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Assessment of spatial variation in water quality of Doodhganga stream in Kashmir Himalaya

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Abstract
The present study was carried out during April 2018 to assess the spatial variability in water quality of Doodhganga-a stream in Kashmir Himalaya and the assessment of land use land cover (LULC) of the four selected sites [Yousmarg (Site-A), Nowhar (Site-B), Chadoora (Site-C) and Barzulla (Site-D)] based on differential anthropogenic pressures. At each site samples were collected from three locations (which served as three replications) and data was represented as mean value of all locations. At Site-A (comparatively clean site), the mean value of parameters viz. temperature, pH, electrical conductivity, BOD, total hardness, sulphate, orthophosphate and ammonical nitrogen increased significantly downstream with minimum mean value recorded as $10 \pm 0.1°C$, 7.7 ± 0.02, 72.2 ± 0.06 μScm^{-1}, $1.5 \pm 0.5 mgL^{-1}$, $67.2 \pm 0.5 mgL^{-1}$, $9.2 \pm 0.2 mgL^{-1}$, $0.09 \pm 0.01 mgL^{-1}$ and $0.53 \pm 0.01 mgL^{-1}$ respectively. On the other hand maximum mean value for all these parameters viz. $20.6 \pm 0.03°C$, 8.1 ± 0.01, 179.8 ± 0.23 μScm^{-1}, $3.5 \pm 0.06 mgL^{-1}$, $259.2 \pm 0.5 mgL^{-1}$, $29.6 \pm 0.3 mgL^{-1}$, $0.35 \pm 0.01 mgL^{-1}$ and $0.82 \pm 0.01 mgL^{-1}$ where recorded at Site-D. Similarly, dissolved oxygen recorded maximum mean value at Site-A ($8.6 \pm 0.08 mgL^{-1}$) and decreased significantly downstream and its minimum mean value was recorded at Site-D ($6.0 \pm 0.5 mgL^{-1}$). Land use/land cover (LULC) of Doodhganga watershed revealed considerable change in some LULC classes during the selected time period (2000-2018). Total share of area under agricultural field, mixed plantation, water body and wetlands reduced by 3.23%, 1.61%, 0.14% and 0.04% respectively. On the other hand, built up, and horticulture/orchards increased by 3% and 1.46% respectively. Change in physico-chemical characteristics of water of Doodhganga stream elucidates increased pollution load downstream.

Keywords: Stream, Doodhganga, physico-chemical characteristics, LULC, pollution

1. Introduction
Stream water is an important natural source for sustenance of diversity of life. With the increase in global population, the demand for water also increases. The lotic ecosystems are under constant threat owing to upsurge in pollution loads which is affecting aquatic ecology [1, 2]. The easily assessable surface water makes it prone to anthropogenic pollution. Pollutants open a bunch of problems leading to deterioration of water quality, buildup of lethal chemicals, reduction in surface area and loss of aesthetic value [3]. Stretches of streams flowing through urban areas are most often used as dumping sites for wastes discharge from households and industries [4]. In the same way, agricultural runoff also pollutes streams [5]. Pollution of lotic water bodies with life threatening pollutants is a matter of concern for human health and environment [4]. Seasonal and spatial variations in precipitation, runoff from surfaces and base flow intensely influence the discharge in streams which in turn affects the pollution load in streams [6]. LULC changes are an infinite processes occurring on earth's surface and these changes are the result of economic diversification, technological progression, population pressure etc. Doodhganga watershed of Kashmir Himalaya indicates declining trend in stream discharge. Due to climate change, agricultural lands are converted into orchards, increasing human population together with decreasing stream discharge account for LULC changes in the watershed. Further conversion of natural vegetated areas to paved surfaces like built-up has direct effect on water budget of the Doodhganga watershed [7]. Doodhganga stream is among the principal tributaries of river Jhelum and an important source of irrigation and drinking water to the inhabitants of district Budgam and Srinagar. Thus its water quality monitoring is extremely important to avoid any health and ecosystem

related issues. The present study was carried out to evaluate spatial variation in water quality and pollution load in Doodhganga stream along the gradient of increasing urbanization and anthropogenic pressure.

