 (14)	0.63 (15)	82.27 (32)	6.19 (9)	4.28 (6)	105

Qalmabad	(+0.02 (10)	(-0.250) (5)	(-1.070) (9)	32.08 (10)	0.95 (18)	22.64 (9)	11 (27)	10.28 (31)	119
Khanan	0.00 (13.5)	(-1.550) (24)	(-2.520) (22.5)	37.89 (16)	0.00 (7.5)	20.45 (5)	8.16 (19)	5.90 (17)	124.5
Arin	(+0.050 (5))	(-0.520) (8)	(-2.740) (25)	30.77 (7)	0.00 (7.5)	13.07 (3)	8.87 (21)	7.52 (22)	98.5
Sumlar	(+0.210 (1)	(-0.290) (7)	(-3.770) (28)	39.53 (19)	1.56 (22)	24.03 (10)	6.44 (13)	5.12 (10)	110
Haril	(-0.040) (18.5)	(-1.620) (26)	(-1.52) (15)	32.16 (11)	0.9 (17)	30.35 (14)	5.34 (6.5)	5.85 (16)	124
Mawar	(-0.120) (31.5)	(-0.590) (10)	(-2.520) (22.5)	31.06 (8)	0.00 (7.5)	72.72 (27)	6.97 (15)	5.02 (8)	129.5
Inderdeji	(-0.110) (29)	(-0.550) (9)	(-1.400) (12)	28.97 (4)	1.87 (24)	16.82 (4)	9.97 (26)	10.44 (32)	140
Potwari	(-0.120) (31.5)	(-0.800) (15.5)	(-2.970) (26)	42.2 (23)	0.00 (7.5)	24.67 (11)	9.57 (25)	5.56 (14)	153.5
Wanpur	(+0.040) (7)	(-1.380) (21)	(-0.200) (8)	40.77 (20)	0.00 (7.5)	52.3 (18)	3.74 (2)	5.49 (13)	96.5
Chitibandi	0.00 (13.5)	(-0.730) (11.5)	(-2.030) (17)	35.89 (13)	1.28 (19)	66.02 (23)	6.43 (11.5)	4.22 (5)	113.5
Malangam	(-0.080) (23)	(-0.730) (11.5)	(-4.020) (30)	41.44 (21)	1.32 (20.5)	22.37 (7.5)	4.88 (4)	3.71 (2)	119.5
Waderbala	(-0.030) (17)	(-1.250) (20)	(-2.370) (21)	45 (24)	3.75 (30)	53.75 (19)	9.01 (22)	9.01 (28)	181
Monbal	(-0.090) (25)	(-1.450) (23)	(-2.200) (20)	46.88 (26)	3.13 (28)	35.94 (17)	13.05 (32)	9.13 (29)	200
Lache	0.00 (13.5)	(-0.750) (13.5)	(-3.670) (29)	34.72 (12)	0.00 (7.5)	72.22 (25.5)	9.03 (23)	8.63 (27)	151
Potus	(-0.120) (31.5)	(-1.150) (19)	(+0.200) (6)	36.84 (15)	0.88 (16)	56.14 (20)	6.43 (11.5)	8.04 (23)	142
Wangat	(+0.180) (2)	(-2.440) (30)	(-1.470) (13.5)	38.89 (17)	2.78 (26)	72.22 (25.5)	7.02 (16)	3.25 (1)	131
Waniarm	(+0.110) (3)	(-1.660) (27)	(-3.370) (27)	53.12 (31)	0.00 (7.5	78.12 (28)	11.23 (28)	9.28 (30)	181.5
Quyalmukam	(-0.060) (21.5))	(-1.370) (22)	(-1.570) (16)	50.00 (29.5)	1.32 (20.5)	22.37 (7.5)	6.45 (14)	6.45 (19)	151
Rishwari	(-0.100) (27)	(-0.800) (15.5)	(-1.470) (13.5)	49.07 (28)	1.86 (23)	60.18 (21)	11.67 (29)	8.45 (25.5)	182.5
Kandi	(-0.060) (21.5)	(- 0.750) (13.5)	(+2.030) (3)	45.54 (25)	3.58 (29)	67.86 (24)	7.67 (17)	6.52 (20)	153
Walthur	(+0.060) (21.5)	(-3.200) (31)	(-0.080) (7)	47.17 (27)	1.89 (25)	80.19 (30)	9.13 (24)	5.37 (12)	177.5
Chontwaliwar	(-0.100) (27)	(-3.650) (32)	(-5.130) (32)	50.00 (29.5)	2.86 (27)	79.28 (29)	8.47 (20)	8 (24)	220.5
Kitsan	(-0.050) (20)	(-1.870) (28)	(-2.170) (19)	41.83 (22)	4.09 (31)	65.3 (22)	12.03 (30)	8.45 (25.5)	197.5
Zachaldara	(-0.080) (23.5)	(-2.250) (29)	(-2.070) (18)	61.96 (32)	5.43 (32)	81.52 (31)	12.14(31)	5.34 (11)	207.5

