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# Prioritization of Micro Watersheds in Giri Catchment for Conservation and Planning

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## Origin of Research Problem

Since the last decade of 20th century (1990s), decentralised planning and implementation of natural resource management (NRM), along with the effective involvement and participation of local institutions and communities have been receiving importance and publicity (Ramakrishnanet al, 2002; Baumann and Farrington, 2003; Lele, 2004; Kumar, 2007 and Sivanna, 2009: 3). India with 328.72 million hectares of total geographic area (2.42% of global area) supported about 1.21 billion people (about 17.50% of world population) in 2011. In India, about 68% of people are dependent on agriculture, directly or indirectly (Census of India, 2011). Land and water resources are limited and their judicious utilization is imperative, especially in countries like India, where the population pressure is increasing continuously (FAO, 1985). With the growing population, the land-man ratio is decreasing making it essential to improve the productivity to meet the increased demand for basic necessities like food, fodder, fuel and fiber (Datta, 1995: 592).

Conservation of land and water resources has badly suffered in India particularly after independence (Shankar, 1999: 359). In India, the concept of 'priority watersheds' was developed in the 3rd plan period (1966-69) when the All Indian Soils and Land Use Survey (AISLUS) was restructured to include responsibility for integrated watershed management programmes (Shagufta, 2010: 4).

It has been observed that any particular micro watershed may get the top priority due to various reasons, but, often, the intensity of land degradation is taken as the basis. The assessment of the physical parameters of the land is possible by analyzing the slope, soil, geomorphology, land use and terrain parameters with the help of GIS. Das et al, (2012: 995) averred that criteria for watershed prioritization are subjective in nature and difficult to implement in ground reality due to various reasons. In their study, highest priority indicates maximum soil erosion in the specific mini watershed and confirms that it must be given maximum attention for soil conservation. Bewket and Teferi (2009) informed that Universal Soil Loss Equation (USLE) together with satellite remote sensing and geographical information system provide useful tool to estimate erosion hazard over watersheds and facilitate sustainable management at priority level. Katiyar and Garg (2006) have used weighted index on the basis of slope, vegetation, brightness etc. for the prioritization of watersheds. The index is intuitively appealing and is helpful in identifying areas where soil conservation measures need to be employed on a priority basis. Therefore, watershed prioritization is considered an important aspect of planning for implementation of its development and management programmes. Watershed management has assumed great importance in the mountainous region due to higher potential soil loss and reducing storage capacity of a number of reservoirs (Jha and Paudel, 2010: 97). Besides, there is a need to preserve the soil-water-vegetation ecosystem in micro-watersheds in harmony with resource exploitation and development programmes.

The large financial, administrative and skilled man power commitments involved in treating watersheds require a selective approach. Identification of smaller geo-hydrological units is therefore needed for more efficient and better targeted resource management programmes. This has created renewed interest in the creation of input database and their analysis to identify problem areas largely associated with relatively steep slope, less vegetal cover, poor land capability, high drainage density, higher potential soil loss, higher proportion of agricultural labourers, BPL households and scheduled caste population to take up conservation measures. These characteristics of different micro-watersheds show their association with the level of ecological health of the concerned geo-hydrological unit. Morphometric parameters coupled with integrated thematic information relating to land use, edaphic, land capability and selected socio-demographic characteristics support decision making process of resources management within micro-watershed. In fact, the information relating to these parameters and the priority classification of micro-watersheds help in taking up soil and vegetation conservation measures in a more scientific manner.

Despite the introduction and implementation of various watershed development schemes and other rural development programmes, the issue of watershed development, conservation and planning is at its infancy stage. Many studies on watershed prioritization using both traditional methods and modern inputs from geo-informatics have been conducted in various basins and catchments in India. However, a quality study on prioritization of Giri catchment (Fig.1) has not been conducted from a spatial perspective so far. Therefore, it raises an academic curiosity to conduct a comprehensive study on prioritization of micro-watersheds within Giri catchment.

## Objectives of study

1. To characterize the micro-watersheds on the basis of morphometric, physical, socio-demographic and RUSLE indices.
2. To prioritize the micro-watersheds on the basis of weight assigned to each indicator studied.

