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**CLIMATE CHANGE AND LOCAL PERCEPTION IN
RAJOURI DISTRICT, JAMMU REGION, WESTERN
HIMALAYAS, INDIA**



Thesis submitted to the
BHARATHIAR UNIVERSITY, COIMBATORE
for the award of
DEGREE OF DOCTOR OF PHILOSOPHY
in
ENVIRONMENTAL SCIENCES

by
Mohd Zeeshan
(Reg. No. 2012R029)

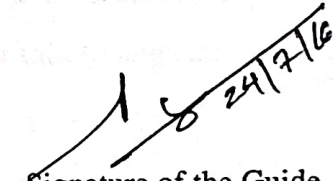


Sálim Ali Centre for Ornithology and Natural History (SACON)
(Aided by the Ministry of Environment, Forest and Climate Change, Govt. of India)
Coimbatore 641 108, India

August 2016

Certificate

This is certify that the thesis, entitled “CLIMATE CHANGE AND LOCAL PERCEPTION IN RAJOURI DISTRICT, JAMMU REGION, WESTERN HIMALAYAS, INDIA” submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Environmental Sciences is a record of original research work done by Mr. Mohd Zeeshan during the period January 2012 - July 2016 of his research in the Department of Environmental Sciences at Sálím Ali Centre for Ornithology and Natural History (SACON), Anaikatty, Coimbatore - 641 108 under my supervision and guidance and the thesis has not formed the basis for the award of any Degree /Diploma /Associateship /Fellowship or other similar title of any candidate of any University.


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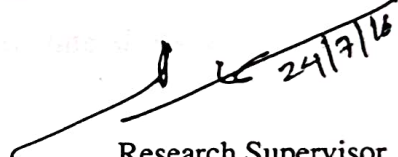
Declaration

I **Mr. Mohd Zeeshan** hereby declare that the thesis, entitled “**CLIMATE CHANGE AND LOCAL PERCEPTION IN RAJOURI DISTRICT, JAMMU REGION, WESTERN HIMALAYAS, INDIA**”, submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in **Environmental Sciences** is a record of original and independent research work done by me during **January 2012 – July 2016** under the Supervision and Guidance of **Dr P A Azeez, Department of Environmental Sciences at Sálim Ali Centre for Ornithology and Natural History (SACON), Anaikatty, Coimbatore – 641 108**, and it has not formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or other similar title to any candidate in any University.

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This is to certify that the Ph.D. candidate Mr Mohd Zeeshan working under my supervision has published / accepted for publication a research article in the refereed journal named **Environmental Monitoring and Assessment**(Vol. No ...! S.S..... Page Nos.... S.S.O.....) in the year of publication 2016 authored by Mohd Zeeshan and P A Azeez. The contents of the publication incorporates part of the results presented in his/her thesis.


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Chapter 1

INTRODUCTION

1.1 Global climate change

Climate change is a global issue with wide implications on the biosphere, environment, biodiversity, species survival and human well-being. Climate change affects all the important sectors of the economy, including agriculture, forestry, hydrology and water resources, natural ecosystem and biodiversity, coastal areas, settlement and health [1]. Several studies on climate change contain predictions of significant temperature increase and its negative effects on biodiversity [2]. The estimates of climate change vary depending on the specific climate models, the time horizon and the emission scenario used [3]. During 1880-2000 global land surface temperature increased by 1°C. Temperature in tropics and subtropics has increased 0.7-0.8 °C from 1950 to 2000 [4]. Climate models predict an increase in 1-2 °C warming in the tropics by 2050 and 1-1.5 °C by 2100 [5]. Uncertainty in climate change trend is greater for rainfall than temperature [6] and much greater for extreme events such as cyclones, floods and droughts [7].

A rise in 1 °C temperature is reportedly moving the ecological zones on earth by 160 km in Northern Hemisphere [8]. Earlier study on global temperature between 1861 and 1984 shows three warming years in 1980s [9]. In response to climate change in northern Hemisphere the range of terrestrial plants and animals has spread 6.1 km per decade northward in the past 50

years [8]. Climate change poses a serious threat mainly to the developing world especially the urban areas wherein more than 50% of the population lives in slum that is expected to rise in near future[10]. Climate change is a key driver of extreme weather events. Agriculture relies on natural resources and weather, thus being inherently vulnerable to climate change impacts [11, 12]. In India several studies have reported increasing trend of surface temperature during last century [13–20], insignificant trend in rainfall [21, 22, 16, 23, 6], and a significant decreasing/increasing trends in rainfall in regional basis [24–26, 17, 20]. All climate models predicted global surface warming trend under the influence of rising green house gases in the atmosphere that caused a rise in the melting of glaciers in Himalaya by 33-38% [27, 28, 20]. Generally warming influence the hydrological pattern and in Himalaya melting of winter snow occur in early spring leading to water scarcity in summer and autumn, a time when the demand is high [29, 30]. Water storage capacity is very less in regions like Himalaya due its topographic uniqueness. Therefore, consequence of hydrological changes for future water availability on a large section of population is likely to be severe. Himalaya, third largest in ice coverage, is critical globally and the rising glacier melting has negative effect on water supply especially in China and India [31], Bangladesh, Pakistan and other countries in the area. Natural melting cycle of glaciers in summer from Hindu Kush Himalaya (HKH) provide 70% of the summer flow in Ganges and 50-60% in other rivers [32].

1.2 Climate change, health and food security

Evidence of climate-health relationships shows increasing health risk under growing prediction of climate change [33]. Mortality of more than 150,000 people from 1975 to 2005 due to anthropogenic climate change is reported by World Health Organization. Health risks range from heat-related mortality and morbidity due to direct thermal stress to spread in the incidence of infectious disease [33]. Intense summer heat waves and drought can cause heat strokes, allergies and in extreme cases death [34]. The summer of 2003 with average 3.5°C above normal temperature was probably the hottest in the past 500 years in Europe [35]. During August of 2003, 22000 to 45000 deaths occurred across Europe [36, 37]. Decrease in crop productivity is reported in Central and South Asia due to climate change,

though the actual changes vary across the region [38]. Predicted climate change by 2050 will reduce agricultural production to 9% and 21% in the case of fisheries and aquaculture in the developing countries [39]. Malnutrition remains one of the largest health crises worldwide, especially in the underdeveloped regions, and according to the WHO currently there are approximately 800 million people who are undernourished [40]. Several studies in India predict fall in agriculture production in response to climate change although the specific impacts vary with crop, level of agronomic management, region and season [41–55].

1.3 International efforts on global climate change

The world's first climate change conference on "Climate and Mankind" was held 12-29 February 1979 in Berlin. After the discovery of ozone-hole in high latitudes, Intergovernmental Panel on Climate Change (IPCC) was established in 1988. It was established by two United Nations organizations (the World Meteorological Organization - WMO and the United Nations Environment Programme - UNEP) and later endorsed by the United Nations General Assembly, to study specifically climate change. Since then, IPCC has extensively covered studies on regional to global climate change under its different assessment reports. The reviews and assessments by IPCC, the leading non-profit international organization working with the help of scientist worldwide [4], are currently the most relied scientific information in public domain on climate change. The IPCC has three working groups, the first one focusing on "the physical science basis of climate change", second on "climate change impacts adaptation and vulnerability" and the third on "Mitigation of climate change" [4]. It had already published five assessment reports, of which the latest was in 2013/14. IPCC published its first and second assessment report in 1990 and 1995 respectively. These reports substantiate anthropogenic emission of gases causing climate change primarily from the burning of fossil fuels as the key driver for climate change. In fact, the works of IPCC, its findings, set the stage for Kyoto Protocol in 1997. Kyoto protocol is the first International legally binding effort to reduce six green house gas emissions (GHS) by developed countries to curtail climate change. It came into force in 2005 and was agreed upon and accepted in 2006. Targets set to reduce emission of GHS were so high that it needs individual level

engagement [56] and commitment. Since 1995 conference of the parties (COP) which is the supreme decision-making body of the convention reviews emission inventories submitted by the parties and assess the progress made in each year [57]. COP adopts and takes decisions to promote the effective implementation of the convention [58]. The recent COP 21 was held in Paris in December 2015, where in "Intended Nationally Determined Contributions (INDC)" was deliberated and largely agreed upon.

1.4 Climate change in the Himalayas

The Himalayas, unique in terms of geological and environmental settings, habitats, ecosystems and cultural diversity, is identified as highly vulnerable to climate change [20]. Therefore, adaptation strategies to cope with the repercussions of climate change in the region are vital. To evolve and formulate the adaptation strategies, intensive and extensive scientific information as well as the involvement of local inhabitants are highly important. In spite of climate change and its repercussions on the relevant geographical scale being widely debated for the past couple of decades, our understanding of the locals' knowledge base and perception about climate change or its consequences still is very little. Since last three decades, scientists across the world had widely covered climate change studies, its impact on land use and biodiversity. Despite debating for several years, the studies lacks documentation of local to regional changes due to climate, perception among the people and impact of climate change on vulnerable sector such as water and agriculture [20].

1.5 Perception on climate change among the public

Understanding local people's perceptions of climate change is fundamental to address the challenges of land conservation and poverty alleviation [59]. Practical knowledge of climate research needs to ensure the diverse policymakers and the public understanding on the risks and uncertainties relevant to the physical, biological and social processes [60]. Broadly, strategies to reduce green house gas mitigation and adaptation efforts at the ground level require literacy on climate in a society [61]. Analyzing local observations reconnects with the natural world and that would benefit and improve climate literacy in a society [62]. As

Himalayas are vulnerable to climate change, local and regional climate change indicators are valuable for adaptation planning that should directly recognize the experience of local communities [62]. This can deepen the relation between local and global climate change and support adaptation and mitigation strategies. The Himalayas suffers from data deficiency on climate change at local and regional scales. It is in this context that the present study was undertaken, basing on the following questions / objectives, selecting the Rajouri district as the study area.

1. Do the records / data from the observatory stations and satellite sources show any information relating to climate change for the district, and if yes, what is the range of variation from the regional to a global level?
2. Have the local people observed changes in climate, and if yes, what are their perceptions and experiences relating to the changes in the area for the past three decades?
3. Do climate records agree with the perceptions of local inhabitants in the Himalayas?
4. Are the youth aware of climate change and its impacts, and does the formal education systems there encourage them to engage in environment-friendly activities?
5. Does climate change impact vulnerable sectors such as water and agriculture?

The thesis that consolidates the work is presented in six chapters including the introduction and study area. A brief summary of the whole is also presented at the end.

Chapter 2

STUDY AREA

2.1 Brief history, physiography and population

Until 1967, Rajouri was part of Poonch district in Jammu & Kashmir (J&K) state of India. In order to have further development on 2 September 1967, Rajouri was bifurcated from Poonch district. The district covers an area of 2630 km² as per the state revenue records. Rajouri remained an area of great importance as it has linkage to Mahabharata. Historians identify Panchalaya Desha to Panchal range of mountains and Rajouri was a part of that kingdom. According to the Chinese traveller Hieren, who visited the area in 632 AD, Rajouri was then known as Rajapuri i.e. “the land of kings”. According to F. E. Pargitor, second branch of Aryan immigrants crossed Himalayas in the north and west and settled in Rajouri and Poonch areas. Albaruni in his book “India” wrote the name of Rajouri as Rajavari. Same name was given by Srivar who wrote “Rajatarangini”. With the passage of time this name changed from “Rajavari” to “Rajapuri” and finally to the present day name i.e. “Rajouri”.

Further to the bifurcation of the Pooch district, the district Rajouri is demarcated as lying at 33° 22' to 33° 14' N and 74° 7' to 74° 39' E (left to right) and 33° 34' to 33° 6' N and 74° 20' to 74° 21' E (top to bottom, Figure 2.1). Rajouri town lies towards West of the Jammu city (150 km), J&K, Western Himalayas, India. The district, covering an area of 2630 km², is characterized with the Pir Panjal region, mountainous terrain and valleys,

and topography ranging in altitude from 460 to 3900 mASL. Forest cover in the district is 1,267 km². The district features mountain ranges running from northwest to southeast. The terrain is undulating with high peaks and dissected valleys, separated from Kashmir valley by the Pir Panjal range in the north-eastern side. The climatic, topographic, geological and altitudinal variations have generated its unique landscapes. Rajouri is subdivided into seven tehsils (administrative divisions), eight blocks (administrative subdivision lower to the tehsil) and 160 panchayats (the lowest unit of administration, also known as village council). The district population, 483284 in 2001, has increased to 619266 (91.85% rural and 8.14% urban) in 2011 [63], a decadal growth of 28%. The major languages spoken in the district are Urdu, Pahari and Gujjari.