Source: Based on Sample survey, 2013. Figures in parenthesis represent the ranks.

Table 1.5. Classification of sample villages into various categories of risk

Composite Score	Category Of Risk	Altitudinal Zone A	Altitudinal Zone B	Altitudinal Zone C	Altitudinal Zone D	Altitudinal Zone E	Altitudinal Zone F	Altitudinal Zone G
50- 90	Very Low	Chatragul Ajas Naidu Shirhama	Aragam	-	-	-	-	
91- 130	Low		Aloosa Shiltra Gund Qalmabad	Arin, Mawar Sumlar, Haril Khanan Wanpur	Chitibandi Malangam	-	-	
131- 170	Medium	-		Inderdeji Potwari	Lache Potus	Wangat Quyalmukam Kandi	-	Uninhabited
171- 210	High	-	-		Waderbala Monabal	Waniarm Rishwari Walthur	Kitsan	
211- 250	Very High	-	-		-		Chontwaliwar Zachaldara	

Source: Based on sample survey, 2013

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Short Communication

Weed of Worry: Proliferation of *Parthenium hysterophorus* L. in Kashmir Valley

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ABSTRACT

The paper reports the increasing incidence and range expansion of *Parthenium hysterophorus* L. (congress grass) in the Kashmir valley, India. Taxonomic description of the plant species is supplemented with photographs and an ecological note, which may facilitate its easier field identification and implementation of an early warning and rapid response strategy to prevent this obnoxious weed from spreading across the valley.

Key words: *Range expansion, invasion, Parthenium hysterophorus L., Kashmir valley.*

INTRODUCTION

Parthenium hysterophorus L. (English name: congress or carrot grass), native to Central and South America, is an annual herbaceous weed of family Asteraceae which has spread rapidly across the globe since 1970s (Evans, 1997). It grows abundantly in a range of habitats such as wastelands, vacant lands, orchards, roadsides, floodplains, fields and pastures. Generally, drought and subsequent reduced vegetation cover creates ideal situation for establishment and colonization of *P. hysterophorus* (hereafter Parthenium) at a particular place. It is posing a serious threat to both natural and agricultural ecosystems across the world as it outcompetes the native species by its allelopathic effects, high seed producing capacity and lack of predators in the areas where it gets established (Belz *et al.,* 2007).

Parthenium is an aggressive colonizer and easily establishes and proliferates in quick progression at a given site thereby limiting the growth of native plants. A high proportion of people in Parthenium infested areas develop severe allergic reactions to the plant or its pollen; it can cause dermatitis, asthma and hay fever. Parthenium weed is toxic to cattle if consumed in large amounts by cattle; tainted beef or poor milk quality from livestock has been reported (Adkins and Shabbir, 2014). Parthenium weed can also cause indirect losses to crop production by acting as a secondary host to a number of important crop pests and diseases. These include economically important pests such as the common hairy caterpillar (*Diacrisia obliqua* Walk.) *Xanthomonas campestris* pv. *phaseoli* and tobacco streak virus (Adkins and Shabbir, 2014). The weed not only affects human health, livestock and crop production but it also adversely affects biodiversity of the infested areas (Belz *et al.,* 2007; Javaid and Riaz, 2012; Adkins and Shabbir, 2014). Parthenium has been reported to be a robustly allelopathic species and this trait is considered to be important in aiding both its invasion and persistence in an extensive range of native and non-native ecosystems (Javaid and Riaz, 2012; Adkins and Shabbir, 2014). Regions invaded by Parthenium are found to have significantly altered soil pH, nutrient content and plant species composition (Timsina *et al.,* 2011).

