Kashmir Himalaya, which is well known for its freshwater bodies viz., streams, rivers, springs, lakes, wetlands, etc. the world over, has of late seen a deterioration of its precious water resources. For long, studies have been focused on the lakes and wetlands and there are only a few studies on lotic systems. In recognition of the fact that there is an urgent need to conduct rigorous studies on lotic ecosystems of Kashmir Himalaya using the state of the art knowledge of river ecology and allied sciences, the present study was conducted in an ecosystem perspective on “Doodhganga Stream” which is one of the principal tributaries to River Jhelum in the valley of Kashmir. The conceptual model followed in the present study focuses on the links which connect streams with their catchments. In essence, it may be stated that the watershed (drainage basin) and reach scale factors influence the conditions in streams which in turn influence the life histories and biotic interactions of organisms living in them and thus on long term basis these factors together shape the biotic communities in streams. Conversely, the structure of biotic communities reflects the physical and chemical conditions in streams which in turn reflect the status of the drainage basin. The above statement gains support from the earlier statement of H.B.N. Hynes (1975), the father of modern stream ecology, who put it that “in every respect the valley rules the stream”. To this I suggest that “in every respect the stream reflects the valley”.

Kashmir valley, so called the paradise on earth, lies between 33° 20’ and 34° 54’N latitudes and 73° 55’ and 75° 35’E longitudes and covers an area of 15,948 km². Topographically, it is a deep elliptical bowl-shaped valley bounded by the lofty mountains of the Pir-Panjal Range in the South and South-West and the Greater Himalayan Range in the North and East, with 64% of the total area being
mountainous. The shielded valley of Kashmir is characterized by distinct orographic features and snow clad peaks and resembles the mountainous and continental parts of the temperate latitudes. Thus, the valley of Kashmir has a continental climate marked by well defined seasonality. On the basis of temperature and precipitation four seasons in a year have been recognized namely: winter (December to February), spring (March to May), summer (June to August), and autumn (September to November). The average rainfall at Srinagar is 659 mm per annum and most of the precipitation occurs in the form of snow during winter and early spring.

Traversing the valley is the River Jhelum and its tributaries. The Jhelum (also called Vitasta/Vyeth) has been and continues to be the key element of the giant ecosystem of Kashmir. Doodhganga, which is a major left bank tributary to River Jhelum, takes its origin on the eastern slopes of the Pir-Panjal mountain range of Himalaya below the Tatakuti peak which is at an altitude of more than 4500 m a.s.l. The source waters of the stream in the upper reaches are the snow fields, springs and a number of smaller lakes.

The main aims and objectives of the present study on Doodhganga stream were to work out the composition and dynamics of the stream in terms of physico-chemical limnology, periphyton and macroinvertebrates so as to understand the overall stream ecology in terms of physical, chemical and biological aspects and how these reflect the characteristics of the drainage basin in the spirit that “in every respect the stream reflects the valley (drainage basin)”. To accomplish these objectives data was collected on the general drainage basin land use/land cover characteristics, dynamics of physico-chemical characteristics of the riparian soil, hydrology and geomorphology of the stream, dynamics of physico-chemical characteristics of stream water and the qualitative and quantitative aspects of the stream periphyton and macroinvertebrates. For the purpose of sampling seven study sites were selected with Site 1 at Branwar, Site 2 at Chadora, Site 3 at Wathora, Site 4 at Wathora on the tributary Shaliganga stream, Site 5 at Kral Pora, Site 6 at Natipora and Site 7 at Bemina. The data sets were then integrated using statistical methods to understand the overall status of the stream and the correlations between these components. Following are in brief the major findings of the present study on Doodhganga stream and its drainage basin.
1. The drainage basin of the Doodhganga stream was characterised in terms of the land use/land cover classes and it was found that the total drainage basin area of the stream was 494.20 km$^2$ with 43.45% area under agricultural land use followed by scrub (15.18%), plantation (12.27%), blank forest (11.18%), forest (10.02%), built-up (6.48%), grassland (0.72%), and water-body (0.69%) in a decreasing order. When the land use/land cover classes within individual sub-basins above each study site were considered it was observed that there were clear trends with forest and blank-forest land cover registering a decreasing trend downstream while on the other hand, agriculture and built-up categories registered an increasing trend. The surface geology in the drainage basin was dominated by the Karewa formations with sand/silt/clay being the dominant material. The slope was steep in the upper reaches which showed a gradual decline in the downstream areas.