## Database and Methodology

The Giri catchment and its micro-watersheds have been delineated from the collected Survey of India toposheets at 1:50,000 scale. The drainage network has also been generated from these toposheets and further morphometric indices have been calculated and assessed the weight for prioritization for conservation and planning. The CARTOSAT DEM with 30m resolution has been used for relief, aspect and slope analysis. The study

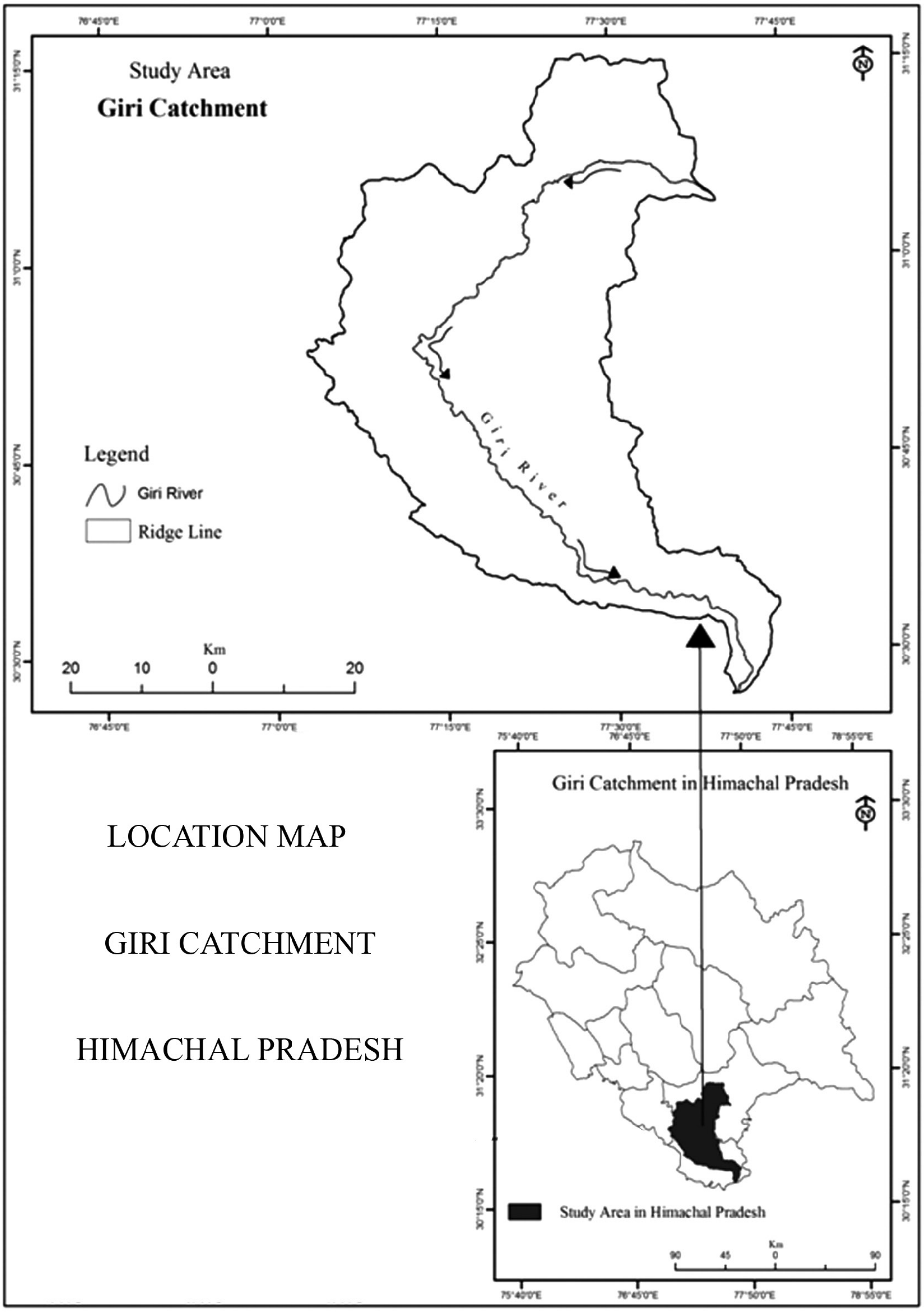

Study Area
Giri Catchment
Legend
Giri River
Ridge Line
Giri River
Km
20 10 0 20
Giri Catchment in Himachal Pradesh
LOCATION MAP
GIRI CATCHMENT
HIMACHAL PRADESH
Study Area in Himachal Pradesh
Km
90 45 0 90

Fig.1 :