2. Materials and Methods
2.1 Study Area
Doodhganga originates from eastern slopes of Pir Panjal mountain range of Himalaya beneath Tatakuti peak approximately 4500m above mean sea level. Water is fed to this stream by variety of sources such as snow fields, springs and small lakes. The stream is important source of water for residents of district Budgam and Srinagar [8]. This study was carried out during April 2018 for the preliminary evaluation of pollution level in Doodhganga stream. Approximately 65 km stretch of the stream from Yousmarg to Barzulla was selected in the order of increasing human disturbance and urbanization (Fig.1). In total, four sites were selected with three locations within each site viz. Site-A [Yousmarg (upstream) 33˚52 'N, 74˚39' E, 2120 meters a.m.s.l], Site-B [Nowhar (middle reach) 33˚53' N, 85˚48' E, 1906 meters a.m.s.l], Site-C [Chadoora (middle reach) 33˚56' N, 74˚48' E, 1620 meters a.m.s.l] and Site-D [Barzulla (downstream) 34˚02' N, 74˚ 47' E, 1594 meters a.m.s.l]
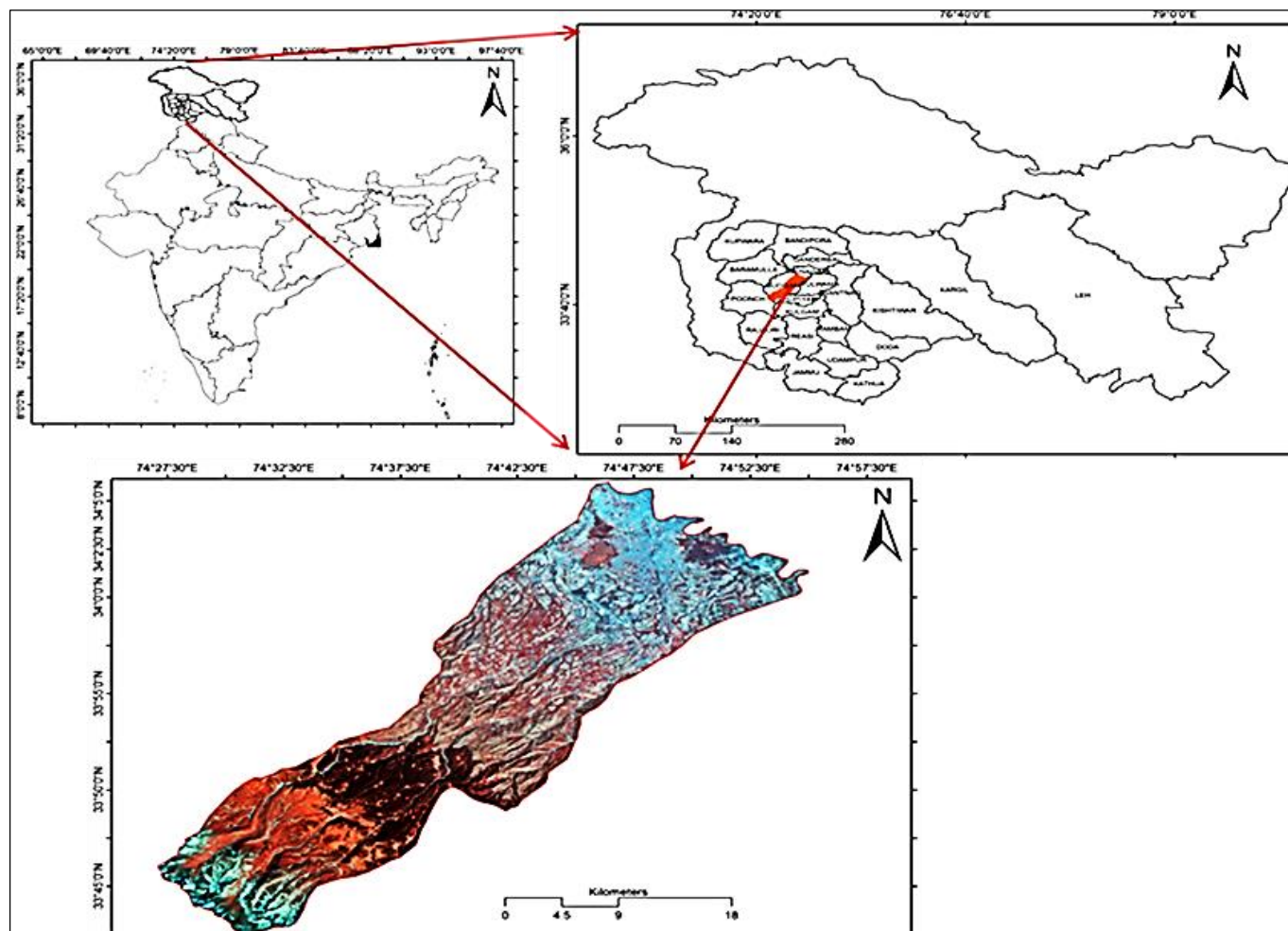