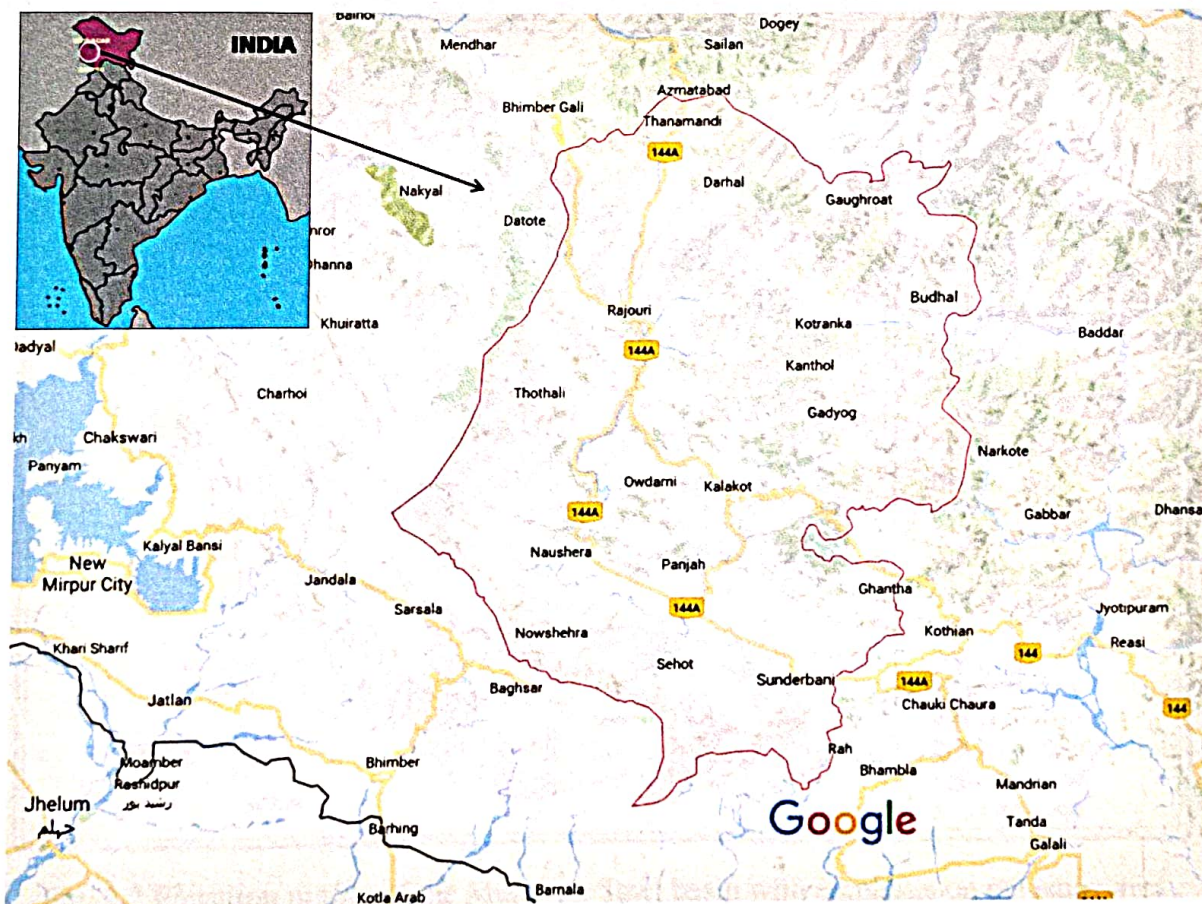


Fig. 2.1 Study area and its environs

Rajouri town and its outskirts, with 5663 houses and 35995 people [63], is the most populated area in the district. The district is drained by several perennial and many more

streams that are ephemeral referred to as “nullah” in vernacular. Of these, Nullah Thanna, Nullah Darhal, Nullah Ans and Nullah Kalakote, tributaries of Munawar Tawi are perennial. The area is endowed with several springs, brooks and rivulets that join the Munawar Tawi. People in Rajouri town and around depend on Munawar Tawi for their domestic, livestock and irrigation needs. Munawar Tawi, originating from the Pir Panjal range of Thanamandi and Darhal, flow towards south entering Rajouri town Figure 2.2. Then it takes a turn towards east to enter Chingus, and then turns towards south through Nowshera and Sehot entering Punjab of Pakistan via a place called “Kot Maira”. After 162 km from Rajouri town, Munawar Tawi joins Chenab as a right tributary at the place called “Marala” in Pakistan.

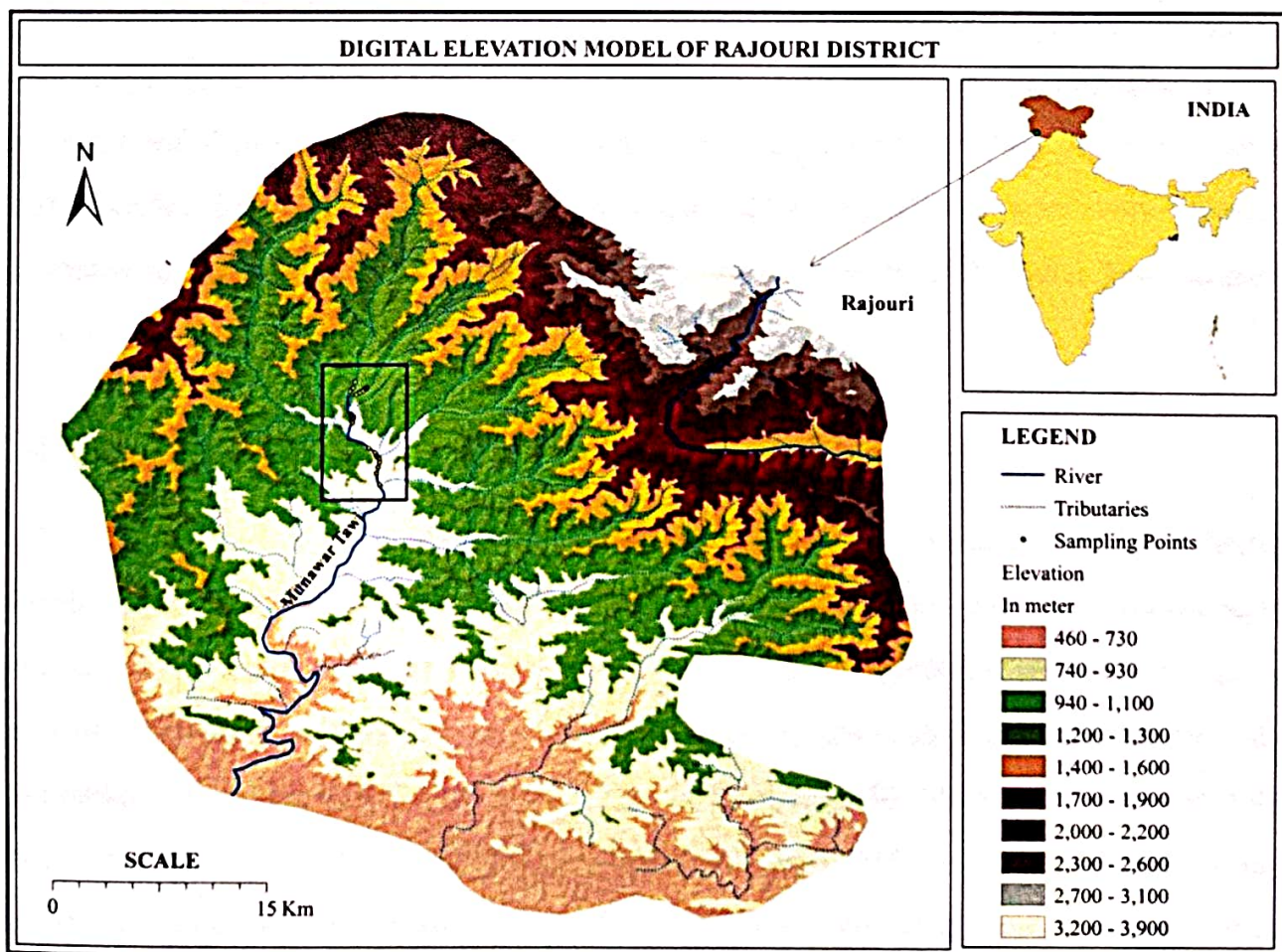


Fig. 2.2 Elevation profile of the Munawar Tawi basin with emphasis on the study area

2.2 Geology

Geological formations of Rajouri district vary from older metamorphic and crystalline in upper north to Murree group and Siwalik towards south in Rajouri town and its surroundings, it is predominantly Murrees. About 80% of the district is covered by Murree group of rocks (pink sandstone and clay) of late Eocene to the early Miocene period [64]. A geological map of the district is shown in Figure 2.3.

2.3 Climate

The climate of Rajouri district ranges from semitropical in the southern part to temperate in the mountainous northern part. Rajouri town falls in the temperate region. The district receives rainfall from the south-western monsoon during June to August. Average annual rainfall varied from 689 to 1293 mm/year during 2002 and 2014 respectively. During November to March, the northern part particularly the catchment of Munawar Tawi receives heavy snowfall.

2.4 Agriculture

In J&K, 65% of the population depends on agriculture for livelihood. In Rajouri district as well, the economy is primarily based on its agriculture with rice, wheat and maize being the major crops. Cereals, Bajra, Millets, pulses, green leafy vegetables, condiments, spices, and fruits such as guava, mango, banana and walnut are also cultivated [65]. Of the total land under cultivation in the district, 47.6% is under maize, 46.3% under wheat and 5.4% under rice, bajra (pearl millet - 0.56%) and other millets (0.03%) [65]. Maize is cultivated during April and May in upland areas far from irrigation. Wheat is sown during October - November and reaped in April - May. Paddy, raised close to the streams and river, mainly starts with the onset of south-western monsoon (May - June). Paddy and Maize are reaped in September and October. Average yield of rice in Rajouri was lower than the average for the whole India during 2000 to 2011 [66]. During 2011-2012, average yield of maize in Rajouri was higher than that of India [67], whereas average yield of wheat is lower than the Indian

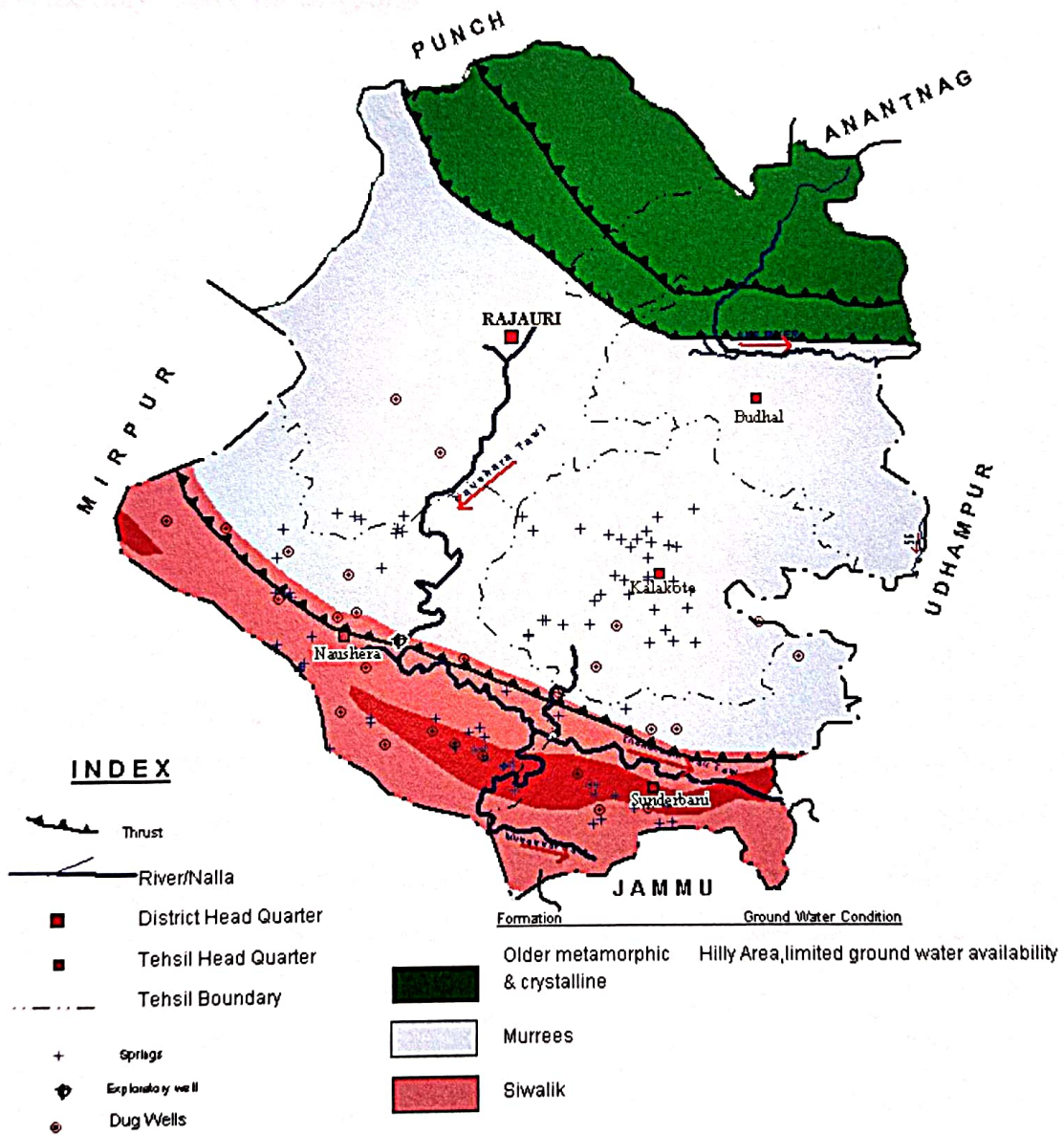


Fig. 2.3 Hydrogeology of Rajouri district (Not to scale), Source Central Ground Water Board, Government of India, 2013

Chapter 3

CLIMATE CHANGE AND LOCAL PERCEPTIONS

3.1 Introduction

The fifth assessment report (AR5) by the Working Group two (WG2) of the Intergovernmental Panel on Climate Change (IPCC) reported, at country scale in South Asia a trend of increase in the annual mean temperature [69]. The AR5 under its Asia supplementary material, based on studies undertaken in India [70, 19, 71], reports an increase of 0.56, 0.68 and 0.0056°C from 1901 to 2009, 1880 to 2000, and 1948 to 2008 respectively. However, several regions in Asia, in fact, lag behind in temperature monitoring and need to expand coverage for reasonably assessing the trends. The AR5 also reported seasonal mean rainfall in South Asia showing inter-decadal variability with a trend of decline that varies across regions. In India, the annual rainfall, monsoon rainfall and rainfall in each month during monsoon show insignificant trends from 1901 to 2009 [19]. Though the fall in rainfall in the winter (January-February) and rise in the post-monsoon (September to December) are reported for the subdivisions that includes Jammu & Kashmir (J&K), however records of precipitation in the region are poor to draw sound conclusions. The Himalayas, one of the world's biodiversity hotspots, is highly vulnerable to climate change effects [31, 72]. It is

undergoing rapid environmental changes with the on-going exploitation of various resources [73], regardless of worldwide recognition of its unique biodiversity, exceptional cultural heterogeneity, geological and ecological vulnerability, and its critical role in Asian climate and hydrologic cycle. Flash floods [74, 75] and the subsequent casualties in mid-June 2013 [76] are widely cited as instances of the repercussions of unrestrained alterations in the region. The human impact of climate change would be severe in the Himalayas as it is the source of eight major rivers sustaining 1.4 billion people [77]. Nevertheless, there is a lack of systematic analysis of the specific impacts of the changes on Himalayan ecosystem, biodiversity, and livelihood [78].

