Evaluation of land denudation and Rivulets water quality in the Gomti Basin of Indian Central Himalayas-A case study

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Abstract: *A study was conducted to estimate the rate of solid and dissolved mass denudation from six prominent landuse systems of Bhetagad micro watershed, Gomti basin of Indian Central Himalaya. An investigation was also conducted to assess the seasonal variation in water quality parameters such as TSS, TDS, pH, EC, DO,* NO_3^- PO_4^{3-} *and E .Coli influenced by rainwater in the four sub-catchments of Gomti basin i.e. Bhetagad, Garurganga, Gomti and Ghanghali. The rate of land denudation for prominent landuse systems of the Bhetagad micro watershed was estimated during the period April 15, 2002 to August 31, 2002 (16 rain events), while water quality monitoring was done for four selected rivulets of the Gomti basin same rain events and period. The results revealed that rate of soil loss from prominent landuse systems influenced to the soil chemical constituents dynamics of the different land uses and simultaneously altering the water quality parameters of the all rivulets water. Results exhibited that the concentration of suspended solids, nitrate ion and phosphate ion were found higher compared to permissible limits as recommended by WHO (1993). However the dissolved oxygen concentration was found less than permissible limit. Study indicated that the there was an urgent need for an appropriate surface water and land resources management plan in the study area.*

Key words: *Water quality, Rivulet, Land use, Chemical denudation and Indian central Himalayas*

INTRODUCTION

Land denudation of different landuse systems and water quality assessment in the Indian central Himalayas is considered to be severe problems for watershed management programs. These problems are results of human encroachment in the catchment area. In the rainfed zone of Indian central Himalayas the river and rivulets are the main sources of drinking water, originated from forest and fed by ground water and rainwater. The reports of news dailies and the findings (Bartarya, 1993; Joshi 2001 & Joshi and Kothyari 2003) a high drinking water scarcity is experienced in the peak of summer and monsoon season. With modernization and rapid population growth in the water catchment area brings tremendous changes in the land denudation, water quality parameters and water quantity as well.

However, the knowledge on the rate of chemical denudation and its adverse effects in the water quality was limited from this zone. Since past few decades, much attention has been given to estimate the soil erosion losses and contamination in drinking water in the Indian central Himalayan region as results of land denudation and health hazards. A much contemporary work has been done for estimating the erosional losses (Pandey et al. 1983; Rawat and Rawat 1994 and Sharma et al. 2000) and for assessing the surface water quality in the region (Bhatt and Pathak 1992; Bartarya, 1993; Joshi 2001). The present investigation deal to estimate the rate of land denudation from six prominent land landuse systems i.e. pine forest, tea plantation, agriculture land, pasture land, grazed land and bare land from Bhetagad watershed of the Gomti basin. This study was also designed for know the seasonal variation in water quality parameters of the rivulet waters of Gomti basin.

MATERIALS AND METHODS

Study area

The present study was carried out in the rivulets of the Gomti basin, located in between 29^0 4' to 30^0 02' N and 79^0 28' to 79^0 47'E and encompassing a geographical area of 362.8 km^2 in Indian Central Himalayas (Fig.1). Geologically