2. Riparian zone, being an important component of the drainage basin has been recognised to be of immense importance in maintaining the health of stream ecosystems. In the present study, the physico-chemical characteristics of the riparian soil at different study sites revealed that the soils were of sandy texture making them more porous and had their pH on the alkaline side. The soil conductivity in general, exhibited a clear increasing trend downstream evidencing the anthropogenic influence and also the deposition of more fertile soil by the stream in downstream riparian corridor. Among the extractable cations, calcium was the most abundant at all the study sites. On an average, the order of the cations present in the riparian soil was Ca$^{2+}$>Mg$^{2+}$>K$^+$>Na$^+$ and generally the concentration of these ions increased while moving downstream along the riparian corridor. Extractable phosphorus was seen to maintain positive correlations with potassium and nitrite-nitrogen, which are generally of organic origin in the soil, suggesting that the availability and dynamics of phosphorus in the riparian soil is more linked to the organic components and their degradation in different seasons. The total extractable iron concentration depicted significant (P<0.05) correlations with Weil carbon suggesting that its availability is linked to the carbon pool in the soil. Among the study sites, Site 1 registered the highest average values of Weil carbon reflecting to the better health of the soil at this site. Among the inorganic forms of nitrogen, extractable ammonium-nitrogen was the most abundant and was fairly available at all the study sites during the study period. The three inorganic forms of nitrogen appeared to be in some sort of dynamics with
each other as the concentrations of ammonium-nitrogen and nitrate-nitrogen were negatively correlated. In terms of the concentration of different nutrients Site 2 was found to be most degraded which is attributable to excavation of the stream bed and bank materials at the site.

3. The present study on Doodhganga stream was carried out during the base flow/low flow conditions and is thus a reflection of the stream during these conditions only. Among the hydrological parameters flow velocity along the spatial downstream gradient registered a decrease which is attributable mainly to the orographic features. Among all the study sites, Site 1 was seen to have the highest average discharge mainly because of the diversion of water in the downstream reaches for irrigation and drinking purposes. Seasonally spring maintained the highest discharges at majority of the study sites because of the higher rainfall and also because of the spring thaw causing large snow melts. The broader geomorphological characteristics revealed that the Doodhganga stream belongs to order 5 with steep channel and basin slopes and moderate stream channel sinuosity. Using the criteria as suggested by Rosgen (1994) for stream classification, it was found that study sites 1 and 2 belonged to stream type ‘B’, Sites 3 and 4 belonged to stream type ‘E’ while as study sites 5, 6 and 7 belonged to the stream type ‘C’. It is pertinent to mention here that the Rosgen stream classification system was fairly applicable in case of Doodhganga stream. In addition, using the criteria of stream classification of UNESCO/WHO/UNEP (1996) the Doodhganga stream was classified as a “stream”.