Fig 1: Map showing study area

2.2 Water Analysis
Water samples from selected sites were collected in pre-cleaned bottles of 1 L capacity during April, 2018 and the samples were brought to laboratory for further analysis as per the standard methods following APHA, 2005 [9].

2.3 Temporal Changes in various LULC Classes of Doodhganga Watershed
2.3.1 Satellite Data: The Satellite data sets used for the study of temporal variation in LULC of Doodhganga stream watershed were; Landsat TM dataset (October, 2000) with spatial resolution of 30m and Landsat-8 OLI dataset (October, 2018) with spatial resolution of 30 m.

2.3.2 Data Analysis
The watershed of Doodhganga stream was generated by using ASTER digital elevation model (DEM) with a spatial resolution of 30 m. The flow chart of the methodology adopted for change detection in LULC of the study area is shown in Fig. 2.
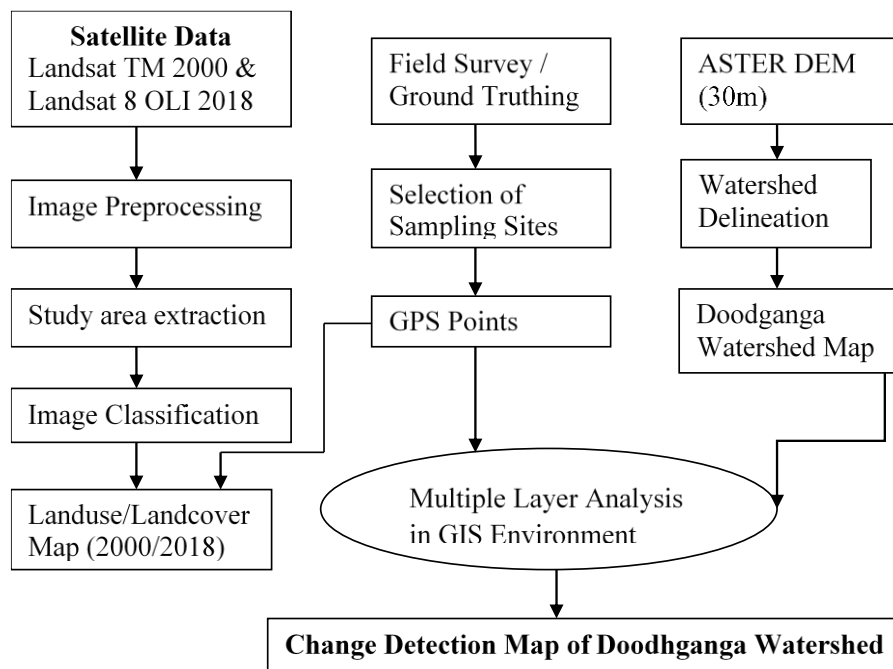
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┌─────────────────────┐    ┌─────────────────┐    ┌─────────────────┐
│   Satellite Data    │    │  Field Survey / │    │   ASTER DEM     │
│ Landsat TM 2000 &   │    │ Ground Truthing │    │     (30m)       │
│ Landsat 8 OLI 2018  │    │                 │    │                 │
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│ Image Preprocessing │    │  Selection of   │    │   Watershed     │
│                     │    │ Sampling Sites  │    │  Delineation    │
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│ Study area extraction│   │   GPS Points    │    │   Doodganga     │
│                     │    │                 │    │ Watershed Map   │
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│  Landuse/Landcover  │        │  Multiple Layer Analysis  │
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                    │ Change Detection Map of Doodhganga Watershed│
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Fig 2: The flow chart of the methodology adopted for change detection in LULC of the study area

3. Results and Discussion

3.1 Physico-Chemical Characteristics of Water

Water temperature followed increasing trend from Site-A to Site-D (R^2 = 0.84).The minimum mean value was recorded at Site-A (10±0.1°C) and maximum mean value was recorded at Site-D (20.6±0.03°C) (Fig. 1). Increasing trend of temperature from upstream to downstream may be due to decrease in altitude [10], less canopy density in the riparian area and decrease in flow velocity [11].