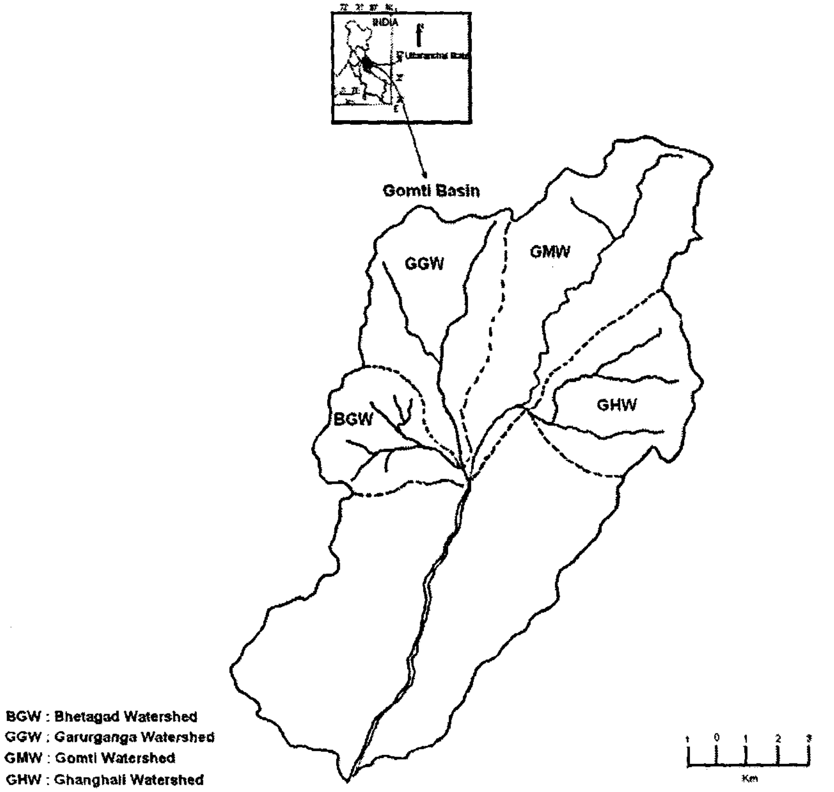

Figure 1. Map of sub-catchments of Gomti basin, Indian central Himalayas

the study area consists of Almora crystalline. Berinag crystalline, Schist gneisses, peg mattes, granite, and quartzites represent the Almora crystalline ambhibolites and marbles. The Berinag crystalline is entirely covered with Berinag quartzites. The Gomti basin having many tributaries out of which Gomtinala, Ghanghali, Garurganga and Bhetagad have been selected for the water quality study, the details of catchments landuse distribution presented in Table 1. The rivulets originated from tope forest and passes through the settlements and agriculture land and the high land of the study area dominated with pine forest. The rural communities have exploited the forest at great extent for fuel wood, timber and leaf litter. The watershed had a warm temperate climate with distinct different seasons viz, spring, summer, monsoon, autumn and winter. Meteorological data (calendar year 2002) showed that the area had a mean annual maximum temperature in June (37^0 C) and minimum in January (2^0 C).

Table 1. The sub-catchments details of Gomti basin, Indian Central Himalayas

Name of catchment	Bhetagad watershed	Garurganga watershed	Gomtinala watershed	Ghanghali watershed
Total geographical Area (km^2)	22.28	62.53	78.57	42.55
Total inhabitants (Census 1991)	6287	10710	7922	11150
Forest Land (%)	67.73	54.6	65.02	69
Rainfed Agriculture Land (%)	20.54	12.79	8.12	22.82
Irrigated Land (%)	2.03	4.34	0.92	3.4
Tea Plantation (%)	2.90	1.61	2.40	0.6
Pasture Land (%)	1.44	7.20	7.89	0.42
Grazed Land (%)	0.72	7.95	4.48	0.33
Others (%)	4.64	11.51	11.17	3.43

The land denudation was estimated from six prominent landuse systems was made by collecting the rainfall data, overland flow, total suspended and dissolved losses for each rain events from period 15th April to 31st August 2002. Rainfall data for the study period was collected with help of tipping buckets (Simon's Rain gauge British type), which were installed in close vicinity to each erosion plot (having least count 0.2mm). Readings were taken at 8.30 am (IST) an interval of 24 hrs for the study period.