Table 1 : Indicators and Their Prioritization Scheme

| **A. Morphometric Parameter** | **Formula** | **Weightage Criteria** |
|---|---|---|
| Stream Length (Ls) | Length of stream | Higher the Stream Length, More the Priority |
| Basin Length (Lb) | $Lb = 1.312 * A^{0.5}$ | Higher the Basin Length, More the Priority |
| Mean Stream Length (Lsm) | Lsm = Lu/Nu | Higher the Means Stream Length, More the Priority |
| Stream Frequency (Fs) | Fs = Nu/A | Higher the Stream Frequency, More the Priority |
| Mean Bifurcation Ratio (Rbm) | Rbm = Average of bifurcation ratio of all orders | Higher the Mean Bifurcation Ratio, More the Priority |
| Length of over Land flow (Lg) | Lg = 1/Dd*2 | Higher the Length of Over land Flow, More the Priority |
| Drainage Density (Dd) | Dd = Lu/A | Higher the Drainage Density, More the Priority |
| Form Factor (Fr) | $Fr = A/Lb^2$, where Fr = Form Factor | Less the Form Factor, More the Priority. |
| Circularity Ratio (Rc) | $Rc= 4\pi A/P^2$ | Less the Circularity Ratio, More the Priority |
| Average Weightage Slope (Aws) | Aws= (A1*ws1)+(A2*ws2)…. n/A1+A2…n | Higher the Weighted Slope, More the Priority |
| Elongation Ratio (Re) | $Re = (2/Lb)X(A/\pi)^{0.5}$ | Less the Elongation ratio, More the priority |
| Compactness Constant (Cc) | $Cc = 0.2821*P/A^{0.5}$ | Less the Compactness Coefficient, More the Priority |
| Basin Shape (Bs) | $Bs = Lb^2/A$ | Less the Basin Shape, More the Priority |
| Slope | Derived from DEM | Higher the Slope More the Priority |
| Description: A = Area of the Basin (km2) , Lb =basin length, Lu = The total stream length of order 'u', Nu = Total number of stream segments of order 'u', Nu+1 = number of segments of the next higher order, P = Perimeter, Aws= Area weighted Slope. A1 = Area of first slope class, A2 Area of second slope class, ws1= Weight assigned for 1st slope class. | | |
| **B. Socio-Demographic Parameters** | | |
| Percentage of BPL Families | Low, Medium and High | Higher the Percentage, More the Priority |
| Percentage of SC Population | Low, Medium and High | Higher the Percentage, More the Priority |
| Percentage of Agricultural Labourers | Low, Medium and High | Higher the Percentage, More the Priority |
| **C. Other Parameters** | | |
| Forest Cover | Less, Moderate and High | Less the Forest Cover, More the Priority |
| Pasture, Barren and Rocky Land | Less, Moderate and High | Higher the Pasture, Barren and Rocky Land, More the Priority |
| Agricultural Land | Less, Moderate and High | Lower the Agricultural Land, More the Priority |
| Land Capability | Class-1 to Class-VIII | Higher the Class, Less the Priority |

| | | |
|---|---|---|
| Soil Depth | Shallow, Medium Deep and Deep | More the Soil Depth, Less the Priority |
| Water Yield Capacity | Less, Moderate and High | More the Yield, Less the Priority |
| Rainfall | Less, Moderate and High | Higher the Rainfall More the Priority |
| Average Annual Soil Loss Potential | A = R.K.L.S.C.P | Higher the Average Annual Soil Loss Risk, More the Priority |
| Description: A = Average Annual Soil Loss Potential, R = Rainfall Erosivity, K = Soil Erodibility, L = Slope Length, S =Slope Steepness, C = Land Cover Management Factor, P = Conservation Practices Factors | | |

has utilized the remote sensing data (LISS IV-MX) for generation of land use / land cover information. Information regarding land capability, soil depth and water yield capacity has been generated from the published maps of National Bureau of Soil Survey and Land Use Planning Nagpur, 1997. Besides, socio-economic information relating to total population, total scheduled caste (SC) population, total households, total number of villages and number of agricultural labourers at village level have been gathered from District Census Handbook-2011, Directorate of Census Operations, Shimla. The data relating to below poverty line (BPL) households at the village level have been collected from the official website of Department of Rural Development, Himachal Pradesh, Shimla. The similar data which were not available for some villages on the official website have been procured under Right to Information Act – 2005 from offices of community development blocks of Shimla, Solan and Sirmour districts. The information regarding the existing watershed development plans in study area has been collected from the Department of Forests, Department of Agriculture, Department of Panchyati Raj, Himachal Pradesh, Shimla. The multi-temporal rainfall data have been collected from the Indian Meteorological Department, Pune, India. All the attributes studies at micro-watershed level has been portrayed in table 1.