The pH of stream showed alkaline nature of the water. Site wise comparison revealed significant increasing trend of pH down the gradient (R^2 = 0.82) with minimum mean value at Site-A (7.7±0.02) and maximum mean value at Site-D (8.1±0.01) (Fig. 2). Stream water has the capacity to maintain pH within narrow range due to their high buffering capacity [12]. The alkaline pH may be credited to the increase in buffering substances of carbonates of calcium and magnesium as a result of increased anthropogenic pressure in riparian area downstream [13]. Further high pH in lower reaches of stream may also be attributed to domestic sewage, urban and commercial runoff [14].

Electrical conductivity is the measure of amount of dissolved ions in water which in turn indicates the extent of mineralization in water body [15]. Electrical conductivity of Doodhganga stream shows significant increasing trend (R^2= 0.99) downstream (Fig. 3). Minimum mean value (72.2±0.06 μScm^{-1}) was detected at Site-A and maximum mean value was recorded at Site-D (179.8±0.23 μScm^{-1}). The increase in conductivity in middle and lower reaches of the stream may be due to increased stream bank erosion, agricultural and urban runoff [16].

Dissolved oxygen shows negative correlation with water temperature and organic load of the stream. Dissolved oxygen significantly decreased downstream (R^2 = 0.93). Its maximum mean value was recorded at Site-A (8.6±0.08mgL^{-1}) and minimum mean value was recorded at Site-B (6.0±0.5mgL^{-1}) (Fig. 4). The decrease in dissolved oxygen in lower reaches of the stream may be attributed to increased temperature, less discharge of the stream, high organic load, discharge of agricultural runoff, domestic and municipal sewage [15].

Biochemical oxygen demand (BOD) of Doodhganga stream followed increasing trend (R^2 = 0.93) from upstream to downstream and varied negatively with dissolved oxygen and positively with temperature. The minimum mean value of BOD was recorded at Site-A (1.5±0.5mgL^{-1}) and maximum mean value was recorded at Site-D (3.5±0.06mgL^{-1}) (Fig. 5).

The increase in BOD value from upstream to downstream may be ascribed to increase in anthropogenic pressure, change in land use land cover, increased urbanization, surface run-off from commercial and residential areas, increased microbial load and release of domestic sewage in the stream [17, 18, 19]. The BOD revealed oligosaprobic nature of the stream in upper reaches and mesosaprobic nature of the stream in middle and lower reaches. The stream is approaching to critical levels of pollution in the lower reaches.

An increasing trend of total hardness was observed downstream (R^2 = 0.99) with minimum mean value recorded at Site-A (67.2±0.2mgL^{-1}) and maximum mean value recorded at Site-D (259.2±0.5mgL^{-1}). The increase in total hardness may be attributed to increased mobilization of hardness causing ions (calcium and magnesium) due to increased biological activity and subsurface flow down the gradient [8]. Hard water is associated with corrosive nature and cause economic losses to sanitary products.

The minimum mean value of sulphate was recorded at Site-A (9.2±0.2mgL^{-1}) and maximum mean value was recorded at Site-D (29.6±0.3mgL^{-1}) (Fig. 7). The increasing trend of sulphate (R^2 = 0.89) downstream may be due to release of sulphate ions from domestic and commercial sewage [20] and increased fertilizer use in agricultural areas downstream [8]

Orthophosphate concentration of water increased significantly downstream (R^2 = 0.92) (Fig. 8) with minimum mean value recorded at Site-A (0.09±0.01mgL^{-1}) and maximum mean value recorded at Site-B (0.35±0.01mgL^{-1}). The increasing trend downstream may be attributed to runoff from agricultural fields laden with dissolved fertilizers, urban runoff and organic wastes from domestic and municipal sewage [21, 22].