Air temperature and snow cover variability are sensitive indicators of climate change [79]. Studies on glaciers over the Hindu Kush, Karakoram and Himalayas reported significant thinning from October 2003 to 2009, highest in J&K (0.66 ± 0.09 m per year) and lowest in Karakoram (0.07 ± 0.04 m per year, Käab et al. [80]). Glacier cover in Zaskar valley, J&K has reduced by 15 km^2 (2%) from 1962 to 2001 [81]. However, studies on glacier change in the Indian Himalaya suffer from a level of uncertainty due to inadequate resolution of data [82]. Realistic conclusions can only be drawn using data with sufficiently higher resolution. In this regard, the contentions particularly relating to the projected date of melting of the glacier [83] reported in the earlier IPCC report (Fourth Assessment) is worth recalling [84]. Despite the well-acknowledged high sensitivity of Himalayan snow and glaciers to climate change, hardly a few studies have been carried out on them [85–88]. On the small glaciers and ice caps in Indian Himalayas, which are the source for several rivers, sustaining millions of human lives, studies are even lesser.

Global average temperature increase for the past century was 0.8°C and since 1975 to 2005, the increase is 0.6°C [89]. In the Himalayas, the average temperature has increased by 1.5°C ($0.06^\circ\text{C}/\text{year}$) and precipitation has increased by 163mm ($6.52\text{mm}/\text{year}$) from 1982 to 2006 [78]. A significantly increase in winter, monsoon and annual temperatures and decrease in the monsoon precipitation was observed for north-western Himalaya from 1866 to 2006 [90]. In Gulmarg and Pahalgam in Kashmir valley, the temperature has increased by an

average of 1.7°C from 1981 to 2010 [91]. Studies have also shown a hike in temperature and fall in rainfall in some localities in high altitudes [31, 92]. As observed by Piao et al. [93] for more accurate and realistic prediction of the changes, regional climate simulation (especially temperature and precipitation) and attempts to model the responses of crops to diseases, pests and atmospheric components consequent to the changes need to be much strengthened.

As regards climate change adaptation, it is essential that the local public is made aware of the implications, and the adaptive strategy is developed in consultation with them, drawing from their traditional knowledge base conjointly with external expertise. Some of the studies [94–102] stressed the need to consider local knowledge to improve understanding of climate change and its long and short term implications. Taking on board local inhabitants in the process of evolving adaptation actions could help in drawing upon the traditional wisdom to enrich and strengthen policy formulations. Moreover, seeking public participation and their opinion would help in democratization of policymaking process and in taking prudent decisions on people's collective future [103]. However, no much comprehensive studies have been undertaken on the Western Himalayan local knowledge on the environment. Generally, the local understanding is rarely given due attention by the experts formulating solutions [104] against such broad changes. It has been suggested that a synergy (see, for example, Few et al. [105]) of local understanding and external expertise would be crucial for effective climate change adaptation.

In that context, the present study examines the actual climate data as well as the local people's perception and engagement towards climate change. The district Rajouri in the Western Himalayas, J&K was selected as a model. We address the following questions in this study:

1. Do the climate records (as per the ground observatory stations and satellite records) show changes as seen in other regions worldwide,
2. Do the local people perceive climate change and related environmental variables for the past three decades?

3. Are the locals perceiving climate change (the risk associated) engaged in adaptation actions
4. Does the perception vary from rural to the urban population and according to the socio-economic status?
5. Does the local people's perception on climate change agrees with the climate records of the area?

3.2 Study Area

The detail is provided in chapter 2.

3.3 Methods

3.3.1 Household survey

The household survey was conducted using a questionnaire that consists of three sections; first and second sections structured with fixed choices as answers and the last section open for descriptive answers from the respondents (Appendix A). The first section included nine questions gathering the respondent's perception on the change in rainfall, temperature, wind speed, humidity, pollution, trees, traffic, crop productivity and crop varieties for the last three decades. The second section on engagement, adapted from Bohensky et al. [106], had three questions for knowing household level engagements against climate change. The questions on engagement are based on a conceptual model that involves three interconnected spheres; cognitive, affective and behavioral [107]. These spheres stand for what one knows, how one makes sense of the knowledge and what actions one takes towards it. The third section in the questionnaire contains three questions for the respondents to describe the action they have taken, their views on climate change in the area and suggestion if any to improve the environment / adaptation actions to climate change. The survey was conducted using students, who attended an environmental awareness development program that we had conducted. The students were sensitified to fill each question getting answers from parents or elders at home.

To select the students to assist in the survey, from the list obtained from the chief education officer, schools were shortlisted in a stratified random manner based on the location of the schools (urban vs. rural) and its status (public vs. private). The selected schools were then visited with an order issued by the Director, School education (Division Jammu) to ensure cooperation from concerned officials and teachers. Then, nine higher-secondary schools capable of facilitating the awareness development program and provide administrative help were selected. Of the nine, five were urban schools and four rural, while six were government-funded (public) and three private. The urban schools have students from almost all areas of the district (but the parents / guardians living in the city) whereas rural schools have students from the respective tehsils where they are located. The project was run jointly with an awareness development program, and only students from 11th and 12th standards were selected for the survey. After duly training them on filling the formats, the questionnaire in vernacular was handed over to gather their parents'/elders' perceptions on climate change and their engagement in related matters. The process also served another purpose; students were urged to have discussions with parents to get to know about the traditional knowledge on local environment and the climate change. Interaction of the students with their parents, on an issue not of day-to-day family talk, was considered to aid in shaping and expanding their views on climate change in order to inspire them for actions for adaptation to impending changes.

The survey was conducted from July to November 2013. Students were selected so as to represent each block (or the Panchayat) of the district. The blocks in the district were classified into urban and rural based on data from district statistical office. Of the eight blocks in the district, one was urban and seven rural. The respondent's age, gender and village name were recorded. The students engaged in getting the responses from their parents or grandparents were trained to ask the questions in an appropriate manner. Randomly selected students from the group were evaluated for their performance in filling the questionnaire. The students were instructed to ensure that the respondents are above 40 years age, residents of the area, are of the healthy mental state, and gave their informed consent to record their

answers. Similar criteria were found adopted in another recent study [108]. Of the 738 respondents, while 660 fulfilled the criteria, only 618 respondents answered all questions.

3.3.2 Historical climate data

Mean monthly, minimum and maximum monthly temperatures, and precipitation in Rajouri from 1901 to 2002 were obtained from the Climate Research Unit (CRU) TS2.1 dataset. This data set is gridded (latitude - Longitude grids) at a $0.5^\circ \times 0.5^\circ$ spatial resolution [109]. Additionally, daily maximum and minimum temperature and rainfall data, available only from January 2000 to December 2014, was obtained from the district Agrometeorological observatory station. However, the dataset was found missing the following: maximum temperature from January to May (in 2000 and 2004); minimum temperature in January (in 2002, 2004, 2005 and 2006), February to May (in 2000, 2002, 2004 and 2005), June to August (in 2002 and 2005), September (in 2001, 2002 and 2005), and October to December (in 2001 and 2005). Data on daily maximum and minimum temperatures and rainfall was converted into mean monthly and yearly values for regression analysis, since the data for 1901 to 2002 was available in that format.

3.3.3 Statistical analysis

Answers to the questions in the questionnaire were coded for the analysis. Answers on perception were coded as “increase” = 3, “decrease” = 2, “erratic” = 1 and “no change” = 0. Answers on the respondent’s engagement (questions 1 and 3) were coded as “yes” = 1 and “no” = 0, while for question 2 “some” and “high” were changed to “yes”, and “none” was changed to “no” and accordingly the respective numbers were assigned to each. To test the significance of school type and location, linear mixed model (LM) was used on the summed values for the answers on perception and engagement separately. Schools were included as a random component because that is only a broad indicator of parents’ status that may differ in their effect on parents’ perception on a global change and environmental awareness for reasons other than those that we were testing. We tested the importance of predictors using

Likelihood Ratio Tests (LRTs) on nested models [110]. Linear mixed effects modeling was performed using the `lmer()` function in the `lme4` package [111].

We focused on the individual responses, considering each question independent. To test the significance of school type, and location on individual answers on perception and engagement, Generalized Linear mixed models (GLM) were used. Answers were categorized into two: binomial variable for the answers on engagement, and ordinal variable for the answers on perception to climate change. Ordinal variable analysis on the answers on perception and binomial variable analysis on the answers on engagement were performed. We further performed binomial variable analysis on each answer under the questions on perception. If the question was answered (regardless of what the answer is), a score of 1 was given, whereas no answer merited a score of 0. We used the same set of fixed and random predictors used for the summed variable analysis. The response variable was changed from binomial to Poisson for ordinal variable analysis. We ran the models using the `glmer()` function in `lme4` package of R (version 3.1.2). GLM runs Wald tests on the predictor estimates, which we used to evaluate significant fixed effects directly without reverting to likelihood ratio tests.

Linear mixed model was also used for regression analysis to test the significant change in the temperature and rainfall, maximum and minimum temperature from 1901 to 2002 and the period from 2000 to 2014. All analyses were conducted using R (version 3.1.2).

3.4 Results

All the respondents reported observing changes in climate and other environmental features during the past three decades (Figure 3.1). More than half of them reported increase in temperature (68.2%), rainfall (55.5%), and humidity (65.2%). They also reported increasing deforestation (68.7%), crop productivity (64.1%), environmental pollution (84.5%) and vehicular traffic (87.2%). The answers for the questions on perception categorized into urban or rural and public or private schools are presented under Figures 3.2a, 3.2b, 3.2c and 3.2d.

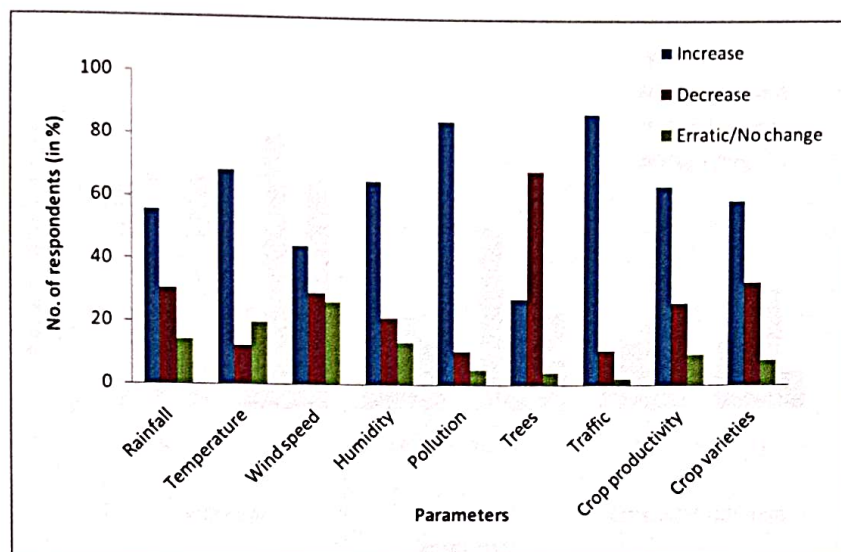
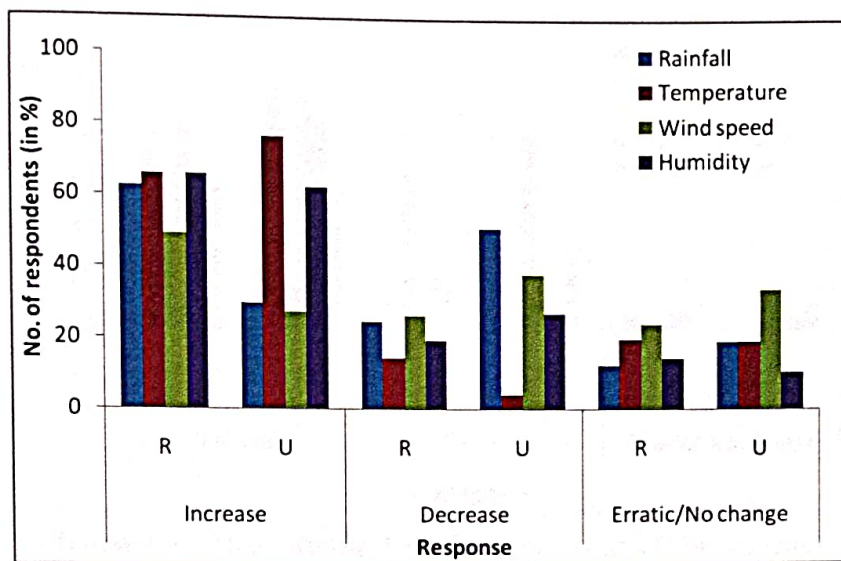
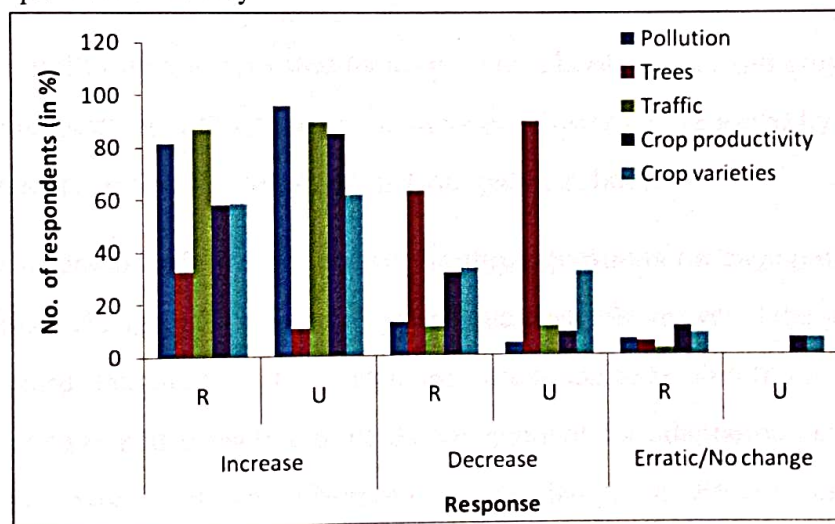