Species richness was analysed by counting the number of plant species by using 50cm x 50 cm cord in each study plot. Vegetal cover related measurements, plant density, basal area and crown canopy area were analysed by methods described by Mishara, (1968). Ten quadrates of size (50cm x 50 cm), for grasses/herbs and 10mx10 m for trees were laid at each site, including respective erosion plots. For erosion studies plot of 20m x 5 m = 100 m^2 size were laid at each site enclosed with a 50 cm high metal sheet, which was, inserted 20 cm vertically into ground 30 cm of area was allowed to remain the soil surface. Surface runoff from each plot was collected in tanks through a gutter and a 7-slot multi slot devisor. Runoff was first collected in 1st tank, and then into a second tank, between the two tanks the 7-slot multi slot devisor was provided. Therefore, in the second tank 1/7th of the total overflow of the first tank was collected. Water quality samples were collected from both the tanks. Concentration of the suspended materials were determined by filtration methods (Heron, 1990 and Hudsun, 1993) using Whatman No.1 (pore size 1.2 μm). Samples were dried at 105^0 C and converted into sediment yield in t/ha. The total dissolved solids concentrations were determined by using Bio aid and Kit. The conservation values for water, suspended solids and dissolved solids were calculated by using the solids were estimated methods Ambasht et al. (1984). The analysis of the parent soil and suspended particles was done following the standard methods of Jackson (1973) and Allen (1989). However the determination of the rivulets water quality, samples of the four major rivulets waters were collected from Kandhar in Gomtinala, Dangoli in Ghanghli, at Devnie in Garurganga and Lohri talli in the Bhetagad from 15th April –14th June and 1st July to 31st of August 2002. Total of 16 rain events were considered for water sampling and water quality analysis for each rivulets just after the rainfall. The water samples were analysed as per methods of APHA (1989). The pH and EC were determined at the sampling sites with help of Bio aid and co portable water and dissolved oxygen by titration method using suitable preservents and nitrate and phosphate ion were determined with help of systronic spectrophometer (106).

RESULTS AND DISCUSSION

Phyto-sociology of sites

The surface vegetative cover, total basal areas (TBA), density and crown cover for herbaceous status for each land use in two different season is presented in Table 2. Results revealed that the phyto-sociology of different landuse types had the continuous grazing in degraded land and pine forest, which reduced the number of herbs and grasses species. However, it remains low for rainfed agriculture and tea plantation sites due to presence of terrace bunding and hedgerow in selected land use systems.

Parent soil and denudation losses

The soil texture ranged from sandy loam to loamy sand in different sites. The infiltration rate was highest 10.6 cm/hr for grazed and lowest 5.7cm/hr for rainfed agriculture land and is 5.8 cm/hr followed by for pine forest was mainly due to the higher clay and silt content. (Table-3) the facts was supported by the attributes of Bubsy and Giffard (1981). The sand content of each plot shows a positive correlation with the infiltration rate. A variation was recorded in cations exchange

Table 2. Vegetal cover and plant diversity of different landuse system of Bhetagad watershed, N=10

Landuse	Season	Surface vegetal Cover (%)	Tree density (no/ha)	Total tree basal area (m^2/ha)	Crown cover (%)	Total no. of herbs species	Total no. of grasses species
Open pine forest	Pre-monsoon	29±03	210 ±4 (pine trees)	31.0±2.8	54±4.	04	02
	Monsoon	46±04	210 ±4 (pine trees)	31.4±2.7	058±3.7	11	03
Tea plantation	Pre-monsoon	51±07	1600 ±12 (tea plants)	0.44±0.32	66±3.8	04	01
	Monsoon	64±04	1600 ±12 (tea plants)	0.46±0.30	30.1±3.0	09	03
Rainfed agriculture	Pre-monsoon	46±05	110±7(*G. optiva, P pessia*)	5.12±1.5	30.1±3.0	06	02
	Monsoon	74±02	110±7(*G. optiva, P pessia*)	5.14±1.5	80±4.2	16	04
Grazed land	Pre-monsoon	31±03	-	-	-	03	02
	Monsoon	39±04		-	-	08	03
Pasture/ Grass land	Pre-monsoon	54±04	-	-	-	08	04
	Monsoon	85±04	-	-	-	19	05
Bare plot	Pre-monsoon	Nil	-	-	-	Nil	Nil
	Monsoon	Nil	-	-	-		

Table 3. Soil characteristics of erosion plots in Bheta Gad watershed

Characteristics	Unit	Pine forest	Tea plantation	Rainfed agriculture	Grazed land	Grassland	Bare plot
Soil texture (Silt+ Clay)	(%)	37	34	36	37	36	32
W.H.C.	(%)	30.8	31.9	33.9	26.6	32.8	31.4
Infiltration rate	cm/hr	5.8	6.4	5.7	10.6	6.0	6.1
Bulk density	gm/cm^3	1.43	1.15	1.22	1.01	1.29	1.25
CEC	Meq/100gm	8.68	14.56	10.24	12.16	13.24	13.20
pH	-	6.39	6.16	6.16	6.84	6.34	6.34

Note: CEC = Cation Exchange Capacity; SL = Sandy Loam; LS = Loamy Sand; WHC = Water Holding Capacity

capacity (CEC) of different land sites. The soil pH for different sites ranged from acidic to neutral (6.10- 6.84).