In India, Parthenium weed is believed to have entered from wheat imported from USA in mid 1950's and since then has spread to most of the regions of the country and is proving to be a great nuisance for the farmers (Navie *et al.,* 1996). It is essentially a weed of wastelands but it is rapidly spreading across urban and rural pockets drastically affecting the local biodiversity of the country.

In Kashmir Valley, it was first reported in 1988, as few individual plants growing near Residency Road Jhelum Bund, Srinagar (Yaqoob *et al.,* 1988) and thereafter there has been no report of Parthenium from the Kashmir valley. However, during recent floristic surveys in Srinagar city, the weed was found to be growing along the roadside of the newly constructed National Highway, in flowering phase in the first week of August 2014, near Lasjan bypass (N34°01′57.7′′ E074°49′ 45.0′′; 1629 metres amsl) and Bemina roadside (N34°06′21.7″ E074°45′ 18.8″;1601 metres amsl) in Srinagar city. Afterwards, the authors also found a large population of Parthenium in flowering phase in the mid-September 2015 growing on graveyard periphery adjacent to a roadside in Sopore (N34°.30′00″ E074°47′00″; 1598 metres amsl) (Fig.1).

Taxonomic description

Parthenium hysterophorus is an annual herb; 0.5-1.5 m in height; stems green, upright, profusely branched, longitudinally grooved, hirsute; leaves simple, alternate, conspicuously dissected, petioles upto 2cm long, abaxial and to a lesser extent adaxial surfaces of leaves covered with appressed hairs; flower-heads (capitula) arranged in terminal panicles at the tips of branches, capitula white or cream in colour having five ray florets and numerous white disc florets in the centre, surrounded by two rows of green involucral bracts; seeds, achene with pappus attached at the top for dispersal (Figure 1).

Ecological note

The weed was found growing in association with plant species, such as *Xanthium strumarium* L., *Cannabis sativa* L., *Trifolium repens* L., *Cynodon dactylon* (L.) Pers., *Amaranthus hybridus* L. and *Anthemis cotula* L. The target habitats of the establishment of the weed in all the observed sites during the present study were dry and disturbed roadsides which witness a continuous influx of trucks and other vehicles, carrying goods and passengers, from the rest of India into the valley.

DISCUSSION

Invasive alien plants are rapidly spreading into the new habitats around the globe and this has resulted in homogenization of the invaded habitats (Vitousek *et al.,* 1997). The invasive plants have higher population densities, greater performance in their introduced habitats than the native ones and often cause displacement of native plants (Blosey and Notzold, 1995; Bais *et al.,* 2003). The invasion by alien plants disturbs the structure and composition of the native vegetation to a considerable extent which in turn alters the food chain and web of the ecosystem (Pimentel *et al.,* 2000). Parthenium figures among the list of the most troublesome weeds of the world (Navie *et al.,* 1996) and creates havoc in the infested regions causing great loss in crop productivity and biodiversity (Dogra *et al.,* 2009).

Fig. 1. *Parthenium hysterophorus* L. (A) Habit (B) Inflorescence (C) Lasjan Bypass site (D) Bemina site (E) Sopore site (F) Uri site.

India has become one of the most affected countries, with Parthenium weed now occurring in almost all the states and posing a major problem in those states that have large areas of non-cropped, rain-fed land (Kumar *et al.,* 2008).

The low winter temperature has been found to inhibit the growth and seed production of Parthenium (Navie *et al.,* 1996) so the valley of Kashmir with its cool temperate climate with low winter temperatures was thought to be immune to this noxious invasive weed. Over the last decade, the valley has witnessed a manifold increase in tourist influx, trade and transportation, which probably facilitated the introduction of Parthenium at various sites in the region. Also with the shifting patterns of climate across the world, the valley seems to be increasingly becoming susceptible to the invasion by alien species, including Parthenium (Khuroo *et al.,* 2007). Further, CLIMEX modelling projection has shown the Himalayan biogeographic region to be climatically suitable for the growth of Parthenium, both under the present and a future projected increased temperature (Shrestha *et al.,* 2015). In this backdrop, if the weed is left unchecked and no measures are taken to control its spread, it will soon invade across the length and breadth of the valley, the way it has spread in rest of India, and damage not only crops but will also displace the native species and affect health of humans and livestock.

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