Fig. 3.1 Overall response to the questions on their perception on climate change (in percentage)

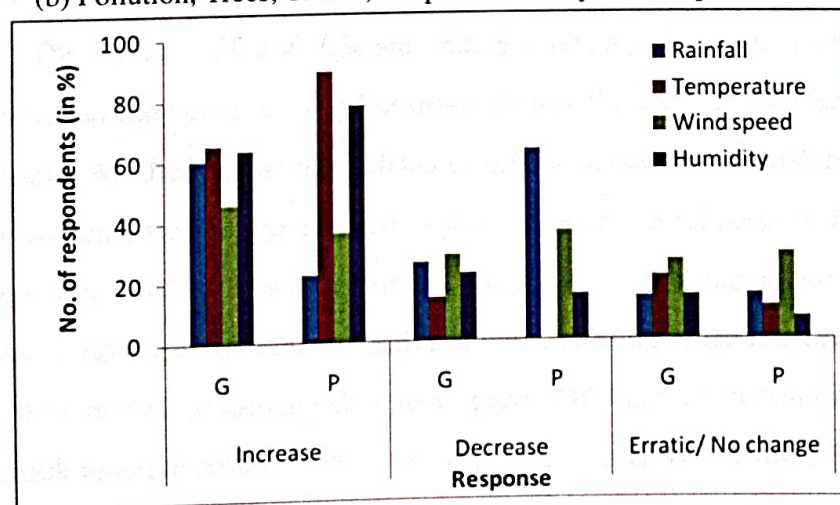
Of the rural respondents, 62.4% reported increase in the rainfall whereas 51.1% urban respondents reported decrease. Temperature is reported to increase by 76.6% from urban and by 65.9% rural respondents, significantly differing in their perceptions. The increase in the wind speed was reported by 49.1% rural respondents while 38.3% urban respondents reported a decrease. In this case also, the rural and urban respondents significantly differed. No significant difference was found between these two types of respondents in the case of atmospheric humidity. The increase in pollution and traffic was reported by a high percentage of both urban and rural respondents. Decrease in the number of trees was reported by 89.6% urban and 62.7% of rural respondents. Increase in crop productivity is reported by 85.1% of urban people while only 57.9% rural people reported the same. No noticeable differences were seen in responses on crop varieties in between urban and rural respondents. Notable variations in responses were found between the parents of public school students and the parents of private schools. For example, on rainfall, there were conflicting observations. Sixty percent (60.1%) of the parents of students studying in public schools reported a rise in rainfall while 63% of those from private schools reported fall. Temperature increase was reported by 89.3% private than 65.1% public schools. Increase in relative humidity was reported to be higher more by private (77.8%) than public (63.3%) respondents. Increase in



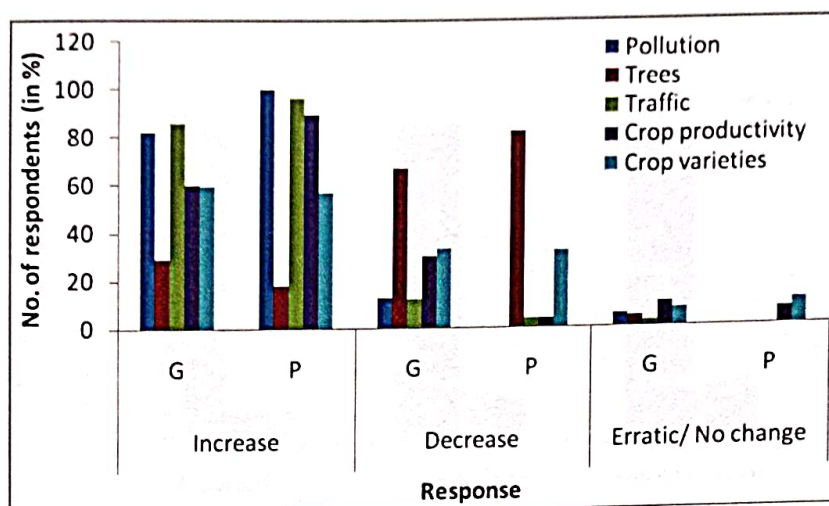
(a) Rural (R) Urban (U) respondents on Rainfall, Temperature, Wind speed and Humidity



(b) Pollution, Trees, Traffic, Crop Productivity and Crop Varieties



(c) From Government (G) and Private (P) schools on Rainfall, Temperature, Wind speed, and Humidity

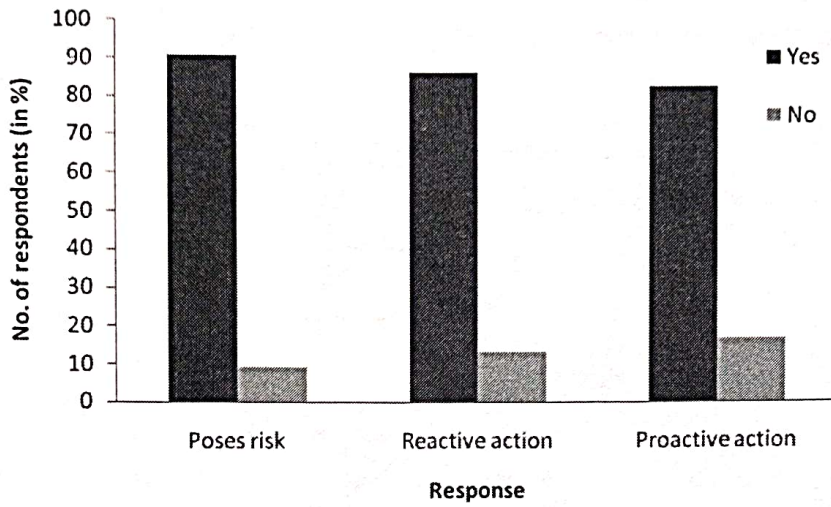


(d) Pollution, Trees, Traffic, Crop Productivity and Crop Varieties

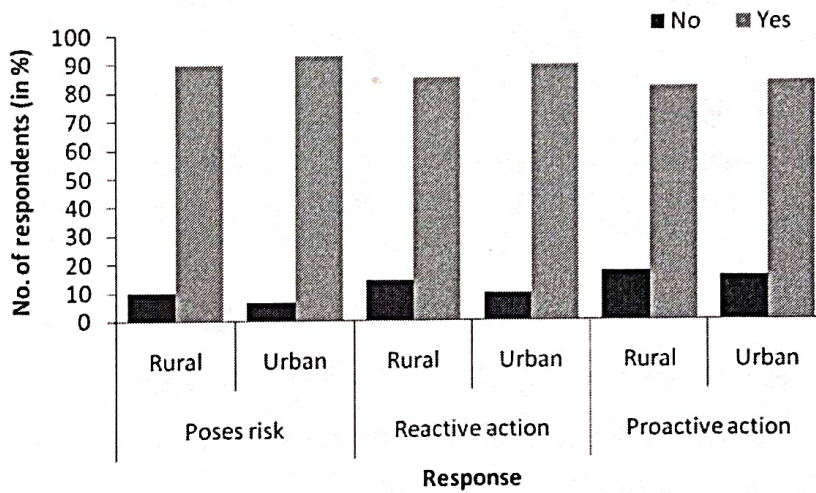
Fig. 3.2 Responses to the questions on perception on climate change

environmental pollution was reported by all private school parents and only 82.2% of the public school respondents. Decrease in the number of trees was reported by 82.1% private school respondents and 66.7% respondents from public schools.

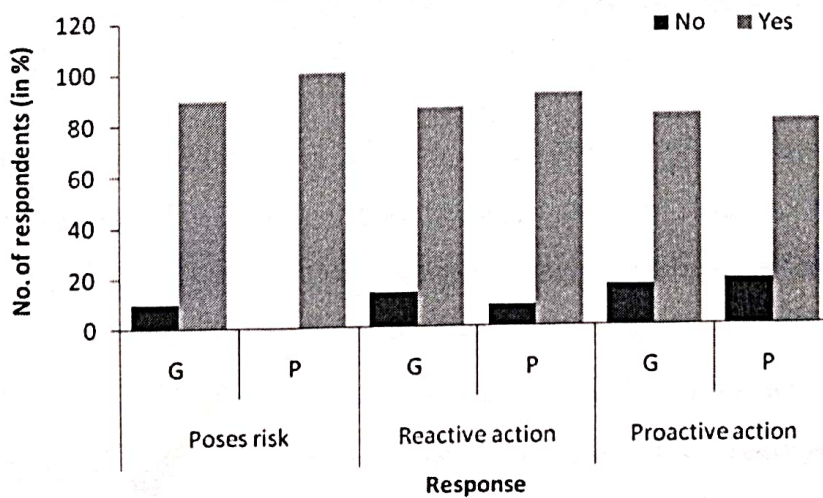
Of the 738 persons who responded to the three questions on engagement in actions relating to climate change, 630 answered the first question, 591 answered the second, and 606 answered the third. People, from their responses, are found to be alert to the risk associated with climate change and proactive towards engagement for adaptation action to climate changes. Of the respondents who observed climate change, 90.9% view climate changes as a risk, 86.8% are willing to take reactive action and 83.1% are taking proactive action (Figure 3.3a). The figures 3.3b and 3.3c summarizes the answers on peoples' engagement, according to whether they are from rural or urban area or their wards are studying in public or private schools. All the parents of students in private schools, and 90% from the public schools perceived climate change as a risk. Of the private school parents 91% and of the public school parents 86% took reactive action. Similarly, 83% of the public school parents and 81% private school parents took proactive actions. Among urban respondents 93% and rural parents, 90% perceived climate change as a risk. Of this, 91% urban parents and 86% rural parents took reactive actions. Of those who took to reactive actions, 84% urban and 83% rural took proactive actions.



(a) Overall



(b) Rural (R) vs. urban (U)



(c) Government (G) vs. private (P)

Fig. 3.3 Responses for the questions on engagement to climate change

Table 3.1 Results of the generalized linear mixed models testing the responses to the questions on perception of the parents / adults on climate change with respect to their wards' school type and location

Features	Change	Random effects (standard deviation) Schools	Fixed effects (regression estimates)			P<
			Intercept	Private	Urban	
Rainfall	Increase	0.483	0.008	-1.003		0.05
Temperature	Increase	0.564	0.345	1.717		0.01
Wind speed	Increase	0.136	-0.297		-0.902	0.001
	No change	0.849	-2.953	-0.995	0.928	0.001
Pollution	Increase	0.53	0.938	1.567		0.05
Trees	Increase	0.652	-0.993		-1.499	0.01
	Decrease	0.058	0.159		1.353	0.001
Traffic	Increase	0.48	1.134	1.37		0.05
Crop productivity	Decrease	0.951	-2.034	-1.944	0.115	0.001
Crop varieties	Not sure	0.485	-3.775	1.493		0.05

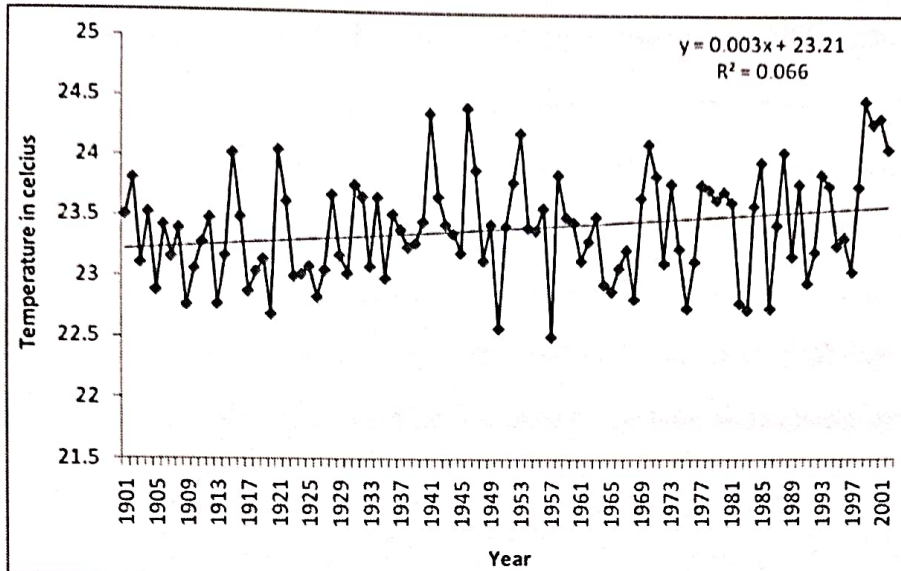
Summed variable analysis for answers on both the sections in the questionnaire, ordinal variable analysis on perception and binomial variable analysis on engagement, showed no significant differences among the answers. Binomial variable analysis for the answers under perception to climate change showed significant results for an increase in rainfall, temperature, wind speed, environmental pollution, trees, traffic, a decrease in trees, crop productivity, no change in wind-speed and erratic crop varieties with respect to school type and location (Table 3.1).