The total overland flow generating precipitation was recorded 681.6mm for the study period. The average rainfall intensity was recorded 3.40 mm/hr range wit of 0.58 to 7.35 mm/hr. The highest of 1188476 liter/ha overland flow was observed from bare land and followed by open pine forest (919735 liter/ha Table-4). The increase in overland flow from bare plot due to the zero vegetation, however, the pine forest shows a combined effect of grazing, trampling and lower surface vegetative cover. Grassland had considerable reduction in overland flow, suspended and dissolved solid losses due to presence of good grass cover. Vegetal cover obstructs the flow and reduces the velocity of runoff, which in turn increased the infiltration losses resulting in reduction of runoff Morgan (1986). Traditionally, maintained agriculture terraces also produced lowest overland flow, suspended and dissolved solid losses. This reduction in water, suspended and dissolved losses is a combined effect of good terrace bunding and grass protection in terrace risers. However, in the pine forest and grazed land higher losses through erosion have also been reported due lack of vegetative cover (Khana and Mathur 1993).

Conservation values

The conservation values (CV) for water, total suspension and total dissolved solids were also calculated (Table-3). In the pine forest, lowest CV was recorded for water (22.61), suspension (98.68) and for total dissolved solids (24.37) followed by grazed land. The result indicated that the agriculture terraces edges and hedgerow in tea plantation efficiently checked overland flow, total suspension and total dissolved solids. Hence, to provide high conservation values for aforesaid parameters in the study area has to need to improve the ground vegetal cover for sustainability of the landuses.

Water quality parameters of rivulet waters

The various water quality parameters of selected rivulets are presented in Table 5. The results obtained by field observation indicated that the streams with high intensive fertilizer application in agricultural land and pasture land have higher concentration of nitrate and phosphate. This becomes due to the contaminants carried through over land flow. Further the higher population density in stream catchment area increases the level of nitrate and E. coli in the rivulets water ecosystems. Thus the complex demographic and landuse features of catchment areas of such surface water bodies brings simultaneous spatial changes in these water ecosystems Hoda et al. (1997) and Vega et al. (1998).

Total suspended solids and dissolved solids

The losses of total suspended solids and total dissolved solids for each rainfall days of pre-monsoon season and monsoon season is presented in Fig. (2a) & Fig. (2b). The mean of TSS (total suspended solids) were recoded 1112 to 1943 mg/l and 920 to 1778 mg/l in summer and monsoon seasons respectively for all the selected

Table 4. Total suspended and dissolved losses from different prominent landuse systems in Bhetagad micro-watershed

Landuse type	Overland flow (l/ha)	Total suspended losses (kg/ha)	Total dissolved solid losses (kg/ha)	Conservation values for water	Conservation values for suspensions	Conservation values for dissolved solids
Pine forest	919735[b]	1398.70[b]	79.09[b]	22.61	94.68	24.37
Tea plantation	120800[d]	129.84[e]	11.83[d]	89.83	99.50	88.68
Rainfed agriculture	58300[e]	140.11[de]	10.20[d]	95.09	99.46	90.24
Grazed land	405604[c]	606.63[c]	36.09[c]	65.87	97.69	65.48
Protected grass land	395924[c]	332.41[d]	36.42[c]	66.68	98.73	65.17
Bare land	1188476[a]	26340.43[a]	104.58[a]	-	-	-

Note: a, b, c, d and e letter in superscript representing Analysis of Variance (ANOVA) significance values at ($P < 0.05$)

Table 5. Mean value of water quality parameters of studied rivulets of Gomti basin during the pre-monsoon and Monsoon