4. The physical and the chemical characteristics of water in the stream reflect the climate and the physical, chemical and biological characteristics of the drainage basin and this was very aptly depicted in the present study on Doodhganga stream. The temperature profile of the water followed a trend similar to that of air with minimum in winter and maximum in summer. The pH of the water was always on the alkaline side and ranged between a minimum of 7.16 at Site 6 and a maximum of 8.77 at Site 2. Downstream there was an increasing trend in the average conductivity values, attributable to the increase of urban and agricultural land use in the downstream reaches. The turbidity values in the stream ranged between 0.99 NTU at Site 1 in December, 2005 and 139.40 NTU at Site 7 in June, 2005. Downstream there was an increasing trend in the average turbidity values, again a reflection of the increased agriculture and urban development in the downstream catchment areas. Seasonally all
the study sites with the exception of Site 2 depicted the highest average dissolved oxygen (DO) concentrations in winter which is due to the lower water temperatures in this season while as Site 2 maintained the highest average DO in autumn which may be attributed to the high photosynthetic activity of periphyton in the very shallow waters at this site. DO showed a decreasing trend downstream, being attributable to the increasing organic load in the stream. Downstream, there was a gradual increase in the average acid neutralising capacity, chloride, total hardness, calcium, magnesium, sodium and potassium levels—all indicating to the increased land area draining into the stream coupled with the increased anthropogenic pressures. On the basis of average total hardness values, Site 1 on the Doodhganga stream was classified as soft water type and Site 2 as moderately hard water type while as all other study sites were classified as hard water type. The dominance pattern of different cations in the Doodhganga stream water was \( \text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+ \), which is a feature most prevalent in Kashmir Himalayan waters. Spring season maintained higher DOC concentration which is attributed to its flushing from the surface organic soils due to frequent rains and snow melt water taking the surface shallow path. In general, there was a gradual downstream increase in average DOC concentrations which is attributable to the contribution made by the increasing land area feeding the stream. Among the inorganic forms of nitrogen, ammonium-nitrogen registered its highs during spring season due to its flushing from the catchment by frequent rains and snow melt water while as, on the other hand, nitrate-nitrogen peaked in autumn when ammonium-nitrogen was at its minimum, thus reflecting a dynamics between the two. A general downstream increasing trend in the inorganic forms of nitrogen was registered, pointing to the increased nutrient loading downstream. Soluble reactive phosphate-phosphorus maintained an increasing downstream trend and showed lower concentrations during spring season because of the dilution effect of increased discharge. Interestingly, Site 1 despite having increased discharge maintained higher phosphorus concentration during spring time which points to the fact that the snow melt seems to flush the phosphorus from the forest floor causing higher concentrations in spring at this site. So, the forest lying upstream Site 1 seems to be a net source of important nutrients which is due to the major deforestation caused in the recent years exposing the forest floor nutrient pool or else some of the forest stands have become aged or dead. Moreover, there was a general downstream increase in dissolved silica and sulphate concentration.
When the studied physico-chemical parameters of Doodhganga stream water were compared with the Indian standards for categorisation of surface waters in terms of surface water quality standards, it was found that all the parameters were within the Class “A” waters except for Site 6 where the average dissolved oxygen concentration satisfied the criteria for both Class “B” and Class “C” waters. As the data on the two important criteria parameters namely coliform count and biochemical oxygen demand was not available so, adopting a precautionary approach the Doodhganga stream water as a whole seems to be better placed in Class “C” surface water, which are waters fit as source of drinking water but must be used after conventional drinking water treatment and disinfection.

5. A taxonomic survey of the periphyton of the stream revealed a total of 141 periphyton taxa, with Bacillariophyta being the most taxa rich group as represented by 105 taxa followed by Chlorophyta with 17 taxa and Cyanophyta with 12 taxa in a decreasing order. The majority of periphyton taxa reported from Doodhganga stream appear to be very similar in composition to a number of studies from Europe and North America. A perusal of the data showed that at Site 1 the most abundant taxon was *Didymosphenia geminata* which has been recorded to be an invasive species in character and has been shown to restrict the distribution of other diatom and non-diatom taxa, thus affecting the stability of the periphyton community. Downstream, the study sites were dominated by the smaller but more motile diatoms, as these sites were affected by siltation which allowed better survival of these organisms. In general the major peaks in the periphyton growth of the Doodhganga stream were recorded in the early spring and late autumn months as is true for many streams in the northern hemisphere. However, the low growth of the community was recorded in April and in summer months because of the higher and more turbid discharge in the stream. Chlorophyll “a”, being an important indicator of the primary productivity, generally followed the density patterns of periphyton with its peaks in early spring (March) and in the late autumn (November) while the lows were registered in April. An important feature noticeable in the chlorophyll content was a general increasing trend in the average values downstream in accordance with the accelerated eutrophication of the stream. Periphyton has been recognized as a highly potent bioindicator depicting the short term influences in the stream ecosystems. In this context the metrics and diversity indices namely Species Richness, Generic Richness, Percent Motile Diatoms
and Fisher’s Alpha performed very well in depicting the changing physical and chemical characteristics of the stream. The present study has shown promising results in using periphyton as bioindicator of the stream health.