Ammonical nitrogen increased significantly downstream (R^2 = 0.82) and showed positive correlation with orthophosphates (Fig. 9). Maximum mean value of ammonical nitrogen was

recorded at Site-D (0.82 ± 0.02 mgL^{-1}) and minimum mean value was recorded at Site-A (0.53 ± 0.01 mgL^{-1}). Increasing trend from upstream to downstream is mainly caused by municipal/domestic sewage and agricultural run-off [21]. Increase in orthophosphates and ammoniac nitrogen reveal eutrophic nature of Doodhganga in lower reaches [23].
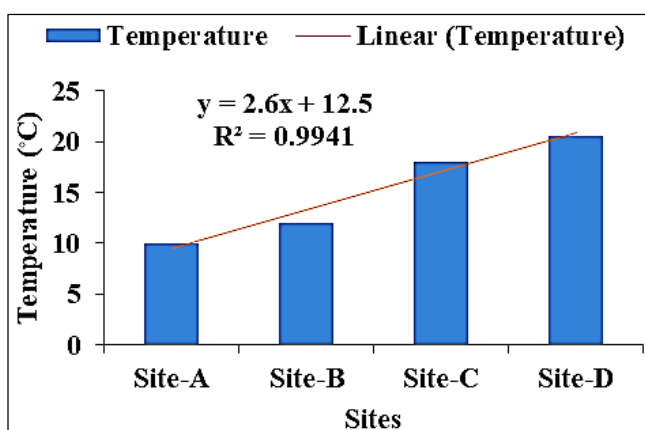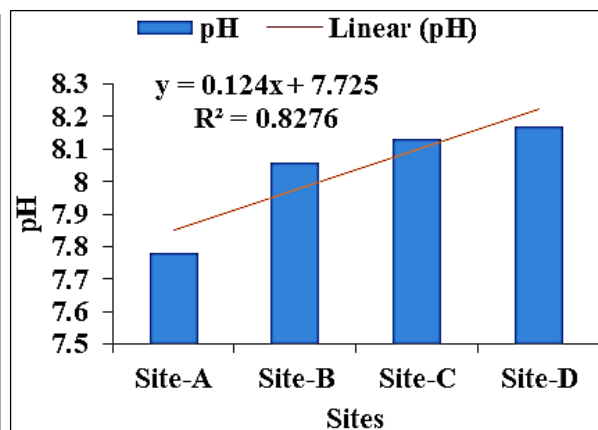