	Season	Pre-monsoon (15th April to 14th June) n= 6 rainy days				Monsoon(1st July to 31st August) n= 10 rainy days			
		Rivulets				Rivulets			
	Unit	Bhetagad	Garurganga	Gomtinala	Ghangali	Bhetagad	Garurganga	Gomtinala	Ghanghali
TSS	mg/l	1629	1943	1112	1423	1023	1778	920	1109
TDS	mg/l	81	108	102	112	62	69	78	78
pH	-	7.81	6.89	7.20	7.05	7.68	7.36	7.51	7.28
EC	μ S/cm	162	212	205	219	135	154	149	146
DO	mg/l	4.48	5.32	5.60	4.80	5.28	5.82	6.84	5.56
Nitrate	mg/l	9.87	17.45	11.14	7.28	15.63	22.54	13.19	11.23
Phosphate	mg/l	5.69	6.79	4.98	3.88	7.03	7.84	7.16	3.77
E. coli	CFU/100ml	284	326	256	127	169	187	106	96

TSS :Total suspended solids, TDS: Total dissolved solids, EC: Electrical conductivity, DO: Dissolved oxygen rivulets. The reason behind the higher range of TSS in pre-monsoon in compare to monsoon season, due to the presence of lower vegetative cover in all the landuse systems and high rainfall intensity accelerated to the suspended solids by sheet erosion in rivulets water eco-systems, Table 2 & Table 5. A similar trend was also recorded for dissolved solids ranged 81 to 112 mg/l and 62 to78 mg/l in pre-monsoon and monsoon seasons respectively. The presence of lower dissolved solids in monsoon rains in compare to pre- monsoon rain, may be due the dissolved solids carried out by overland flow is diluted by soil water already present in rivulets catchment area.

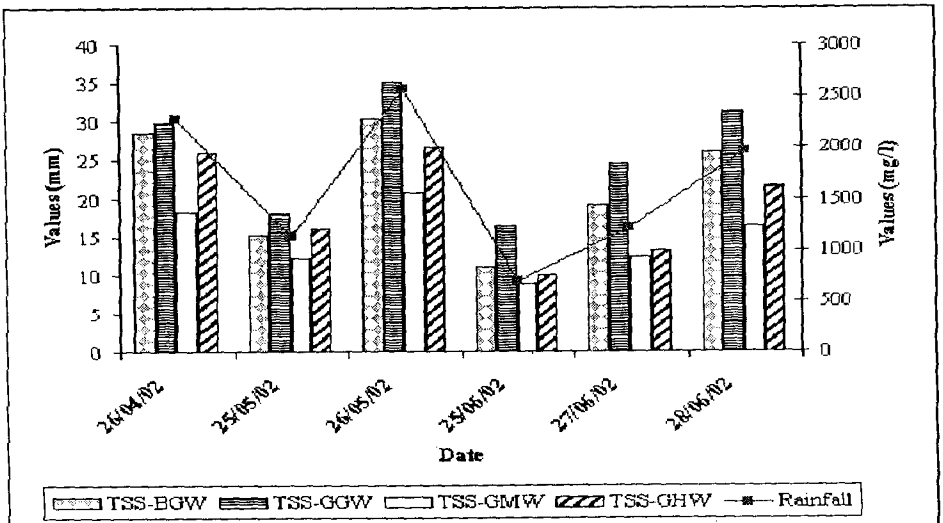

Figure 2a. Variation in Rainfall(mm) & TSS(mg/l) for pre-monsoon in different catchments of Gomti Basin

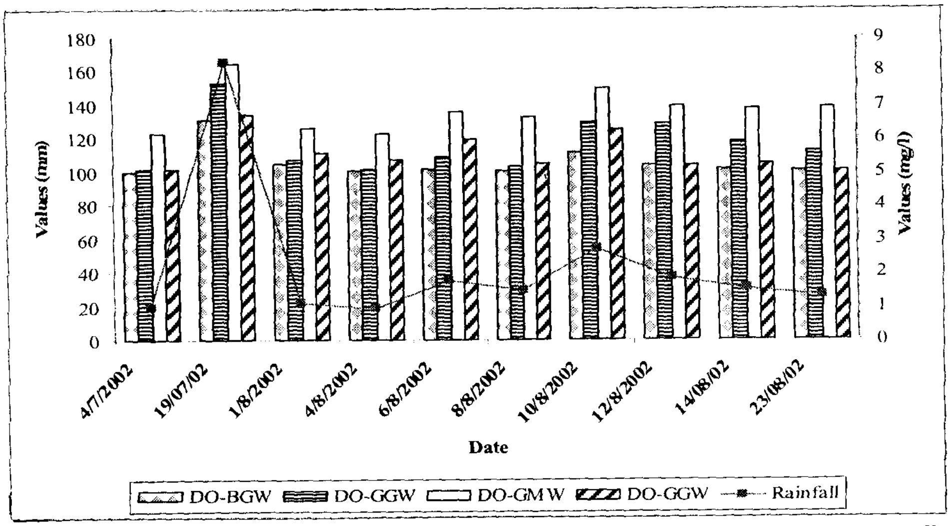

Figure 2b. Variation in Rainfall(mm) & TSS(mg/l) for monsoon in different catchments of Gomti Basin