Mean temperatures, for the period 1901 to 2002, showed a significant decrease for the months of February, March, April, November and December, and a significant increase for the month of August (Table 3.2). Average rainfall for the months of March and November, as well as annual rainfall, showed a significant increase (Table 3.2). The mean maximum temperature significantly increased for February, March, November and December, whereas it decreased for July and August (Table 3.2). The minimum mean temperature increased significantly across the years, particularly for February, March, April, November and December and it

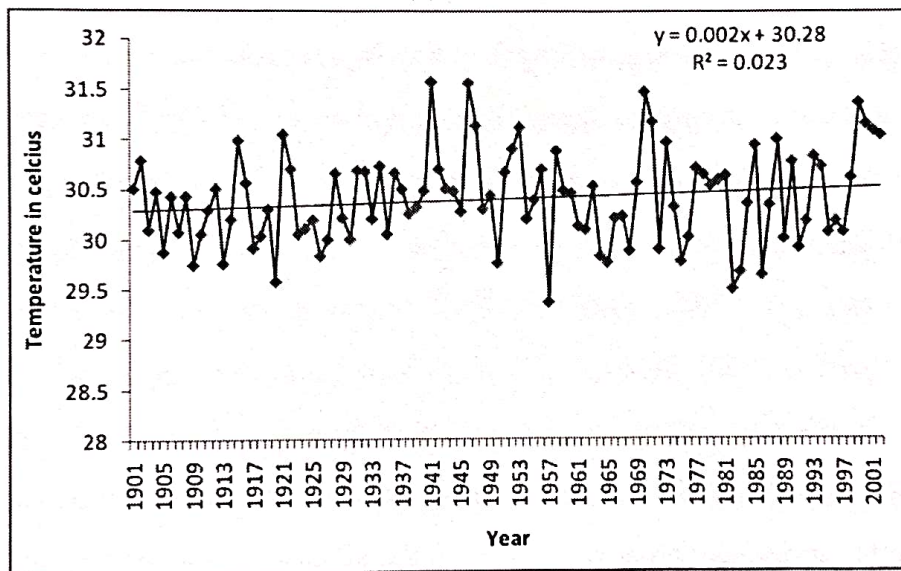
decreased significantly for August (Table 3.2). The variations in mean annual, maximum and minimum temperature are shown in Figures 3.4a, 3.4b and 3.4c. During the period, 2000 to 2014, the mean annual maximum temperature, monthly temperature from August to November, and minimum temperature in December showed significant decrease (Table 3.3).

Table 3.2 Significant changes in mean temperature (including maximum and minimum) and precipitation annually and in different months during 1901 to 2002

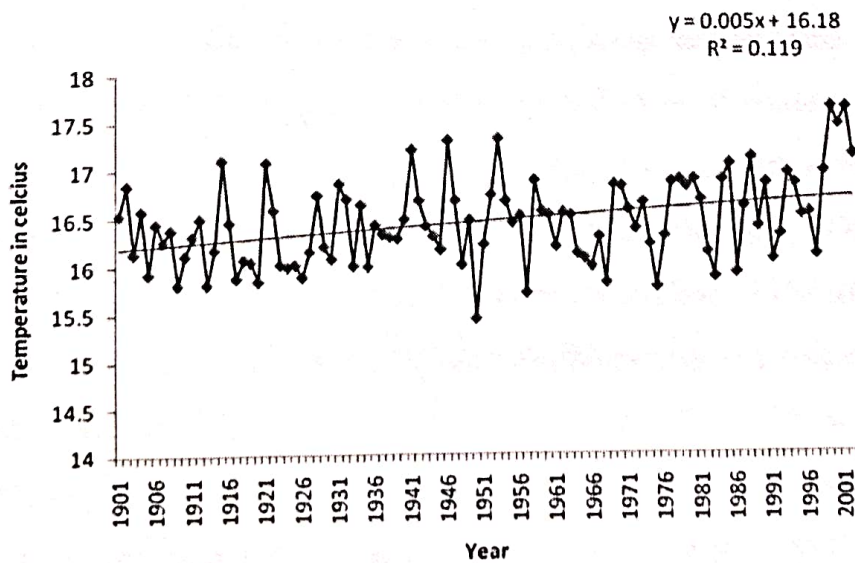
Factor (Y)	Regression estimates (Factor X = years from 1901 to 2002)		R ²	P
	Intercept	Slope		
Mean temperature				
February	-13.021	0.014	0.076	0.003
March	0.309	0.01	0.039	0.026
April	-1.826	0.014	0.064	0.006
August	41.764	-0.006	0.062	0.007
November	4.812	0.007	0.047	0.016
December	-0.898	0.007	0.058	0.008
Annual	15.946	0.004	0.057	0.009
Precipitation				
March	-453.22	0.258	0.057	0.009
November	-165.536	0.089	0.057	0.009
Annual	-184.543	0.129	0.043	0.02
Maximum temperature				
February	-6.505	0.014	0.061	0.007
April	8.003	0.013	0.049	0.015
July	53.587	-0.009	0.093	0.001
August	50.098	-0.008	0.092	0.001
November	15.212	0.006	0.031	0.043
December	8.611	0.006	0.038	0.028
Minimum temperature				
February	-19.823	0.014	0.086	0.0016
March	-9.048	0.011	0.056	0.0096
April	-11.967	0.015	0.081	0.0022
August	34.24	-0.005	0.029	0.0468
November	-5.589	0.008	0.044	0.0189
December	-10.087	0.008	0.052	0.0122
Annual	6.337	0.005	0.11	0.0003



(a) Mean



(b) Mean maximum



(c) Mean minimum

Fig. 3.4 Variation in annual temperature in Rajouri during 1901-2002

The descriptive answers we obtained under the questions on possible actions in response to climate change are i) construction of pucca (cement concrete) houses, ii) tree plantation, iii) use of air conditioner, fan, cooler, and iv) shifting housing colony away from flood plains of the river. Under the second question on perception to climate change, the answers on reasons for climate change includes an increase in the vehicular emissions, deforestation, human population and many believed it as God's will. For the third and last question, their views for improving environmental / climate change are tree plantation and reduction in vehicular emission.

3.5 Discussion

The survey shows that a notable proportion of the locals is aware of the advancing climate change. Majority of the locals knowingly or otherwise relate the changes in rainfall and temperature, they experienced for the past three decades, as indicators of global changes. Our results on the peoples' awareness generally agree with the findings of other studies that reports public to be highly aware of climate change [102]. The significant increase noted in the present study in temperature during the period 1901 to 2002 conforms with the findings during 1971-1994 on most of the middle mountains and Himalayan regions of Nepal [112], during 1979 to 2008 on the high altitude in Himalayas and Tibetan Plateau [113], during 1866 to 2006 in North Western Himalayas [90], during the 1982-2006 period in the Himalaya as a whole [78] and during the 1981 -2010 period in Pahalgam and Gulmarg [91]. As noted by some of the respondents, an increase in temperature can be attributed to deforestation and land use changes and vehicular pollution. It could also be because of the global changes arising primarily from carbon emissions. Some of the earlier studies in the Western Himalayas also ascribe deforestation [114], vehicular pollution [115] along with regional and global climate changes due to black carbon [116] for the changes in temperature. Some of the global level studies that established increase in temperature relate it with increase in the cloud cover in the mountain regions [117, 118] as well as land use change and urbanization [119, 120]. The majority of the parents reported an increase in temperature; but the increase was reported higher from urban than rural and private than

Table 3.3 Significant changes in mean minimum and maximum monthly and yearly temperature for the period 2000 to 2014

Factor (Y)	Regression estimates (Factor X = years from 2000 to 2014)		R^2	P
	Intercept	Slope		
Maximum temperature				
August	561.465	-0.264	0.351	0.012
September	592.577	-0.28	0.326	0.015
October	667.103	-0.318	0.352	0.012
November	708.84	-0.34	0.483	0.002
Annual	649.023	-0.309	0.419	0.005
Minimum temperature				
December	803.473	-0.399	0.277	0.046

public school parents. Precipitation, vital for determining the vegetation cover, provides fresh water to a large population in the mountainous region [121] occur with a regular seasonality. Extreme events, but are dangerous, and their frequency has increased worldwide [122, 123] leading to extensive damages through various means including flood [124].

The present study reports increase in precipitation annually and in March and November from 1901 to 2002. Similarly, increase was reported in pre-monsoon and monsoon season from Spiti River in Western Himalayas and it was ascribed to increasing in temperature [125]. Higher precipitation was also reported to increase during 1905-1995 due to increase in sea surface temperature in the Indian Ocean. While warming raises evaporation and increase water vapor in the atmosphere, the decreasing thermal contrast within the Tibetan Plateau and the tropical Indian Ocean inhibits the transport of water vapor towards Himalayas [126]. In the present study, the perceptions were contrasting from rural to urban, and public school to private schools respondents. It would be interesting to relate the diverging perception among the parents of the different types of schools. The students in the public schools use public transport system to travel to their classes. Hence, rain is of higher concern to them than to the students of private schools who travel in contract-carriers or own vehicles to their schools.

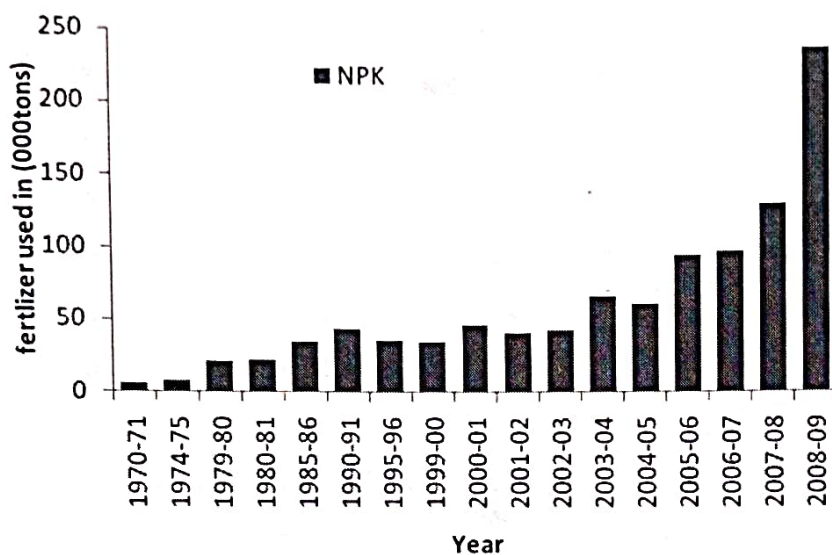
From 2000 to 2014, annual as well as monthly minimum and maximum temperature decreased significantly, though the changes in rainfall were insignificant. A few studies from the Western Himalayas also reported conflicting response to global warming due to local forcing factors as valley temperature inversions [127, 86]. However, in our study due to limited ground observatory stations in Rajouri, it is impractical to narrow down to such local limiting factors. The decrease in temperature is perceived by fewer locals from public schools, largely belonging to lower social strata than the parents of wards enrolled in private schools. Since people from lower social strata are subject to the vagaries of natural elements relatively more than well-to-do segments of the society, minor changes to their usual experience are essentially ignored. While 60.1% of the parents of public school children reported increase in rainfall, 63% parents of private school children reported decrease. It was found that, whether rural or urban, the location of the respondent is insignificant regarding perception of changes in temperature or rainfall. However, the type of the school, reflecting the difference in the social segment to which the students belong, is significant in the matter.

It seems that the local's perception agrees to an extent with the facts on temperature. However, more robust local data would be required to further corroborate this; but the district has only one meteorology observatory to date. The highest proportion of the respondents, 44.3%, reported rise in wind-speed. The increase in wind-speed is reported significantly higher by rural respondents than urban ones. The increase in wind-speed affects crop-yield, shattering and lodging of rice and severe mechanical leaf damage in upland areas [128–130]. Some of the respondents reported no change in wind-speed. Such response is significantly high among those sending their wards to public schools as well as urban respondents. As per the general responses, humidity, pollution, and traffic have also increased dramatically; such responses also did not vary with the respondents. However, the number of respondents who reported an increase in atmospheric pollution and traffic is significantly higher among the parent's of private school students than public schools. Increasing humidity and pollution, especially from respirable particulates, have adverse effects on human health [131–133]. Road traffic has increased significantly, which would contribute to air pollution and its increased environmental and health implications [134]. The majority of the respondents

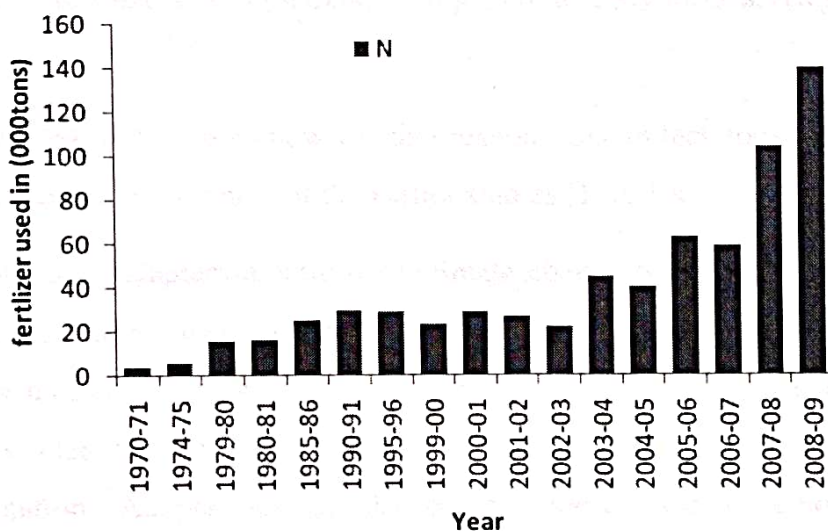
from urban areas and with children in private schools reported a decrease in forest cover. This observation agrees with a study that reported positive correlation between forest loss and urban population, and no correlation with rural population [135]. Several studies also show influence of climate change on crop production, some areas enjoying increase while some suffering decrease [136]. In the present study, respondents reporting increase in agriculture productivity is higher among the parents of urban and private school children. In contrast, respondents from rural areas and public schools reported a decrease in agriculture productivity. Perhaps those respondents are sustenance farmers with not much access to agricultural subsidies or promotion programs. While urbanites are into cultivating high yielding varieties of cereals that require more agrochemical inputs, the rural agriculturists are using a variety of crops, more of traditional varieties that require lesser agrochemical inputs.