Fig 3: Temperature (°C) vs. Sites
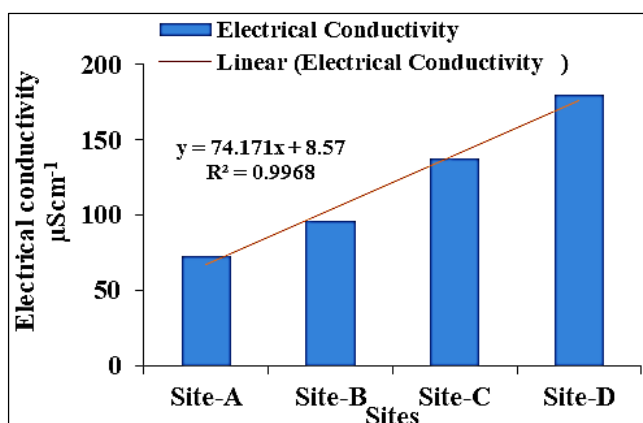

Fig 4: pH vs. sites

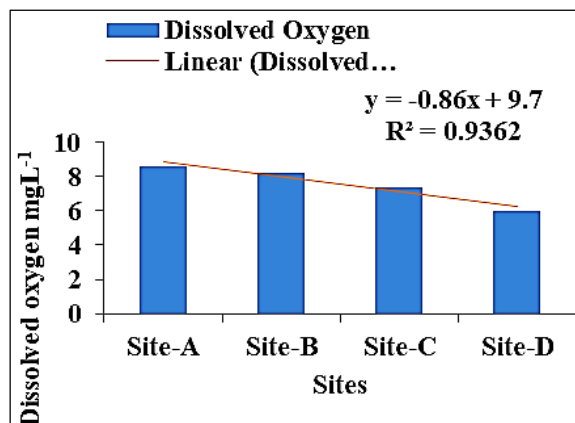

Fig 5: Electrical conductivity (µScm^{-1}) vs. sites

Fig 6: Dissolved oxygen (mgL^{-1}) vs. sites.
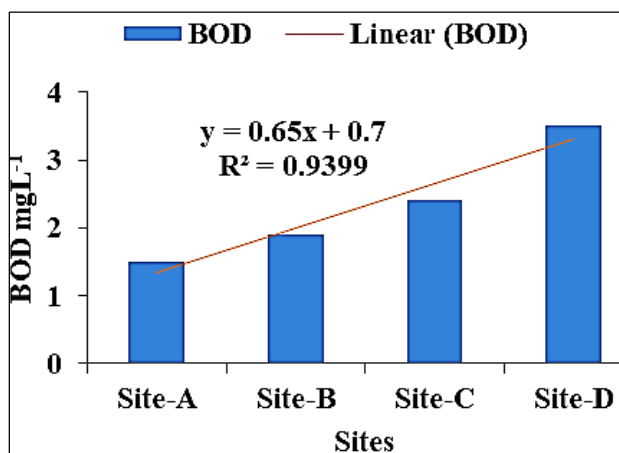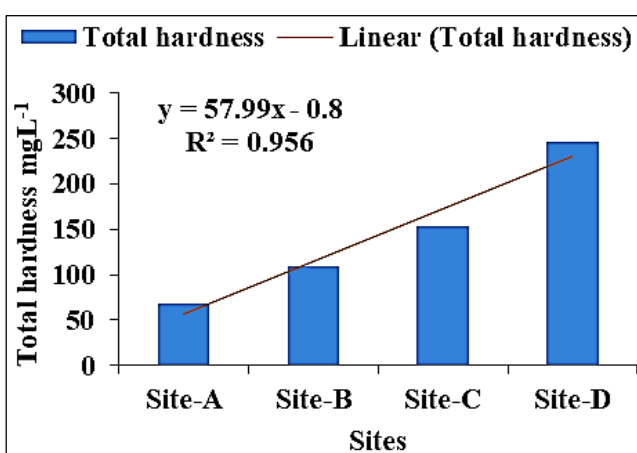

Fig 7: Biochemical oxygen demand (mgL^{-1}) vs. sites.

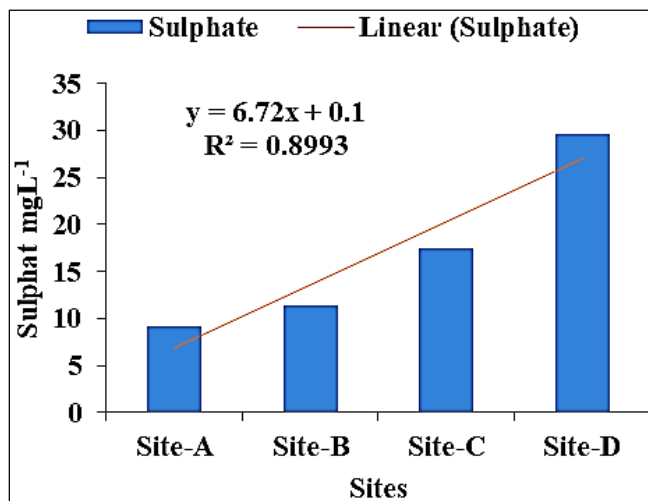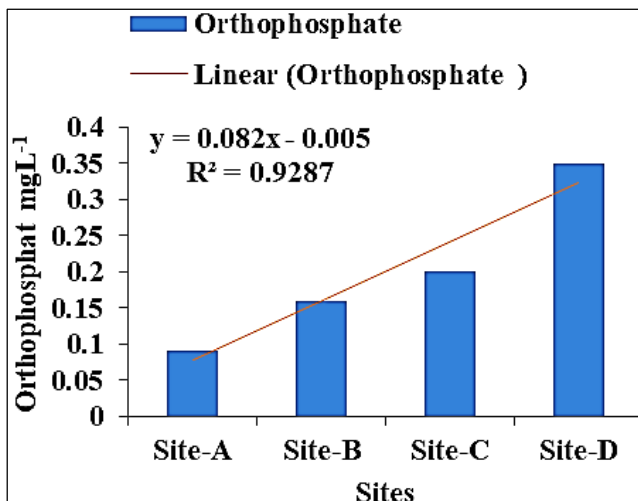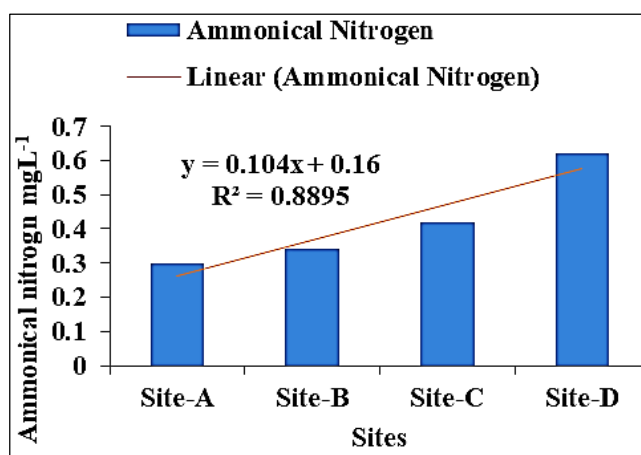**Fig 8:** Total hardness (mgL^{-1}) vs.sites.