The soil risk assessment in the study area has been computed using Revised Universal Soil Loss Equation (RUSLE) (Babu et al, 1978 and Singh et al, 1981; McCool et al, 1995; Thakur2012; Kumar and Kushwaha, 2013; Fathizad et al, 2014). Weightage criteria for the prioritization has also been worked out, computed and analysed. The micro-watershed prioritization scheme has been integrated with the compound score derived from the morphometric, physical, socio-economic and RUSLE parameters. The compound value is average of weighted rank of each indicator for every micro-watershed. In this study, three point scale of weightage ranking has been adopted. The higher weightage is given to those indicators which are largely responsible for land and water degradation in each micro-watershed. Therefore, lesser the compound value, more the priority in final prioritization scheme has been adopted in the present study. Based on compound score, micro-watersheds are classified into 5 categories i.e. very high priority (less than 2.00), high priority (2.00 – 2.10), medium priority (2.10 – 2.20), low priority (2.20 – 2.30) and very low priority where compound value is more than 2.30.

Table 2 : Giri Catchment: Comparative Representation of Priority Micro-Watersheds

| Priority Class *(Index Score) | Prioritization Scheme and Area Under Each Priority Class | | | | | |
|---|---|---|---|---|---|---|
| | *RUSLE Modeling (I) | | Non-RUSLE Parameters (II) | | Final Prioritization (I+II) | |
| | Micro-Watersheds | Area (sq km) | Micro-Watersheds | Area (sq km) | Micro-Watersheds | Area (sq km) |
| Very High (<2) | MW1, MW 5, MW6, MW7, MW8, MW11, MW13, MW14, MW20 and MW25 | 782.60 (29.56) | MW4, MW5, MW11, MW12, MW14, MW18, MW20, MW22, MW23, MW25 and MW26 | 1238.67 (46.79) | MW4, MW5, MW11, MW12, **MW13**, MW14, MW18, MW20, MW22, MW23, MW25 and MW26 | 1286.40 (48.59) |
| High (2.00–2.10) | MW12, MW19, MW26 and MW 27 | 397.65 (15.02) | MW2, MW 6, MW 7, MW10, **MW13**, MW 15, **MW16**, MW17, MW21 and MW 24 | 951.98 (35.96) | MW2, MW6, MW7, MW10, MW15, MW17, MW21, MW24 and MW27 | 928.71 (35.08) |
| Medium (2.10–2.20) | MW 2, MW 10 and MW 21 | 342.32 (12.93) | MW 1, MW3, MW 8 and MW 27 | 324.74 (12.27) | MW 1, MW 3, MW 8 and **MW 16** | 300.28 (11.34) |
| Low (2.20–2.30) | MW17 and MW22 | 229.27 (8.66) | MW9 | 63.49 (2.40) | MW 9 and **MW 19** | 131.67 (4.97) |
| Very Low (> 2.30) | MW3, MW4, MW9, MW15, MW16, MW18, MW23 and MW24 | 895.91 (33.84) | **MW 19** | 68.18 (2.58) | Nil | Nil |
| **Total** | **27** | **2647.49** | | **2647.49** | **27** | **2647.49** |

***Source: Based on Appendix II and III***
***Figures in parentheses show the percent to total area of catchment***
****The Index score is not applicable to RUSLE modeling priority scheme (I)***
***Note: The Micro-watersheds in Bold show the shift with the consideration of RUSLE***

## Characterization of Micro-watersheds

In the present study all the micro-watersheds have been characterized. A cursory look at the absolute relief reveals that the elevation in the Giri catchment varies from the lowest 400 m at Barotiwala (confluence of Giri and Yamuna rivers) to the highest 3620 m above mean sea level at Churdhar range. The study reveals that about 43% area of catchment falls in moderately low absolute relief (1000-1650m), followed by 34.43% in moderate category (1650-2300m). It has been investigated that nearly14% area falls in high category (2300-2950m) and less than 1% area falls under very high absolute relief category (more than 2950m). The average relative relief of the whole catchment is about 9.54 meters. The micro-watershed 15, which is situated in southwestern part of catchment registers the lowest relief (13-25 meter) and micro-watershed 6 located in middle east of catchment records the highest relative relief. The hill shade pattern reveals that valleys and peaks are more conspicuous in northern part of the study area. The slope analysis reveals that north, northeast, middle, middle east and south eastern parts of the catchment are largely under the very steep slope. The nearly level slope is found along the river beds of Giri, Ashini and Jalal rivers. The southern tip of the catchmentis characterized by very gentle slope (1-3% rise). Very steep slope (more than 30% rise) is the most dominant category in the study area. It is evident from the fact that except the southern tip (Paonta – Rampur Ghat region), all other parts are characterized by very steep slope. The study affirms that a large portion of the catchment characterized by very steep slope tends to pose serious threat of soil loss. The multi directional orientation of terrain makes surface runoff complex and less pronounced in this undulating topography. The Giri catchment forms large riverine and gullies at some places.