6. Among macroinvertebrates a total of fifty nine (59) taxa belonging to four phyla namely Nematoda, Annelida, Mollusca and Arthropoda and spread over thirteen orders/classes and forty two families were recorded from the entire stretch of Doodhganga stream. Forty eight taxa out of the total of fifty nine (59) taxa were represented by the phylum Arthropoda and the three arthropod orders namely Ephemeroptera, Coleoptera and Diptera had a representation of ten taxa each. The composition of the macroinvertebrate fauna of the Doodhganga stream at the family and genus levels seems to be very similar to the fauna as reported in other mountainous areas of the world. Along the downstream gradient there was an overall decrease in the number of taxa being attributed to the less favourable substrate present at the downstream sites besides the increased agricultural and urban land use in the catchment. Along the longitudinal gradient there was an apparent zonation in the stream based on macroinvertebrate distribution, with the upper reaches being dominated by Diptera and Ephemeroptera, the middle reaches by Amphipoda and Coleoptera and the lower reaches by Oligochaeta. In addition a definite seasonality in the density and diversity of macroinvertebrate fauna was noticed in the present study. In view of the River Continuum Concept (Vannote *et al*., 1980), the gatherer/collector community dominated the stream at all the sites with relative density ranging between 61.43% at Site 3 and 94.67% at site 7, which suggests that the organic matter of both allochthonous and autochthonous origin is readily available in the main water column throughout. Interestingly, the finer differences between habitats at different study sites were more aptly represented by the second dominant functional feeding group. The macroinvertebrate indices and metrics namely Total Number of Taxa, Number EPT, Number Ephemeroptera, % EPT, % Ephemeroptera, modified Hilsenhoff Family Biotic Index considered without Chironomidae and Oligochaeta, BMWP Score and ASPT score performed very well as bioindicators of changing physical and chemical conditions of the stream along the downstream gradient.

7. In order to categorise the stream into a distinct trophic category, the criteria as suggested by Dodds *et al*., 1998 was used, yet the study sites showed different categorization when different criteria were used. On the basis of total phosphorus
concentration in the water, Site 1 was categorized as mesotrophic while as all the other study sites were categorized as eutrophic. On the other hand, when the mean and the maximum benthic (periphytic) chlorophyll concentrations were considered, sites 1 and 2 were categorized as oligotrophic while the downstream study sites were categorized as mesotrophic with the exception of sites 4 and 5 which fell in the oligotrophic category. So, it can be concluded that although in general the increased nutrient enrichment downstream is indicated by this classification, there are some peculiar stream features which appear to complicate the classification of the stream into a distinct trophic category. Further, the enrichment criteria as proposed by Biggs (1995) was used and according to these criteria, it was found that on the basis of mean conductivity values uppermost Site 1 was categorized as un-enriched while all the other study sites downstream were categorized as enriched. On the basis of benthic (periphytic) chlorophyll ‘a’ concentration ranges, sites 1, 2, 4 and 5 were categorized as moderately enriched while the other study sites were categorized as enriched reflecting the better applicability of this scheme for Doodhganga stream.