Agriculture is the most important livelihood in the area, as is the case of the whole state. Of the people in J&K, 70% depend on agriculture, higher than the national average (58%, [65, 137]). Rice, wheat, and maize are the major crops cultivated in the state. The productivity of rice increased from 1057 to 1842 Kg /ha and wheat from 675 to 1701 Kg / ha from 1964-2011 and 1964-2012 in Jammu region [65]. The agricultural productivity is largely related to agrochemical inputs [138, 139]. In J&K, nitrogen, phosphorus, and potassium (NPK) is the preferred fertilizer and its application has increased during 1970 to 2009 (Figure 3.5a,3.5b,3.5c and 3.5d). Regarding the crop varieties, regardless of school type or locality the respondents reported increase, which possibly could be due to the spread of high-yielding cultivars.

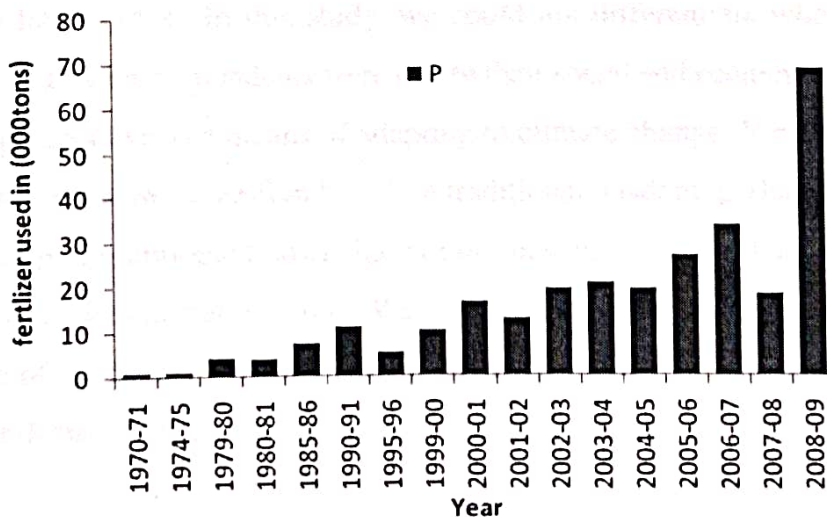
Public engagement is important to mitigate the effects of climate change [107]. Of the total respondents who took note of climate change, a very high percentage perceived the associated risks and took both reactive and proactive actions. The engagement was almost equal among the respondents from different school types and localities, both of which had no significant correlation with their willingness for engagements related to containing climate change. However, our study was not designed to differentiate actions undertaken reactively by individuals to current effects of climate change from proactive actions with expected



(a) Total usage



(b) Nitrogen



(c) Phosphorus

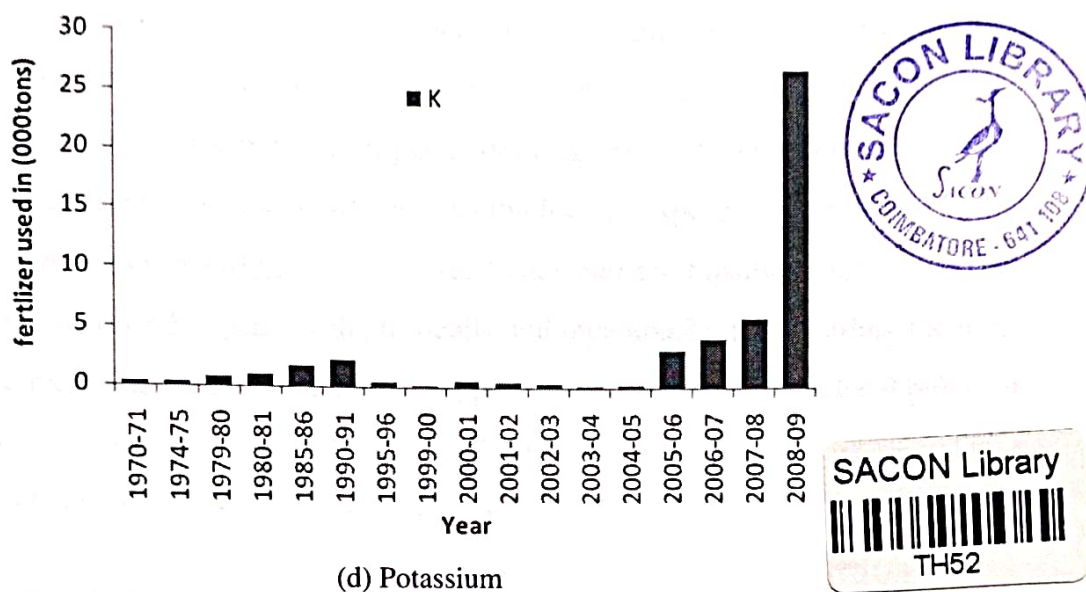


Fig. 3.5 Usage of fertilizers (x 1000 tons) during 1970 to 2009 in J&K (Digest of statistics, 2012)

effects in future. We also do not know whether respondents, in fact, took action in line with their statements as hinted by some of the earlier studies [140, 106].

The responses as adaptation actions to climate change were tree plantation, shifting residences away from the rivers to elevated areas as suggested in an earlier study [141] and using building materials that reduce heat stress during the summer or cold stress during snowfall and winter. Use of fans, coolers, and air conditioners was also reported as an effort in adaptation. Adaptations can also occur in the context of demographic, social, cultural and economic changes, global governance, social conventions and globalizing flows of capital and labor [142]. In this study, we could not differentiate whether adaptation actions mentioned by the respondents were due to their social and economic compulsions or from a larger perspective as a means of adapting to climate change. We also could not get any hint about innovative suggestion based on traditional wisdom, perhaps the subjects we contacted lacking in traditional knowledge or our questionnaire could not elicit the hidden knowledge or responses in that direction. We suggest that future studies need to differentiate the percentage of the people engaged in adaptation action for short or long-term benefits to influence their decision to opt for short or long term adaption action [143]. Climate change

is a global phenomenon hence global governance need to address the issue for the sake of humankind. It is also essential that local measures, as adaptation strategy, need to be promoted, by communicating with the local public drawing their indigenous knowledge base to be suitably strengthened with scientific and technological expertise. Primarily climate change adaptation means ensuring livelihood resilience and establishing a safety net that should essentially involve the locals both physically and ingeniously. Disregarding the local perceptions and ideas and adopting a top-down approach alone would put the local public at the mercy of high technocrats, bureaucrats, and administration, leading to miseries and loss of livelihood and need for subsidizing their sustenance.

3.6 Conclusion

This study reports evidence of climate change in the Rajouri district from 1901 to 2014 based on historical data and local perception. Our findings show that people are highly aware of changes in the climate for the past three decades. It was found that perceptions to climate change vary significantly with locality and school type, perhaps a reflection of the people's socio-economic and educational status. The locals are reportedly engaged in reactive and proactive actions to climate change. However, more studies are required to determine whether the adaptation actions undertaken were appropriate, whether the actions are for short or long-term benefits or only due to specific social and economic compulsions.

Chapter 4

FACTORS SHAPING STUDENTS' PERCEPTION ON CLIMATE CHANGE

4.1 Introduction

Climate change is a key issue in the 21st century [144, 145]. Global average land and ocean temperature have increased by 0.95°C from 1880 to 2012 [89, 146]. Climate models predict $1\text{-}2^{\circ}\text{C}$ increase in temperature by 2050 and $1\text{-}1.5^{\circ}\text{C}$ by 2100 in the tropics [5], but changes in rainfall are more uncertain [6]. In India, mean annual temperature has risen by 0.56°C during 1901-2009 [19]. In the Himalayas, the temperature increase is estimated to be 1.5°C higher than the global average rise of 0.7°C [78]. The Himalayas, one of the biodiversity hotspots in the world, with unique socio-cultural and ecological settings, and substantial glacier ice, is the source of the nine major river systems [147]. Five of these, the Indus, Ganges, Brahmaputra, Yangtze and Yellow river, sustain more than 1.4 billion people directly [77]. This region considered highly vulnerable to climate changes and its repercussions due to its geological specificities, ecological fragility and economic marginality

[31, 101]. The high vulnerability of the Himalayas poses a serious threat to downstream ecosystems and livelihoods and sustenance of major proportion of the people in Asia.

Climate changes are predicted to determine the survival of many species, significantly change habitats, biodiversity, and livelihoods and socio-economic state of humankind [148]. The observed impacts of climate change on physical and ecological systems over the past century are relatively well recognized [149]. The limited evidences that currently is revealed on the Himalayas, ring alarm bells on the fate of the unique mountain ecosystem, biodiversity, the wellbeing of many indigenous distinctive cultures inhabiting those areas, and the invaluable ecosystem goods and services it provides to humankind [112, 150–152]. There are several studies on the observed changes in the Indian Himalayas [153, 154, 19]; But these studies are diverse in terms of methods and scale [90, 92, 82, 81] and not often comparable. In the western Himalayas in Jammu & Kashmir (J&K), floods, drought conditions and cloudbursts in recent years had been attributed to such changes by the popular press [155]. Climate change severely affects the river systems and eventually biodiversity and livelihoods [69]. Globally, 80% of the agriculture is rain-fed, 60% in South Asia and 70% in J&K [156, 157]. More than 85% of the population in the Himalayas depends on agriculture and allied activities, and impacts of climate change tend to be severe on people relying on rain-fed agriculture for a living [158]. The high vulnerability of the Himalayas, though data on the implications of climate change on the area is inadequate [102, 159], calls for ingenious and indigenous methods of adaptation.

Little research has explored the contributions of traditional knowledge, which can benefit climate science policy [160, 95]. Traditional understanding on climate in the Himalayas agrees highly with the available scientific data [102, 161]. Studies on household perception, as a measure of indigenous knowledge, in a few villages from Tibet, eastern and western Himalayas, about climate change have brought in worthy insights [162, 96–100]. Gauging awareness about climate changes among the public, especially the younger generation, and their willingness in engaging in appropriate programs is important in the context of climate

change adaptation. For the purpose, we interviewed students from secondary and higher secondary schools in Rajouri district of Jammu region. We explored the following:

1. The level of awareness about climate change among the students, and their proactive involvement in advocacy and actions to reduce the impacts,
2. Differences in gender and type of school affecting the students' perceptions and their proactive involvement in advocacy and actions,
3. Whether education, such that higher levels of school education, is associated with awareness on greater global change and responsiveness towards the same, and
4. Whether rural and urban students differ in perception and activities relating to possible climate changes.

4.2 Methods

The present survey involved secondary and higher secondary level school students in district Rajouri, PirPanjal region of Western Himalayas, J&K, India. The survey was conducted using a customized questionnaire adapted from Grant and Featherstone [163]. The questionnaire consisted of three sections; Section 'A' exploring the level of awareness and participatory involvement in actions relating to climate change, Section 'B' dealing with involvement in advocacy and promotion of social actions, and Section 'C' exploring willingness to involve in action in environmental activities (see appendix B). At first, each of the sections was formulated to have fifteen multiple choice (answer) type questions. However, after interactions with students and in view of the suggestions from the teachers, we revised the questionnaire. Thus, in the final questionnaire the sections A, B and C consisted of eight, nine and eight multiple-choice questions respectively. Of the eight questions in section A, six covered climate change awareness and two focused on the participatory involvement in activities concerned with the climate change whereas section B and C focused on advocacy and action on the environment respectively. We covered nine schools, during July 2013 to January 2014, and interacted with 1202 students of which 738 completed the questionnaire.

4.2.1 Selection of the schools and students

Nine schools were selected from the list of schools in the district obtained from the office of the Chief Education Officer, Rajouri. At first, stratified random sampling was adopted to select the schools; schools were shortlisted based on a) Location (Urban vs. Rural), b) Type (Public vs. Private School), c) Gender (Male vs. Female) (public schools were single gender whereas private schools had separate sections for males and females), and d) Level (Higher secondary vs. Secondary). Prior to initiating the program, the schools were visited, carrying an order issued by the Director of School Education, Jammu, to seek cooperation from teachers and officials. Those schools willing to facilitate the activities and offered administrative cooperation were then selected for the program. The schools were chosen to cover students from each of the administrative blocks, urban and rural classified based on information from district statistical office. Of the eight blocks in the district, only one was classified as urban while the other seven were rural. Of the nine schools, five were urban and four rural, six were public (public owned / aided) and three privately owned and managed. We chose secondary (8th to 10th) and higher secondary (11th to 12th) standard students for the survey. However, from urban localities, only higher secondary students could be surveyed as secondary class academic schedules were tight and school managers were not willing for any break in their routine for non-curricular activities.