It is evident from the foregoing discussion that Giri catchment is characterized with about 72% area under forest cover which includes about one fourth dense forest and about 49% sparse forest. The central and north-eastern parts of catchment are endowed with dense forest. However, sparse forest cover is dotted over entire catchment except the area under non-agricultural uses and cultivated land. It is found that except micro-watershed 2, every micro-watershed has more than 50 % area under forest. The forest cover varies from the lowest 46.58% in micro-watershed 2 to the highest i.e. 91.37% in micro-watershed 13. The study indicates that about 13% area of total land is under cultivation in the Giri catchment. It has been observed that the agriculture is dominant activity in the north eastern part where people are largely engaged in horticultural activities. Agriculture is also common economic pursuit in the lower Giri river valley along the flood plain of Giri catchment. About 15 micro-watersheds located in central and central west parts of the study area have less than one-tenth of total area under agriculture. The share of agricultural land in 10-20% acreageconstitutes about 3% area of the Giri catchment.

It has been investigated that about 12% area is under permanent pastures, barren and rocky lands in the Giri catchment. The study reveals that only three micro-watersheds namely MW4, MW22 and MW24 have mere more than one-fifth area under permanent pasture, barren and rocky terrain. The MW22 and MW24 located in southern part have less pastures and more rocky and barren land cover because of prevailing mining activities. Eleven micro-watersheds have 10-20% area under pastures, barren and rocky terrain which together accounts about 48% area of catchment. The classification of land capability points out that there are only two land capability classes i.e. Class III constitutingabout 11% area and Class IV accounting about 57% area suitable for agricultural practices. Other land capability classes found in the study area are Class VI, VII and VIII which together account about one-third areaof the catchment and are not suitable for agriculture. Spatially, agriculturally suitable land capability classes (III and IV) occupy the lowest 8% area inMW18 and the highest (100%) in MW12, SW15 and MW26.

The information on soils depth reveals 3 categories namely deep, shallow and medium. The medium deep soils (50-100 meter) account about 60% area and deep soils (100 meter) account about 22% in the study area. The lowest share has been observed in shallow soils (up to 50 meterdeep) which constitute about 18%. It has been found that SW6, SW7, SW8, SW10, SW15 and MW16 located in northern part are rich in soil depth. The study reveals that about 73% area has medium availability of water (100-150 mm/m) in the soils while about 28% area has very low water availability (2 mm/m).