Fig 9: Sulphate (mgL⁻¹) vs. sites

Fig 10: Orthophosphate (mgL⁻¹) vs. sites

Fig 11: Nitrogen (mgL⁻¹) vs. sites

Fig 3 to 11: Showing variation in physico-chemical properties of Doodhganga stream

3.2 Spatial and Temporal Changes in Land use/land Cover of Doodhganga stream Watershed

For the classification of Doodhganga stream watershed, on-screen digitization technique was used. In total, 10 LULC classes were delineated including agriculture field, built up, forest, horticulture/orchards, mixed plantation, meadows, wasteland, snow/glacier, water body and wetland based on shape, size, pattern, tone, texture, and association [24]. The percent temporal change in various LULC classes is shown in Table 1 and the spatial distribution of various LULC classes is shown in Fig.12.

In the present study, the agricultural field which shares the largest LULC classes is reduced from 31.34% to 28.11% exhibiting the total reduction of 3.23% from the year 2000 to 2018. This decrease in LULC class is due to the conversion of agricultural land into horticultural land and built up. This change in LULC class may be ascribed to shifting of agriculture land to horticulture for greater economic benefits. Also, the change in agricultural LULC class to built up is due to the increasing population pressure (Table.1; Fig.12). Our results corroborate with the findings of Shah [25]; Nanda et al. [26]; Kuchay et al. [27] and Aalam [28].

Built-up is one of the main LULC classes that have been extensively studied for change detection. The total area recorded under built up was 7.36% and 10.36% in 2000 and 2018 respectively, exhibiting a total increase of 3% (Table.1; Fig.12). Increase in population and commercial units is responsible for conversion of marshy land and catchment area

of water bodies into built up particularly in the lower reaches of the Doodhganga watershed [28]. The increase in built up typically causes reduction in the agricultural land, wetlands and catchment area of the water bodies through encroachment which in turn deteriorate environmental conditions of the area [27,29,14].

The land under horticulture showed increasing trend. The LULC class under horticulture has been changed from 3.37% in 2000 to 4.83% in 2018 recording a total increase of 1.46%. The growth of horticulture land is attributed to conversion of agricultural land into horticultural land due to more economic benefits associated with the horticultural produce particularly apple orchards [27]. Further mixed plantation showed decreasing trend from 11.23% to 9.62% registering a total decrease of 1.61%. This change may be ascribed to conversion of mixed plantation areas into settlements due to encroachment caused by migration of people from densely packed costly urban areas into less dense areas [28].