Water pH

The pH of the selected rivulets for the studied period was recorded from 6.89 to7.81 for pre-monsoon and monsoon season, Table-5. It was also recorded that pH varied from rivulet to rivulet and a little variation between the two study seasons. In the pre- monsoon season, except the Bhetagad rivulet the pH values shifted towards acidic/neutral side, this becomes due the presence of contaminates via washing, bathing and rural biotechnological practices in the rivulets water ecosystems and is least effected by the catchment landuse distributions. Generally, it falls within the tolerable limits of the values as recommended by WHO (1993).

Electrical Conductivity (EC)

The electrical conductivity of the rivulets water varied between135 to 219 μS/cm. The analysis of variance (at 0.05% P level) showed that significant variation was recoded in between the different rivulets in two different seasons. In general a high EC value in summer is favoured by higher solutes in lower water discharges in different rivulets. The finding supported by the results of Joshi et al. (2001).

Dissolved oxygen (DO)

The mean dissolved oxygen ranged from rivulets 4.48 to 5.60 mg/l and 5.28 to 6.84 mg/l in pre monsoon and monsoon respectively and a little variation was observed between the two studied seasons Figures (3a) & (3b). The higher values of DO in monsoon rain in compare to pre-monsoon rain due to the presence of higher frictions in water enhanced to the rate of oxygen assimilation in the water. Further, in the monsoon season, with increase in the water temperature the biochemical activities increase, results of that the dissolved oxygen content increases in rivulets

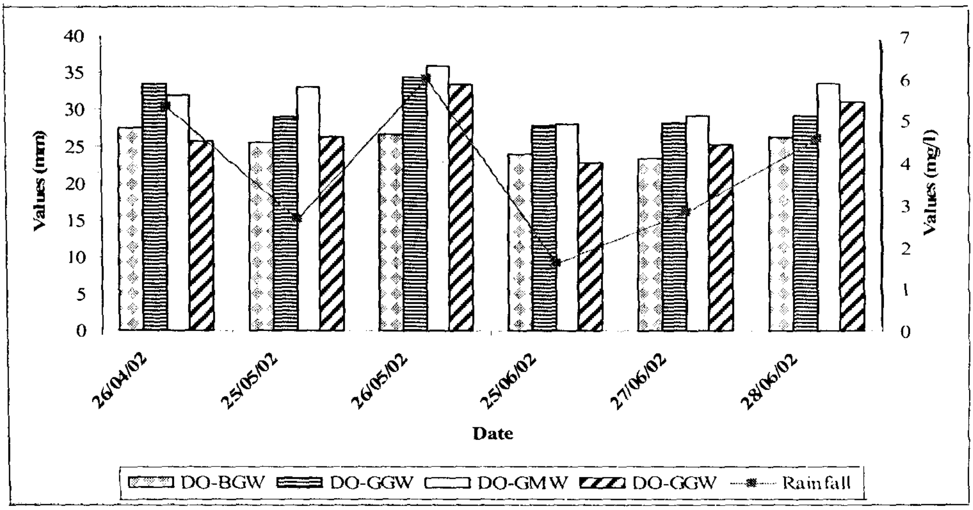

Figure 3a. Variation in Rainfall(mm) & DO(mg/l) for pre-monsoon in different catchments of Gomti Basin