8. An important focus of the present work was to understand how the stream physico-chemical and biological aspects reflect the changing land use/land cover characteristics of the drainage basin. In this regard highly relevant data was collected emphasising that ‘in every respect the stream reflects the valley’. Agriculture an important land use and being a direct manifestation of the anthropogenic use of land showed highly significant (P<0.05) positive correlations with water temperature, conductivity, turbidity, DOC, soluble reactive phosphate-phosphorus, dissolved silica, total iron, ANC, chloride, total hardness, calcium, magnesium, sodium, potassium and sulphate, thus indicating that with the increase in the agriculture land use the concentration of these ions and variables increases. On the other hand, blank forest and forest as land cover categories depicted highly significant (P<0.05) negative correlations with parameters namely water temperature, conductivity, turbidity, DOC, soluble reactive phosphate-phosphorus, dissolved silica, ANC, chloride, total hardness, calcium, sodium, potassium and sulphate showing that the water quality in the stream was better as the extent of forest land in the catchment increased. Built-up land use category is a direct result of urban land use and it recorded positive correlations (P<0.05) with water temperature, conductivity, turbidity, DOC, soluble reactive phosphate-phosphorus, chloride, total hardness, calcium, sodium, potassium
and sulphate. This trend implies that there is an increase in the different constituents of the stream water and also the water temperature as the urban land use increases. The physico-chemical variables of the Doodhganga stream water gave a vivid picture of the changing land use/land cover in its drainage basin.

9. When the periphyton diversity indices and metrics were considered in relation to the changing land use/land cover in the drainage basin it was found that agriculture and built-up land use classes were negatively correlated (P<0.05) with the Fisher’s Alpha for periphyton, thus indicating a decrease of diversity in the periphyton assemblages with the increase in the human influences in the catchment. Fisher’s Alpha was seen to show a positive correlation (P<0.05) with the forest land cover category indicating an increase in the periphyton diversity with the increase in forest land cover. Species Richness showed negative correlations (P<0.05) with agriculture and plantation land use classes, again indicating a decrease in the periphyton diversity with the increase in the anthropogenic activities in the drainage basin while as there were positive correlations of Species Richness with blank forest, forest and scrub land use/land cover classes. The use of periphyton as an important tool to reflect the changing land use/land cover in the drainage basin was found to be highly effective in the present study.

10. The correlations between land use/land cover attributes of the catchment and the macroinvertebrate metrics and indices, showed that agriculture land use is significantly (P<0.05) negatively correlated with macroinvertebrate metrics namely Number EPT, Number Ephemeroptera, BMWP Score, and ASPT score which are metrics whose values on a higher side is an indication of good stream condition. However, with the increase in the agricultural land use, there was a decline in their values, which indicate to the dwindling of stream macroinvertebrate community, and thus the health of the stream. The situation was totally in contrast when percent blank forest and percent forest land cover were considered and as such these land cover categories maintained positive correlations (P<0.05) with metrics namely Number EPT, Number Ephemeroptera, BMWP Score and ASPT score while recording a negative correlation (P<0.05) with Family Biotic Index being considered without Chironomidae and Oligochaeta. These correlations suggest that the increase in percent blank forest and forest land cover leads to an increase in the number of sensitive taxa. Percent built-up land use, which is a direct fallout of urban land use, was negatively
correlated with % EPT, % Scrapers, and ASPT score indicating to the diminishing of the stream macroinvertebrate assemblages with the increase in the urban land use in the drainage basin. On the other hand, the percent built-up land use was positively correlated (P<0.05) with Family Biotic Index when considered without Chironomidae and Oligochaeta which again indicates that there is an increase in the more pollution tolerant taxa with the increase in the urban activity in the drainage basin. The macroinvertebrate community in the Doodhganga stream was found to be highly reflective of the changing land use/land cover in the drainage basin.

11. Riparian corridors have been reported to influence the stream physical, chemical and biological characteristics and thus in the present study the influence of the dynamics of the physico-chemical variables of the riparian soil on the physico-chemical parameters of stream water was assessed. In this context the correlations between these two, on a spatial scale along the longitudinal gradient, showed no significant (P<0.5) correlations between the studied chemical attributes of the riparian soil and the stream water. The reason for this seems that along the downstream gradient in the stream water there is a cumulative effect in the chemical characteristics as more varied and larger land area drains into the stream and there is a continuity along the stream gradient while on the other hand, this cumulative effect and the continuity is lacking in the riparian soil which is mainly affected by the local soil properties and the land area impacting a particular site. However, when the correlations at P<0.05 level were considered on a temporal scale, it was found that although different study sites behaved differently yet there were marked significant correlations in respect of parameters like potassium, DOC, Weil carbon, sodium, nitrate-nitrogen, total and extractable phosphorus etc.