4.2.2 Collection of data

After identifying the schools and the classes, the investigator visited each school and class with the questionnaire and each question was explained to the students in vernacular. Students were then urged to complete the questionnaire in the presence of the investigator. They were permitted to ask for clarifications on the questions only from the investigator. Upon the students completing the questionnaire, the investigator collected the filled ones right away. Of the total 1202 students who participated, only 738 returned completed questionnaires. The rest were partially filled and returned or many failed to return the questionnaire. Hence 738 completed questionnaires were used for the analysis.

4.2.3 Response categorisation and statistical analysis

We coded the answers for each question into proactive and passive, and accordingly the variables for each individual were summed. The proactive answer was coded as 'one' and the passive / negative answer was coded as 'zero' for the sections A and C in the questionnaire, since this section, in fact, was designed to get 'Yes' or 'No' answers. In section B, proactive answers were graded and coded as two (very interested) and one (somewhat interested), while passive / negative answers were coded as zero. In section A, a proactive answer is considered a response meaning almost "I know and I do something as per my perception of climate change" while a passive / negative answer would "I know / don't know and do nothing as a response to my perception of climate change". In Section B, a proactive answer would be "I am very / somewhat interested to be involved in advocacy relating to environment-friendly activities" while the passive / negative answer is "I am not interested to get involved in advocacy for environment-friendly activities". In section C, a proactive answer would be "I am willing to involve in actions for environmental improvement" and the passive / negative answer would be "I am not willing to involve myself in actions for environment-friendly activities". The questions in each section were positioned in the questionnaire to ensure logical continuity.

The responses for each individual under each section were categorized into three grades of proactivity. In the case of the 'Awareness' (Section A) the class intervals were 0-2, 3-5 and 6-8, with the highest proactive response being eight. For 'advocacy' (Section B), the classes were 0-2, 3-5 and 6-9 with the highest response being nine. For "Action" (Section C), the highest response was eight and the categories 0 -2, 3 - 5 and 6 - 8. The scores obtained under each of the above items are summarized in Figure 4.1. The responses were grouped into classes mentioned above, wherein the lowest classes represented the lowest level and the highest class represented the highest level of awareness about climate change and proactivity towards advocacy and action on environment-related activities. The number of proactive respondents with the respective percentage values in each class interval was assorted based on gender, school type, level and location of the schools (Figure 4.2).

Linear mixed models were used to test the significance of gender, school type, education level and location of a student on the summed value for each section separately. School identity was included as a random component in the analysis because schools may differ in their effectiveness to educate on climate change and environmental awareness for reasons other than those that we were testing. We tested the importance of predictors using Likelihood Ratio Tests (LRTs) on nested models [110]. All analyzes were conducted in R, and linear mixed effects modelling was performed using the `lmer()` function in the `lme4` package [111].

We also focused on the individual responses under each section (A, B and C). To test the significance of gender, school type, education level, and location on individual answers Generalized Linear mixed models (GLM) were used. The answers were binary in the case of section A and C, and ordinal in the case of Section B and the errors were modeled accordingly. We used the same set of fixed and random predictors as in the summed variable analysis. We ran the models using the `glmer()` function in `lme4` package. The `glmer()` function runs Wald tests on the predictor estimates, so we could evaluate significant fixed effects directly without reverting to LRTs.

4.3 Results

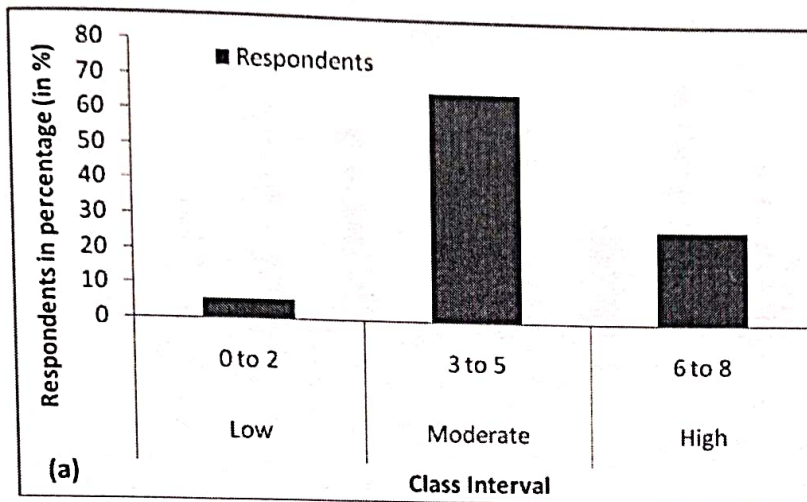
Number of respondents from girl students was less (303) than that from boys (435), from urban students (156) were less than rural ones (582), from students from private schools (90) less than public schools (648), and from secondary students (135) less than higher secondary students (603). The lower number of female respondents was due to their relatively lower numbers (females - 41.05%, males - 58.94%) in the classes. Similarly, the private schools were not very forthcoming to spare time for the students to spend on non-curricular activities such as this. Urban schools caters students from the entire district while students in the schools in the rural locality were only from the respective tehsils (District is subdivided to tehsils for the administrative purpose; they are also called Talukas or Mandals). In their awareness on climate change 5.7% of the students were found to be low, 66.7% moderate and 27.6% high Figure 4.1a). Regarding advocacy concerning environment, 60.2% were highly

proactive (Figure 4.1b). In their willingness to involve in actions relating to the betterment of the environment, 88.2% of the students were found highly proactive (Figure 4.1c).

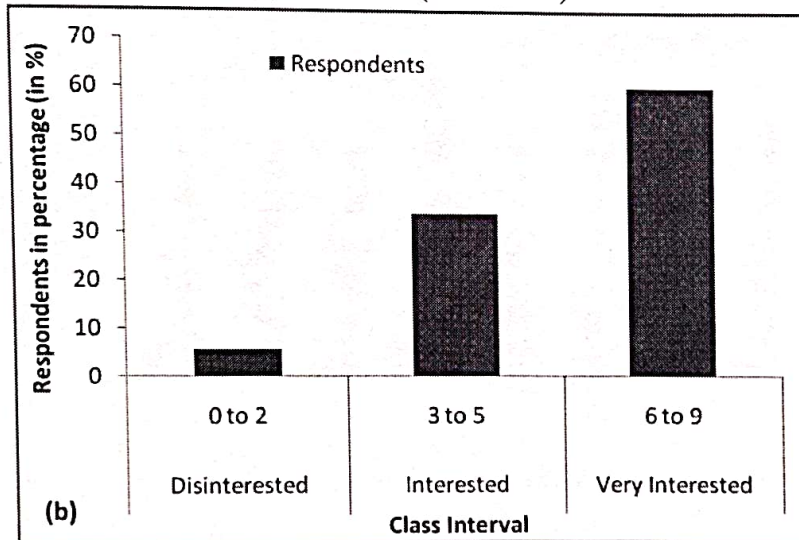
More girls (41.6%) than boys (17.9%), more students from private schools (46.7%) than public schools (25%), more higher secondary students (32.3%) than secondary school students (6.7%), more urban students (55.8%) than those from rural schools (20.1%) were found involved in participatory activities on climate change (Figure 4.2a). More boys than girls, more private school students than public school students, higher secondary students than secondary students, urban students than those from rural school were found to be proactive to involve in advocacy concerning their environment (Figure 4.2b). Girls more than boys and rural students more than urban students were willing to be involved in activities concerning environment (Figure 4.2c).

The results of the linear model analysis indicated that students from higher secondary classes and from urban schools showed significantly higher awareness and proactive attitude than students of secondary classes and rural schools (section A, Table 4.1). Higher secondary students and female students were found more aware than secondary and male students of the risk associated with climate change. They were also more proactive towards climate-friendly activities. Higher secondary students, than those in secondary classes, had noticeably greater knowledge about climate change.

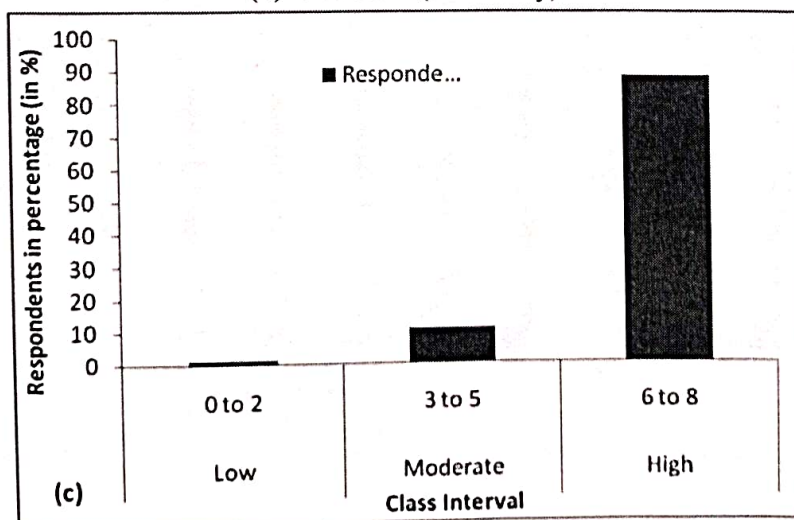
Under section B, higher secondary students, than secondary students, were significantly more interested to be involved in advocacy to use recycled products and save energy; however, they were significantly less inclined to publicize climate change information to make their neighbours aware about it (Table 4.2). Under section C, female students registered significantly higher willingness to take up planting trees than male students. Higher secondary students registered significantly higher interest to stop polythene cover usage by replacing that with cloth / jute / other types of bags and to avoid wastage of the food. Female students and private school students registered significantly higher willingness for action on the solid waste management than male students and public school students (Table 4.3).



(a) Section A (Awareness)

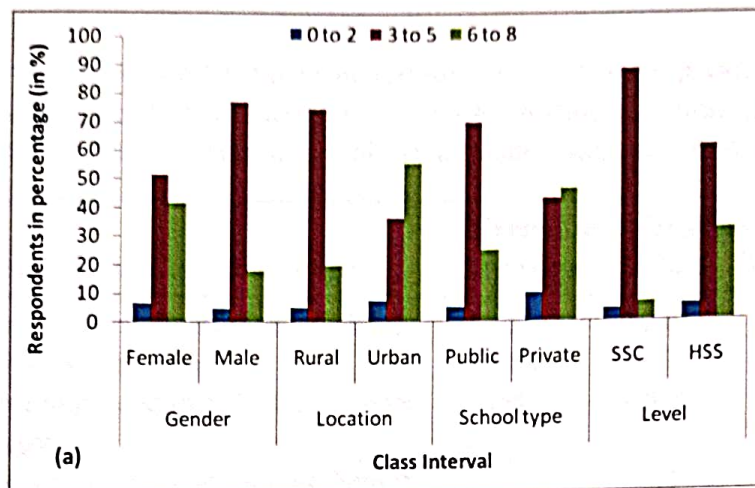


(b) Section B (Advocacy)

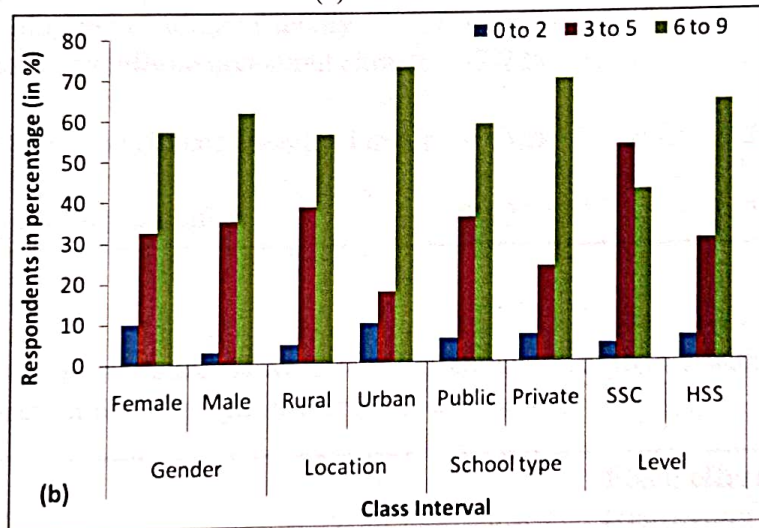


(c) Section C (Willingness for action)

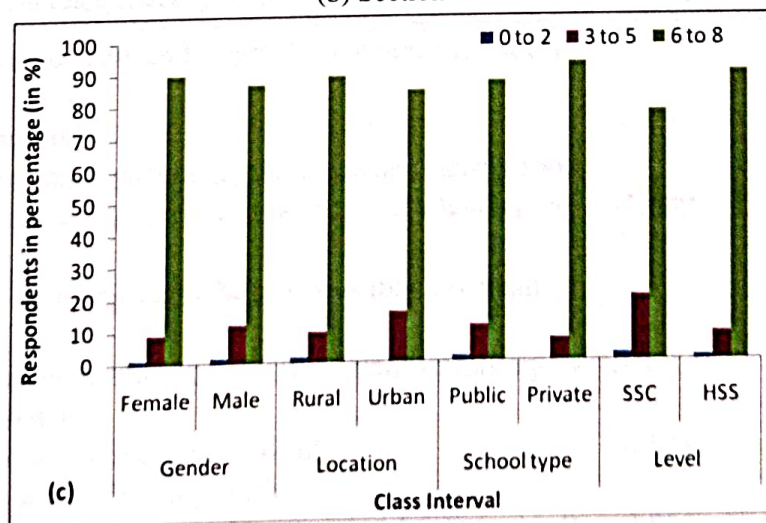
Fig. 4.1 Distribution of respondents (in percentage) under various class intervals corresponding to their responses