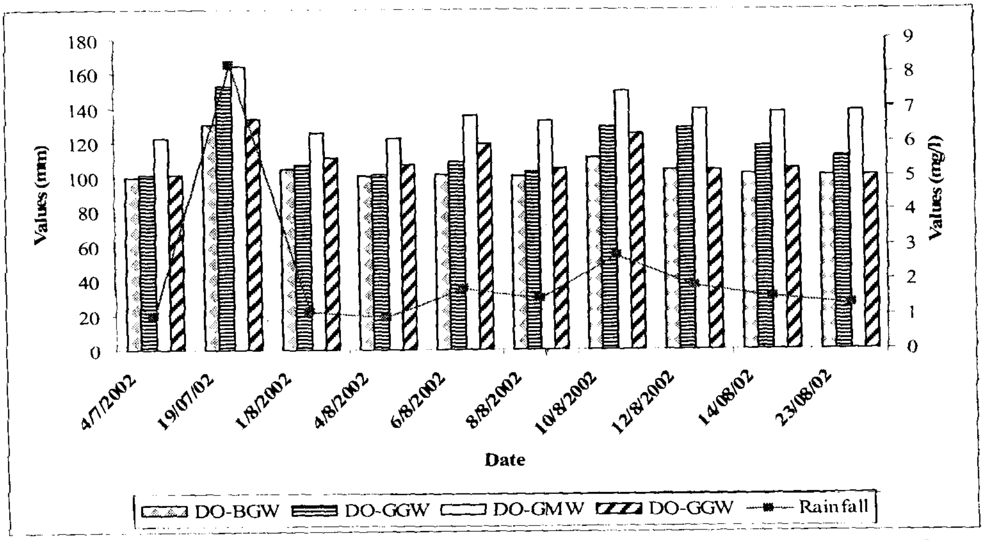

Figure 3b. Variation in Rainfall(mm) & DO(mg/l) for monsoon in different catchments of Gomti Basin

water ecosystems. The fact is also supported by the findings of Joshi and Kothyari 2003 for unconfined aquifers of Bhetagad watershed, Indian central Himalayas. The observed values (4.80 to 6.84 mg/l) of DO in two different rain influenced waters shows very low as compared to WHO recommended standard range (5.0-14.5 mg/l for human drinking and aquaculture point of view as well.

Nitrate and Phosphate

The high anthropogenic contaminants from rivulet catchment and intensive uses of inorganic fertilizers is under common practice in the study area i.e. super phosphate, DAP and urea in the agriculture land and pastureland in have been considered as the main sources of $NO3^-$ and $PO4^{3-}$ in the rivulets water ecosystems. Thus, both contaminants may be entering in rivulets aquatic ecosystems through overland flow and ground water recharges in wells. A large variation of 7.28 to 22.54 mg/l and 3.88 mg/l to 7.84 mg/l for $NO3^-$ and $PO4^{3-}$, respectively (Table -5). Rivulets water of Garurganga and Bhetagad exhibited uncertain rise in $NO3^-$ and $PO4\ ^{3-}$ concentration than the others selected rivulets, is mainly due to intensive uses of fertilizers in the agriculture and grassland systems in the rivulets catchment. Thus, the soil, landuse and drainage pattern of the streams altering the concentration of $NO3^-$ and $PO4^{3-}$. The attribute is also supported by to the findings of the Vega et al. (1998).

Escherichia coli assessment

The rivulets water ecosystems under the pressure of higher settlement waste loads either direct or indirect contamination indicated excess of *E. coli* in the rivulets water systems. The highest *E. coli* variation to 67 to 184 CFU/100 ml was recorded during the summer season rainy events and lowest of 36 to 87 CFU/100 ml in the monsoon season (Table-4). The lower *E.* coli in the monsoon due to dilution effects of the water discharges. This decrease can be also explained in terms of irregular temperature for *E. coli* colonies growing in the monsoon season.

CONCLUSION

The results observed for chemical denudation showed tremendous losses of suspended and dissolved mass from studied landuse systems shows an urgent need of appropriate land management like community forestry, agroforestry and consolidation of degraded patches in the study area.

The results of water quality parameters in the all the four rivulets showed higher amount of suspended solids and *E.Coli* compared to permissible limits prescribed by WHO (1993) and the nitrate and phosphate content also remains nearest the recommended values of WHO (1993). However, low dissolve oxygen content water was not fit for drinking and aquaculture purposes in these rainy events. Thus the inhabitants of the basin have to need take precaution before use of the rain influenced water in the summer as well as in monsoon season.

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