Water bodies including wetlands are severely stressed natural assets in the valley of Kashmir. The total share of Water body and wetland LULC classes has recorded reduction of 0.14% and 0.04% respectively from 2000 to 2018 (Table.1; Fig.12). The increased morphological changes in water bodies and wetlands are caused by anthropogenic pressure, sediment loads carried by rivers into wetlands and changes in water budget and demographic settings. Our Results are in agreement with previous studies carried out by [27, 31, 32, 33]. Decrease in spatial extent of watershed and increased

conversion of land into horticulture and built-up results in water pollution and eutrophication of water bodies [34, 35].

Table 1: Temporal variations of various land use/land cover features of Doodhganga watershed

| LULC types	Area(2000)		Area (2018)		Net change in area	
	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Agriculture Field	18133	31.34	16263	28.11	-1870.00	-3.23
Built up	4260	7.36	5995	10.36	1735.00	3.00
Forest	11132	19.24	11132	19.24	0.00	0.00
Horticulture/Orchards	1952	3.37	2795	4.83	843.00	1.46
Meadows/Grassland	5696	9.84	5696	9.84	0.00	0.00
Mixed Plantation	6498	11.23	5567	9.62	-931.00	-1.61
Snow/Glacier	5602	9.68	5933	10.25	331.00	0.57
Wasteland	3305	5.71	3305	5.71	0.00	0.00
Water body	755	1.30	672	1.16	-83.00	-0.14
Wetland	526	0.91	501	0.87	-25.00	-0.04
Total	57859	100	57859.00	100		
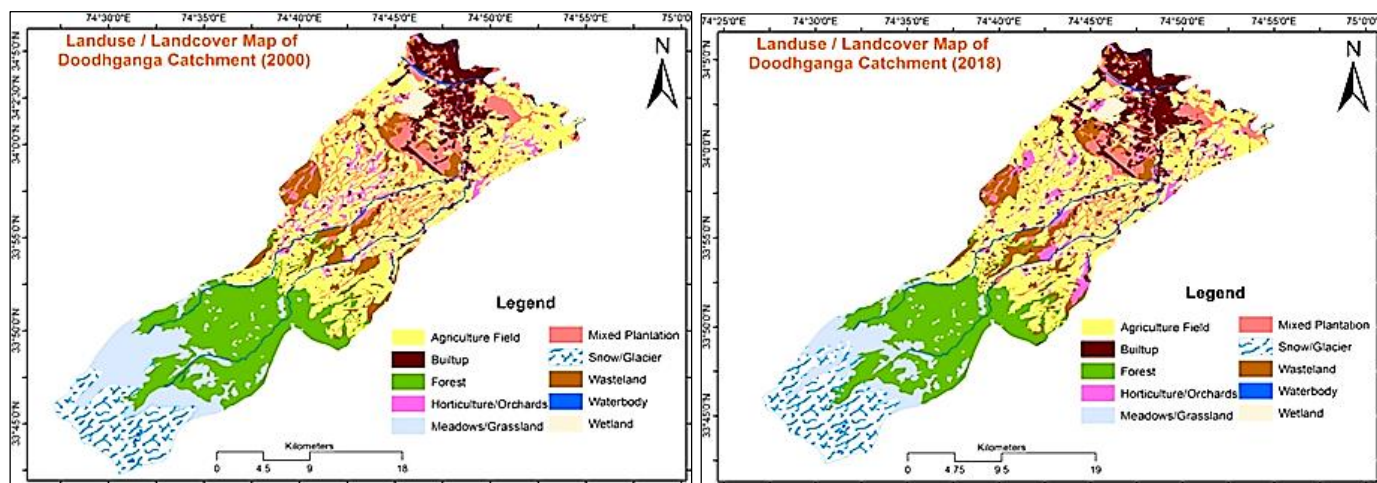
Fig 12: LULC maps of Doodhganga watershed showing spatial and temporal changes in various land use resources during the year 2000 to 2018.

4. Conclusion

Analyses of water parameters revealed significant change in physico-chemical properties of Doodhganga stream from upper reaches to lower reaches. Water quality of Doodhganga stream showed increased load of nutrients downstream particularly in middle and lower reaches. The main factors responsible for changing water quality are discharge of agricultural and domestic wastes into the stream, erosion of river banks due to excessive excavation of sand, increased urbanization and construction of commercial units in riparian area of the stream. Change in LULC particularly conversion of catchment area into built up and shrinking of water bodies increases pollution load in Doodhganga stream.

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