12. In the present investigation hydrological parameters namely flow velocity and discharge were seen to depict a complex behaviour vis-à-vis the physico-chemical characteristics of stream water. Downstream, along the spatial gradient, discharge maintained positive correlations with air and water temperature showing that discharge increases in the downstream gradient with the increases in temperatures mainly because of the melting of snow in the upper reaches. Their was an increase in the turbidity of water with the increase in discharge as depicted by the positive correlation of the two parameters. Discharge maintained a positive correlation with ammonium nitrogen along the downstream gradient which appears to be because of
the flushing of this nutrient from the agriculture dominated drainage basin during
higher discharges and thus increasing its concentration in the stream water. Flow
velocity, being an important component of discharge, maintained the expected
positive correlation with it. In contrast, discharge was negatively correlated with
nitrite-nitrogen, total iron, acid neutralizing capacity, chloride, calcium, sodium and
potassium which can be said to be because of the dilution effect of the increasing
discharge in the stream, so different nutrients varied in their behaviour vis-à-vis
discharge. On a temporal scale discharge again depicted a highly variable response
with other physical and chemical attributes of the Doodhganga stream as the
correlations were seen to vary at different study sites which may mainly be attributed
to the differences in the drainage basin characteristics impacting a particular site. At
majority of the study sites discharge maintained a positive correlation with air
temperature, water temperature, turbidity and flow velocity attributable to melting of
snow in the upper reaches during warmer months and more rainfall in the spring
season leading to higher discharge and consequent increase in flow velocity and
turbidity in the stream water. Generally, it has been seen that discharge maintains a
negative correlation with the concentration of major dissolved ions in the stream
water because of the dilution effect of higher discharge, and the same was the case at
almost all the study sites in the present study. But there were exceptions to this
generalisation which include a positive correlation of discharge at Site 1 with
parameters namely DOC, nitrate-nitrogen, magnesium and potassium. This seems to
be because the forest floor in the upper reaches is leaching these minerals and appears
to be a net source of these nutrients. Once the snow melt water takes the surface route
to reach the stream these minerals are flushed in to the stream leading to their
increased concentration with the increase in discharge. There was also a positive
correlation of discharge with nitrate-nitrogen at Site 2 and ammonium-nitrogen and
sulphate at Site 3 which may be due the flushing of these nutrients from the diffused
sources of agricultural land dominating the immediate catchment of these study sites.
The present study illustrates that there is a need to understand the role of stream
hydrology particularly discharge in regulating the other physico-chemical and
biological variables of streams in a local context and no generalisations should be
attempted in this regard.
13. While assessing the correlations between the physical and chemical features of water and the biological components (periphyton and macroinvertebrates) of the Doodhganga stream, clear trends were noticed which suggest that the water quality is an important factor shaping the biological community and conversely the biological community can be used as an important indicator of the water quality. In the present study among the periphyton diversity indices Fisher’s Alpha was negatively correlated with water nitrate-nitrogen, SRP, total phosphate-phosphorus, dissolved silica, ANC, total hardness and calcium while it was positively correlated with flow velocity indicating that with the increased load of minerals and nutrients in the Doodhganga stream water there was a decrease in the diversity of the periphyton assemblage. Among the periphyton metrics, Species Richness, Generic Richness and Percent Motile Diatoms seem to perform well. The Species and the Generic Richness as metrics displayed negative correlations ($P<0.05$) with major nutrients which indicate that with the increase in the trophic state of the stream water these metrics evince a decrease. Percent Motile Diatoms was a good indicator of increased siltation in the downstream stretches of the stream.