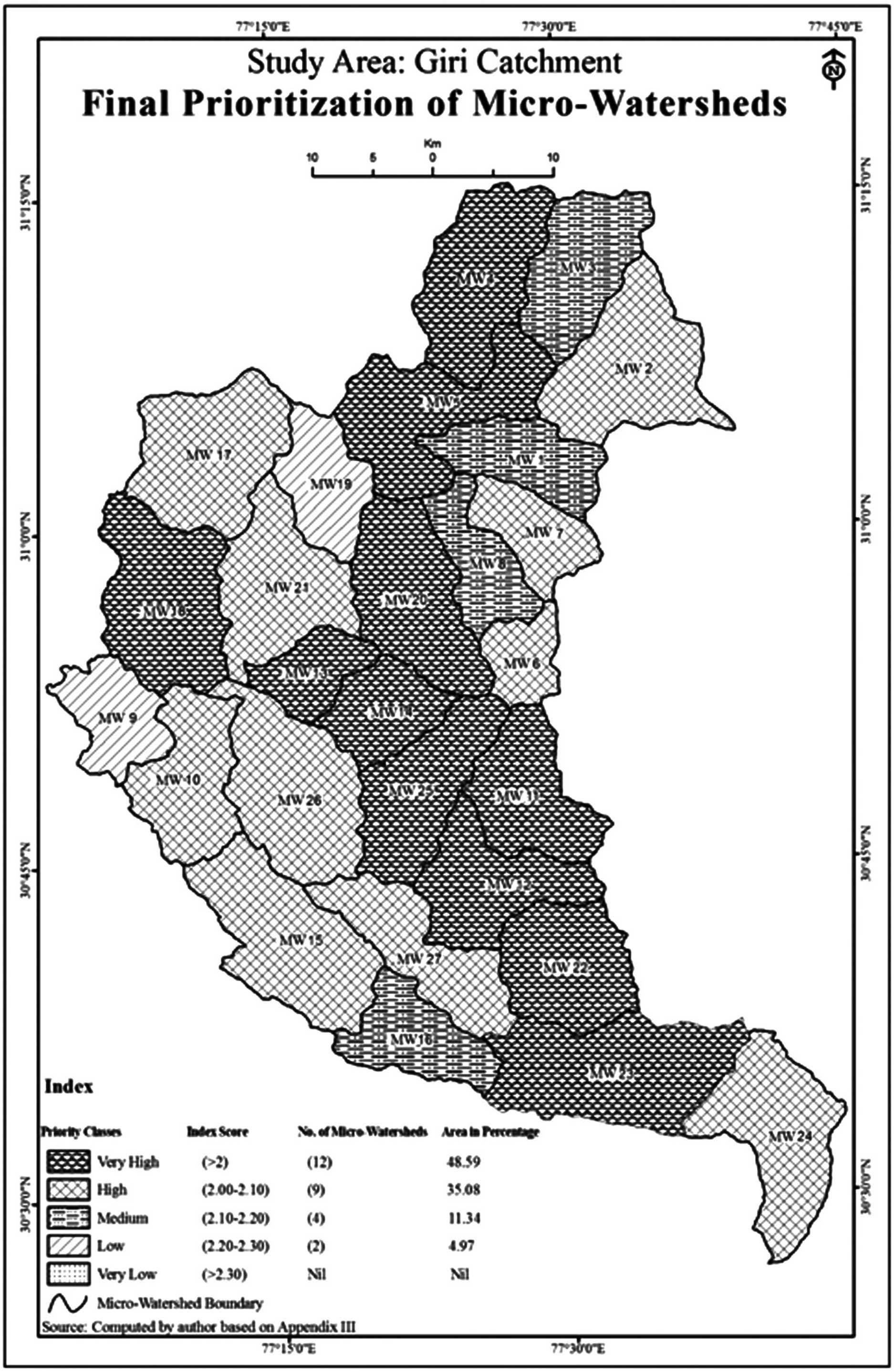
The selected demographic statistics of the Giri catchment reveal that there are about 1776 revenue villages. Out of these about one third are in Sirmour district. About half of the villages are found in Shimla district. Solan district both geographically and administratively comprises a small share in the Giri catchment. The study infers that about half of total villages are located in the northern part of the catchment and distributed over six micro-watersheds namely MW2, MW4, MW5, MW9, MW17 and MW18. The micro-watersheds having 50-100 villages situated in north-west of watershed account about one-fourth of total villages. The micro-watersheds covering less than 50 villages are located in south, southeast and middle-east parts of the catchment.

It has been observed that Giri catchment houses about 624146 persons which is about one tenth of total population of the state. The overall arithmetic population density of the Giri catchment is 236 persons per sq km. It is very high than the state average (123 persons per sq km) as per 2011 Census. The micro-watershed 17 has shown highest density i.e.1595 persons per sq km due to higher population pressure of Shimla city. Micro-watershed 6 has recorded the lowest (60 persons per sq km) density. It has been investigated that micro-watersheds with more than 200 persons per sq km are located in northern parts of catchment. The study reveals that north and northwest part of the Giri catchment is densely populated due to closely spaced large human settlements, dominance of agricultural and horticultural activities and urban based economic occupations. The study reveals that about one third population is scheduled caste (SC) in the study area.There are remarkable spatial variations in the concentration of SC population which varies from the highest (56%) in micro-watershed 22 to the lowest about one fifth of total population in micro-watershed 24. The micro-watersheds having more than 40% SC population are situated in the south and middle-west parts of the study area. This concentration is influenced by the prevailing social laws and landlessness of persons belonging to SC community.

The study brings out that there are about 2% agricultural labourers of total population in the study area. At micro-watershed level, their share varies from the negligible (0.23%) in MW27 to the highest about 7% of total population in MW2. The study infers that 4% households have been observed under below poverty line in the Giri catchment.

It is due to inaccessibility of villages in rugged terrain, historical background of families and existence of old social taboos. Even economic condition of the people has not improved up to expectation because the basic amenities provided to people are recent phenomena in the catchment.The study indicates uneven distribution of BPL households which varies from the negligible (0.61%) in MW9 to a little more than one-fifth in MW20. The highest share (>20%) of BPL households has been found in middle east whereas the central part of the catchment has witnessed 10-20% of total households under BPL category. The study reveals that micro-watersheds having the dense network of villages, large size of population, higher population density, higher proportion of scheduled caste population, agricultural labour force and BPL households call for careful consideration while working out the action plan for prioritization of Giri catchment.