14. Correlations between the physico-chemical characteristics of water and the macroinvertebrate diversity indices and metrics showed well defined trends on spatial scale. The macroinvertebrate metrics like Number EPT, Number Ephemeroptera, and Percent EPT maintained negative correlations with the parameters which increased downstream like water temperature, conductivity, DOC, soluble reactive phosphate-phosphorus, total phosphate-phosphorus, dissolved silica, ANC, chloride, total hardness, calcium, magnesium and sodium. The decreasing trends of these metrics indicate the deterioration of the habitat for the more sensitive macroinvertebrate taxa in the downstream stretches of the stream. The negative correlations and the distinct trends for BMWP Score and the ASPT score with the different physical and chemical parameters of water are an indication that these two metrics were highly suited for assessing the health of Doodhganga stream.

15. Doodhganga stream is facing a number of ecological stresses as have been highlighted in the present study. These ecological stresses include:

i. In the upstream reaches of the stream there has been extensive deforestation in recent years and also the forest stands at many places have become aged, both
these factors contribute to increased nutrient and sediment loading to the stream, affecting the stream biota badly.

ii. The uncontrolled and massive dredging of sand and boulders in the stream, particularly round sites 2 and 5, is causing physical disturbance to the stream which further leads to the destruction of stream biota and also increases the turbidity of the water column. The dredging activity has induced siltation of the stream bed and has led to loss of aesthetic appeal of the stream in these areas. Also there has been destruction of habitat for fish in these stretches.

iii. The downstream stretches in the stream are under immense pressures from agricultural activities and urban runoff which have led to the deterioration of the stream water in terms of its physical and chemical properties with a subsequent deterioration of the biotic components of the stream.

iv. The diversion and extraction of large volumes of water from the stream for agricultural and drinking purposes has made the stream deficient in water particularly in the Site 2 area. The scarcity of water in the stream particularly during the lean period in terms of precipitation (late autumn and early winter) is squeezing the available habitat in the stream and is thus a major threat to the biodiversity sustained by it.

v. The hydropower project, which is under construction in the upstream Branwar forest area of the stream, may alter the hydrology and geomorphology of the stream with subsequent impacts on the biotic elements of the stream.

vi. The increasing agricultural and urban landuse in the catchment of the stream with the consequent degradation of land under forest, grassland and waterbodies is becoming a major driver for degradation of the stream.

vii. The riparian corridor of the stream, the health of which is a must for the ecological resilience of the stream, is under enormous anthropogenic pressures and has either been de-vegetated like in the Site 2 area or has been encroached upon by the urban structures in the downstream areas.

11.1. SUGGESTIONS AND RECOMMENDATIONS

The suggestions and recommendations emerging from the present study can be grouped under two heads. The first includes suggestions and recommendations in general for the lotic systems of Kashmir Himalaya and the second includes the
suggestions and recommendations for the restoration and management of Doodhganga stream in particular.

11.1.1. General Suggestions and Recommendations

- The role played by the riparian corridor in maintaining stream health needs further exploration and facets like the influence of land use/land cover, within the riparian corridor, on the stream physico-chemical and biological characteristics and how improvements in the riparian zone influences the stream need to be investigated. In general more studies are needed to be conducted on the linkages between streams and their drainage basins.

- The Rosgen stream classification (1994) has been found to be highly suitable for the morphological characterisation of Doodhganga stream. So, it is recommended that Rosgen stream classification be tested in other lotic systems of Kashmir Himalaya which will provide an effective mechanism for obtaining reproducible and comparable results for their better management.

- There is scanty literature available on the periphyton ecology of lotic systems in Kashmir Himalaya. Therefore, it is suggested that more studies on this aspect be carried out to elucidate the biodiversity of periphyton and its role in the functioning of stream ecosystems. The role of periphyton as bioindicator of water quality is well known and on the basis of results obtained in the present study, it is proposed that periphyton metrics and indices namely Species Richness, Generic Richness, Percent Motile Diatoms and Fisher’s Alpha shall be useful for lotic systems as a good bioindicator of stream health. In addition, studies are needed to be conducted on the distribution and abundance of invasive species like *Didymosphenia geminata* and their impact on the community structure of other biotic components and the general ecology of streams.