The RUSLE utilized in this study reveals that average annual soil loss risk of the Giri catchment has been observed about 39.26 tons/ha/year. The study infers that about 15% area of the catchment is safe and lies within the permissible soil erosion limit i.e. less than 10 tons/ha/year. The medium average soil loss risk ranges between 10 to 25 tons/ha/year. It comprises about one third area of the catchment. High soil erodibility accounting about 25 to 50 tons/ha/year occupies about 22% area of the catchment. The very high soil erodibility ranges between 50 to 75 tons/ha/year. It constitutes about 8% area of the catchment largely sprawling over the high ridges of the north east and middle eastern parts of the catchment which also characterized with steep slopes and high relative relief. The very high soil loss risk zone shares boundary with extreme soil erodibility class (more than 75 tons/ha/year). The extreme soil loss risk category accounts a little more than one-fifth area of the catchment. The actual soil loss of the Giri catchment has been observed about 26.95 tons/ha/year, while simulated sediment yield computed with Revised Universal Soil Loss Equation (RUSLE) model has been estimated about 39.26 tons/ha/year. The soil loss risk is about 12 tons/ha/year higher than the actually recorded sediment yield data at the outlet of Giri catchment. The study reveals that there are only 5 micro-watersheds namely MW 9, MW 15, MW 16, MW 18 and MW 24 which have more than 30 % area within permissible limit (less than 10 tons/ha/year) of soil loss. Three micro-watersheds namely MW 3, MW 4 and MW 23 have 20-30% area within permissible soil erosion category. Five micro-watersheds namely MW 2, MW 10, MW 17, MW 21 and MW 22 have been observed very critical as these have about 80-90% area under soil loss risk. The remaining micro-watersheds have more than 90% area under soil loss risk. The micro-watershed 6 has been observed the most critical as it has only about 1% area under low soil loss category (less than 10 tons/ha/year) because it is also characterized with highest drainage density (4.19 km/sq km), highest stream frequency (8.74) and highest relative relief (61.37 m). The micro – watershed 9 has the highest area (36%) under low soil loss category. Briefly, it could be inferred that about 12 micro-watersheds which include MW 1, MW 5, MW 6, MW 7 MW 8, MW 12, MW 13, MW 14, MW 20, MW 25, MW 26 and MW



Study Area: Giri Catchment
Final Prioritization of Micro-Watersheds
77°15'0"E
77°30'0"E
77°45'0"E
31°15'0"N
31°0'0"N
30°45'0"N
30°30'0"N
Km
10 5 0 10
MW 2
MW 1
MW 17
MW19
MW 7
MW8
MW 21
MW20
MW18
MW 6
MW13
MW 9
MW 10
MW 26
MW25
MW 11
MW 12
MW 15
MW 27
MW 22
MW16
MW 23
MW 24
Index
Priority Classes
Index Score
No. of Micro-Watersheds
Area in Percentage
Very High (>2) (12) 48.59
High (2.00-2.10) (9) 35.08
Medium (2.10-2.20) (4) 11.34
Low (2.20-2.30) (2) 4.97
Very Low (>2.30) Nil Nil
Micro-Watershed Boundary
Source: Computed by author based on Appendix III

27 have about more than 90% area under beyond permissible limit of soil erosion. In the extreme soil loss category (more than 75 tons/ha/year), MW 8 has the highest (30%) area and MW 9 has the lowest (10.68%) area while there are 10 micro – watersheds which are experiencing more than 25% area under extreme soil loss risk.

**Prioritization of Micro-watersheds**

It has been observed that 12 micro-watersheds namely MW 4, MW 5, MW 11, MW 12, MW 13, MW 14, MW 18, MW 20, MW 22, MW 23, MW 25 and MW 26 have been identified more severe and critical and kept in very high priority category for implementation of watershed development and management programmes (Fig 2). It is evident from the study that these 12 micro-watersheds in very high priority class account about 48.59% area of catchment and are associated with large basin length, high stream frequency, high length of overland flow, large area under very steep slope, large population size and higher share of agricultural labourers. More than half of the area of these micro-watersheds has been observed under land capability class III and IV which are suitable for agriculture. Besides, these micro-watersheds are also characterized by low soil depth and poor availability of water in soils. Except the MW 18 and MW 23, each micro-watershed has more than 20% area under extreme (More than 75 tons/ha/year) soil loss risk category and about more than 90% area under beyond permissible soil erosion limit (More than 10 tons/ha/year). Thus, these micro-watersheds need necessarily introduction and implementation of watershed conservation and planning.