- The study of macroinvertebrates in flowing waters of Kashmir Himalaya is again a lesser known facet of stream ecology. It is therefore, suggested that additional studies be conducted on this biotic community with emphasis on studying both their temporal as well as spatial dynamics. The use of macroinvertebrates as bioindicator of stream health is a well tested and
favourite procedure among stream ecologists and on the basis of results obtained in the present investigation, it is suggested that macroinvertebrate metrics and indices namely Total Number of Taxa, Number EPT, Number Ephemeroptera, Percent EPT, Percent Scrapers, Family Biotic Index considered without Chironomidae and Oligochaeta, BMWP Score, ASPT score and Fisher’s Alpha shall be useful for lotic systems of Kashmir in general, as bioindicators of stream health.

- In recent times, worldwide an emphasis has been placed on characterisation of stream ecosystems into distinct trophic categories and the same is required in case of Kashmir Himalayan lotic systems. As evinced by the present investigation the trophic state classifications of Biggs (1995) and Dodds et al. (1998) may be used for all other Kashmir Himalayan streams for their trophic state characterisation.

- Of late, major emphasis is being given by the government and non-government agencies on the management of watersheds and millions of dollars are being spent on watershed management projects but worldwide very little information is available on physical, chemical and biological monitoring of restoration of streams and their catchments (Riley, 1998; Center for Watershed Protection, 2000). The present work has illuminated some of the facets in this regard, but the role of stream physico-chemical and biological components in monitoring the health of not only the stream proper but the entire drainage basin needs further elucidation, so that standardised procedures are worked out in this regard. An important facet of study would be to disentangle the influence of increasing land area draining into a stream in the downstream stretches and that of the changing land use/land cover and other anthropogenic impacts on the physical, chemical and biological aspects of streams.

- Among the physico-chemical parameters of water temperature, conductivity, turbidity, DOC, SRP, dissolved silica, total iron, ANC, chloride, total hardness, calcium, magnesium, sodium, potassium and sulphate were found to be highly indicative of the changing land use/land cover. These physical and chemical tracers can thus be used as indicators of changing drainage basin
land use/land cover and for monitoring the effectiveness of watershed management practices.

Considering the biological indicators, the different periphyton and macroinvertebrate indices and metrics performed differently in terms of their response to the changing land use/land cover categories. Among the periphyton indices Fisher’s Alpha and Species Richness were the more robust indicators and performed very well. On the other hand, among the macroinvertebrate indices and metrics Total Number of Taxa, Number EPT, Number Ephemeroptera, Percent EPT, Percent Scrapers, Family Biotic Index considered without Chironomidae and Oligochaeta, BMWP Score, ASPT score and Fisher’s Alpha were very indicative of the changes in the drainage basin land use/land cover characteristics. It is therefore, suggested that these metrics and indices can be used as bioindicators of drainage basin health and for monitoring the effectiveness of watershed management practices.

11.1.2. Suggestions and Recommendations for Doodhganga Stream

Few specific suggestions and recommendations for the management and restoration of Doodhganga stream are:

- The Doodhganga stream being an important source of drinking water for a large population needs to be managed as a public healthy priority and not as a channel for irrigation and it is suggested that the Public Health Department of the State be given charge of the stream besides all those waterbodies which are used as sources of drinking water for mass populations. This will ensure that drinking water of highest possible quality is made available to people at large.
- The catchment of the stream is highly prone to erosion because of the silty texture of the soil and thus, it is important to stabilise it by implementing afforestation and reforestation programmes.
- The riparian corridor, being a vital component of the stream, needs to be protected and encroachments on it need to be prevented.
In the populated areas of the stream catchment, provision of proper drainage system and waste water treatment facilities are needed to be provided which will help in preventing the direct inflow of sewage, sewerage and industrial effluents into the stream.

The use of fertilisers and pesticides/herbicides in agriculture/horticulture need to be kept to the minimum and an integrated management plan needs to be followed in this respect.

The dredging activity in the stream for extraction of sand and boulders needs to be monitored and all those sections of the stream which are transitional in terms of current velocity must be avoided for extraction purposes.

The Doodhganga Hydropower Project should only be proceeded with after carrying a proper environmental impact assessment, which is hoped to provide safeguards against the stream’s degradation.