The nine micro-watersheds namely MW 2, MW 6, MW 7, MW 10, MW 15, MW 16, MW 17, MW 21 and MW 24 have been classified into high priority class and account about 35% area of the catchment (Fig. 4). These micro-watersheds are characterized by high basin length, length of overland flow and high area under very steep slope. Besides, large population size with higher share of SC population, sizable waste lands, low soil depth and higher amount of rainfall have been noticed other important factors responsible for receiving attention towards conservation plan of these highly prioritized micro-watersheds. The study further reveals that micro-watersheds namely MW 1, MW 3, MW 8 and MW 16 have been observed in medium category of catchment prioritization. In all, these micro-watersheds constitute about 11.34% of total catchment area. It has been investigated that eight characteristics namely stream frequency, size of SC population, area under agricultural land, area under land capability class III and IV, soil depth, water yield capacity, amount of rainfall and soil loss risk have shown moderate effect on the overall ecological health and soil loss response in these 4 micro-watersheds.

In the present study, low priority has been assigned to only two micro-watersheds namely MW 9 and MW 19. These micro-watersheds account about 5% area of the total catchment and characterized with comparatively low lying area, less area under very steep slope, low drainage density, low relative relief, less number of constituent revenue villages, less BPL households, comparatively small size of population, deep soils and large vegetal cover. A look at the processes reveals that these micro-watersheds are also associated with very steep slope and these have not been treated earlier under any watershed development schemes, so that planners and policy makers should deal with the comprehensive approach of natural resources management.

## Conservation and administrative measures

Based on the foregoing observations, following conservation and administrative measures may be suggested for treatment of micro-watersheds of Giri catchment.

The micro-watersheds having the characteristics of more length of overland flow, higher drainage density, high bifurcation ratio, high stream frequency, large area under very steep slope, high relative relief, low forest area, low agricultural land, shallow soil depth, low water yield availability along with demographic features inducing environmental problems can be overcome by agronomic, mechanical conservation measures and people – public participation initiatives. Considering the nature and type of parameter which could result into either boon or bane, an array of conservation measures and administrative initiatives have also been proposed.

The check dam structures arrest the overland flow and increase groundwater recharge, increase soil moisture and thus function as an important soil conservation measure. Sausage walls and gabion wall are made up of locally available stones woven in wire crates and needed to place across the flow direction to check the soil erosion. The narrow trenches built along contours especially in slopes up to 30% rise for collecting overland flow and increasing soil moisture are known as Gradoni. The catch water drains and runoff diversion sites are the manmade drains constructed along the contour lines for the collection and diversion of the flow of the streams. These help to check the runoff in peak periods and for utilizing the water during lean periods. The stream bank protection is needed to prevent bank erosion. It includes construction of spurs, wing walls, wire crates etc. Besides, contour terracing facilitates the proper drainage of the excess water in very steep slope area and reduces the runoff thereby minimizing the soil erosion. The packing is to be carried out along contours, combined with other activities. The hedging method not only solves conservation problems of shallow deep soil but also produces biomass and stabilizes the ground further by root system.

The 12 micro-watersheds namely MW4, MW5, MW11, MW12, MW13, MW14, MW18, MW20, MW22, MW23, MW25 and MW26 of very high priority class require check dams, sausage walls, gabion, gradoni, plantation along river beds, stream bank protection, contour terracing, contour trenching, stone packing, hedging, eco-development, governmental schemes of welfare, social forestry, environmental awareness, eco – friendly public participation programmes, ploughing, furrowing, farm forestry, organic fertilization, dams and irrigation, mechanization of agriculture and rainwater harvesting kinds of measures for the conservation and planning. The micro-watersheds MW2, MW6, MW7, MW10, MW15, MW17, MW21, MW24 and MW27 of high priority class need immediate attention in the form of check dams, sausage walls, gabion, gradoni, plantation along river beds, social forestry, fencing at the panchayat level, eco – friendly public participation programmes, ploughing, furrowing, farm forestry, organic fertilization, hedging and rainwater harvesting. The micro-watersheds of medium priority class namely MW 1, MW 3, MW 8 and MW 16 call for runoff diversion sites, stream bank protection, contour terracing, rainwater harvesting, recharge through pits and wells, afforestation, harvesting structures, fencing and soil enrichment kinds of conservation measures. Few conservation measures namely check dams, runoff diversion dams, social forestry and hedging have also been suggested for micro-watersheds of low priority class.

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