(a) Section A



(b) Section B



(c) Section C

Fig. 4.2 Distribution of respondents (in %) corresponding to their responses with respect to gender, location, school type and level, for sections

Table 4.1 Regression results from linear mixed models (LM) testing variation among the respondents and generalized linear mixed model (GLM) testing variations in responses with respect to each question under section A (only significant results are shown)

Section A <i>What do you know about Climate Change?</i>	Fixed effects (regression estimates)			
	Intercept	Urban	Male	Level
I look / read for information on climate change	0.124	3.214		
Climate change is a risk to me	-3.911		-1.202	0.568
I try to do everything I can to reduce my impact on climate change	-1.34	1.886		
Climate change will harm other human beings				
Climate change will kill plants and animals				
I don't do anything to be climate friendly	-5.323		-1.017	0.494
I've never noticed any information about climate change	-7.225			0.552
I'd like to do more to be climate friendly, I don't know what to do	-0.375		2.506	-0.304
LM testing significance variation	2.433		2.641	3.617

Table 4.2 Regression results for GLM testing variations in responses with respect to each question under section B (only significant results are shown)

Section B <i>How often do you encourage others to do?</i>	Fixed effects (regression estimates)		
	Intercept	Urban	Level
Buy locally grown fruit and vegetables when they are in season			
Grow their own food			
Think about how much packaging there is when buying food			
Think about whether something can be recycled when buying products	-1.689		0.099
Buy the goods by using carry bags (reusable) instead of polyethene			
Find out about climate change from TV / books / talking to neighbours / teachers	0.8		-0.084
How much solid waste they can control	-0.689	0.446	
Turn off the tap while cleaning teeth			
Switch off power when not used, stop using heaters, don't leave TV on standby etc.	-0.554		0.077

Table 4.3 Regression results for GLM testing variations in responses with respect to each question under section C (only significant results are shown)

Section C Would you like to do this?	Fixed effects (regression estimates)			
	Intercept	Urban	Male	Level Private
Switch off electricity when not required				
Use minimum water for bathing, washing etc				
Don't throw out the wrapper of chocolate, biscuits and Kulfi etc in the street / roads / commercial market				
Plant at least one tree in a year as your friend	6.53		-1.498	
Avoid using polyethene bags in daily life	-1.211			0.296
Use cloth / jute bag instead of polyethene for shopping	-3.636			0.466
Avoid wastage of the food	-3.669	-1.831		0.56 2.587
Dumping of household waste (solid waste) without throwing it in open sewage river pond	0.461	-1.025	-0.934	1.34

4.4 Discussion

Climate change awareness, knowledge, perceived risk and support for mitigation or adaptation strategy vary greatly across the world [164]. A recent survey covering 119 countries indicated that in Latin America and Europe understanding of the anthropogenic cause of climate change is the strongest predictor of the risk perception [165]. The study reported that while the local temperature change is perceived to be the strongest predictor in Africa and much of Asia, in India 65% of the respondents were found not even aware of climate change. The authors state that improving basic education and climate literacy at the local scale are vital for public engagement in climate change action [165]. Fielding and Head [166] investigated engagement in environmental actions among secondary and post-secondary level students and found that they have a higher interest in environmental knowledge, held stronger pro-environment intentions, and involved in pro-environment behaviours proactively. Several studies have reported student willingness to undertake specific pro-environment

action towards mitigating global warming [167–169]. Our study shows that the majority of the students have a moderate level of awareness, although they are highly proactive (very interested) to involve indirectly (by involving in advocacy) or directly (at their household level) to undertake activities to reduce environmental deterioration (Figure 4.1). These results also agree with the findings by Wong (2012) in Hong Kong of only a moderate level awareness among secondary students, even though 94% of them showed willingness for a low-carbon living and pro-environment activities. In contrast, earlier studies in Hong Kong found primary and secondary student's environmental awareness and engagement in green living to be weak [170].

The present study shows girls to be more aware and more likely to get involved directly (by taking actions), given a chance, in environmental planning than boys. Boys were better in indirect involvement (advocacy). Several studies across the world have reported higher level of environmental knowledge and concern among females than males [171–178]. Females suffer most from environmental issues, especially in the developing and underdeveloped world. In the developing world, 70% of the people are below poverty line are females [179, 180]. In most of the traditional societies, females serve the role of caregiver [181], which probably leads to their greater concern towards environmental issues. They are said to be ecologically "nurturing" than males [182, 183]. However, greater concern among females does not reflect higher involvement in actions due to limited access to resources and higher domestic responsibilities [176]. In our study, higher keenness was seen among girls than boys in involving directly; but girls were lower in advocacy. This could be due to dissimilarity in gender-socialization and socio-cultural restrictions women face in conventional societies to interact freely compared to male members. Higher secondary and private schools students are higher in awareness and are proactive to involve directly as well as indirectly. Higher secondary students are probably more aware due to the presence of environmental sciences in their curriculum. Students of private schools largely hail from better-educated families [184, 177]. Similar is the situation in the study area. Generally, quality of education system in Kenya, Columbia, Tanzania, the Philippines, the Dominican Republic and India is reportedly better in private than public schools [185–187], which

possibly also explain private school student's level of awareness and proactive involvement. Urban students are more aware and proactive to involve indirectly while rural students are more forthcoming to involve directly (Figure 4.2). In urban area, indirect involvement is probably easier and can play vital role to maintain its environment such as through awareness and household segregation of management of solid wastes. In rural locality due to availability of land, students have opportunity to involve directly in activities such as tree planting. Linear mixed model analysis applied on the responses relating to awareness (Section A), advocacy (Section B) and action (Section C) shows that students in higher secondary classes and urban schools are significantly more aware of climate change. They are also more interested in activities related to its control, possibly due to greater exposure to environmental, social and political information. Chan [188] also found senior graders to be more knowledgeable about environmental issues. GLM results also show that urban students to be more mindful and proactive to reduce their impact on climate change. Higher secondary students and female students are more aware of the environmental risks and are more proactive towards climate-friendly activities. Females and senior graders were high in positive attitudes towards the environment and willingness to engage in pro-environment behaviours [189, 190]. However, several studies undertaken to assess students' knowledge, using explanatory diagrams and qualitative and quantitative questions, reported some misconceptions about climate change, global warming and greenhouse effect [191, 192] among them. About understanding on global warming and ozone depletion among senior secondary students, a study showed that they incorrectly linked global warming with ozone depletion [193]. In our study, even students who are found relatively unaware of the activities to be undertaken to reduce climate change (climate-friendly activities) showed willingness to involve. Although a very high percentage of the students show their willingness to involve in environment-friendly activities, Yeung [194] reported senior secondary students in Hong Kong are not willing to choose environmentally positive behaviours that conflict with their perceived personal freedom.

Our study shows under advocacy, students' vary considerably on the topic of their interest, possibly due to their day-to-day exposures, or it may reflect the concerns of their parents, teachers, students or peers. Those from urban localities were worried about solid wastes.

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Girls and students in general from private schools registered significantly high interest in solid waste management. For direct involvement, girls generally gave significantly higher importance on planting trees. A study by Cheung et al. [195] found that university students perceive the concept of climate change but, in fact, was more concerned about environmental pollution, reflecting their limited understanding about the issue. Higher secondary students were less inclined to publicize climate change information, but they were interested in using recycled products and saving energy (Table 4.2). It seems that the students would require precise information on their locality, so that they can actually see matters in a better light and would incite their interests. Students from rural areas were willing to take part in the environment-friendly activities that can resolve issues relating to flooding, droughts, and landslides. As would be true for the whole of India, the rural populace in our study area is more involved in actions relating to common benefits, losses or hardships because the local level issues are more pertinent to their ethos, sustenance, livelihoods or occupations. Therefore, apart from the global issues, it is vital to provide information on local ecology and environmental problems that could be realistic to the locals and would encourage them to take appropriate actions [196]. Rajouri is drained by many streams that join forming the river Munawar, which is the source of water for drinking, livestock, irrigation and other domestic uses. However, after entering the city the quality of water in the river deteriorates due to sewage directly entering the river course and the lack of appropriate facilities for solid waste management. Most of the students are either well aware of the issue or would have heard much from their elders and have identified it as an intimate concern of theirs.

As noted above rural students are not as high in awareness as those from urban areas are. However, during our interactions we found them more receptive to environmental awareness and associated activities. Schools, particularly private schools in the urban locality, give priority to the performance of their students in routine examinations conducted as per the set curricula. As per that, environmental science, as a subject, does contribute to their marks / credits, and environment-friendly activities are ignored largely in the formal pedagogy. Even though, Environmental Science is a compulsory subject in higher secondary level, the general practice is that most schools rarely include any activity related to environmental awareness.

Not much effort is made by teachers or other officials in schools for the students to get direct exposure such as generation of realistic knowledge or field activities. Therefore, largely the subject is sidelined as one to be read only to pass. Yet, the students under present survey show notable levels of awareness, willingness to involve in actions and advocacy related to environmental protection.

Understanding people's perception on climate change is an important initial step to understand their response towards developing adaptation strategy to mitigate the impact of climate change [162]. However, understanding the perception does not provide any insight to the basis of actions taken by the persons. The perceptions are just indicative of the respondents' level of understanding and reflect respondents' cognizance of the implications. It reflects the respondents' capacity in linking discernible changes, such as that in temperature and precipitation, to global changes with wider implications. It is also suggestive of their sensitivity to contemporary environmental issues. The level of perception among the students in the Rajouri district gives hope that appropriate future actions can be developed and adopted. It hints that the students, if appropriately exposed to the deeper understanding of the science of climate change and its implications, could help in developing effective future adaptation strategies. However, environmental science in the school curricula is currently handled in a casual manner, with priority given to other subjects that are tested during board examinations. Environmental Science, with hands-on experience of the local issues, needs to be given more importance in formal education. The curricula need to be improved by giving due importance to climate change so that the native youth gets concerned and involve in the development of adaptation strategies taking into account the local traditional knowledge and local ecological, geological and cultural uniqueness. The present study does not investigate their actual involvement in line with their statement and that would require further studies.

4.5 Conclusion

Most of the students are aware of the climate change and perceive the changes as due to anthropogenic activities. However, the awareness (moderate and high) is not reflected in their involvement (either directly or indirectly) in environment-friendly activities. The students are

highly proactive showing high willingness to involve in activities to reduce environmental changes. Girl students are more aware of climate change and its associated risk and are more proactive to involve directly in environment-friendly activities (pro-environment actions) such as tree plantation and solid waste management. Higher secondary students are more aware perhaps due to their curricula that include environmental education. Although students from urban schools are more proactive towards reducing the impact of climate change through advocacy, rural school students are proactive to engage directly for environment-friendly activities. We found most students of rural and urban localities concerned about environment associated problems they could see in their own immediate environments; rural students concerned about drought in summer, flooding, and landslides in the rainy season, whereas urban students more concerned with solid waste issues.

Environmental education through formal didactics plays a vital role to generate awareness among the younger natives about their environment. However, the subject receives low priority at schools in the study area. Reframing the contents of environmental science and education to emphasize direct exposure, environmental advocacy, and action is required, and drawing students to environment improvement activities focusing on certain key issues relating to climate change adaptation in the region is vital for the future.

Chapter 5

HYDRO-CHEMICAL CHARACTERIZATION AND QUALITY ASSESSMENT OF MUNAWAR TAWI, FLOWING THROUGH RAJOURI

5.1 Introduction

Surface waters are highly susceptible to pollution especially due to discharge of wastewaters [197]. In most of the river basins, across the world, human activities have altered the fluxes of nutrients from the landscape to surface water leading to negative effects on water quality [198]. Growing industrialization, urbanization and modern agricultural practices while increasing demand for fresh water deteriorate its quality [199–201]. Seasonal variation in precipitation, surface runoff, interflow and ground water flow has a strong effect on river discharge and thus on the concentrations of chemicals in the river water [202–205]. Irrigation with water of unacceptable quality leads to contamination of soil [206–208]. Countries

downstream to Himalayas face constraints in access to water and in addition, water pollution is one critical environmental problem in many parts of the area [209]. India with 4% fresh water resources supports 16% of the world population [210] and with increasing population and consequent demand for water, conservation of river basins and other water sources is very crucial in the coming years. In Himalayas, for the distinctive terrain, numerous streams (lower order ones such as primary, secondary and tertiary) flowing through, are the lifeline for majority of the inhabitants, several exquisite habitats and species. Studies in Jammu & Kashmir (J&K), have focused on large rivers such as Jhelum, its tributaries [211–213], lakes [214, 215], ground water [216] and large springs [217]. The lower order rivers, streams that are the main source of water for all human needs are least studied. In this context, the present study selected Munawar Tawi, a third order river, that serves as the main source of water for domestic and agriculture purposes in Rajouri district. Munawar Tawi, largely free of anthropogenic pollution for there are no industries and urban centers in its upper reaches, on reaching the Rajouri town receives considerable amount of sewage and domestic wastes. Since there has been no study on Munawar Tawi, we felt it desirable to look at its quality, especially in view of its importance for the local people and the environment. We examined major water quality parameters in the river at Rajouri town and its upstream and downstream locations. Assessing the water quality of Munawar Tawi can serve as a baseline for future change analysis in view of growing industrialization and urbanization in the area, and climate change.

5.2 Study area

The study area is described in detail in chapter 2.

5.3 Methods

Water samples from twenty-seven sites around the three locations (Rajouri town, its upstream and downstream, Figure 5.1) were collected along Munawar Tawi, in January and June 2014, for physicochemical analysis. Around each of the three locations, nine sites were identified and from each of the sites water samples were collected in triplicate (one each

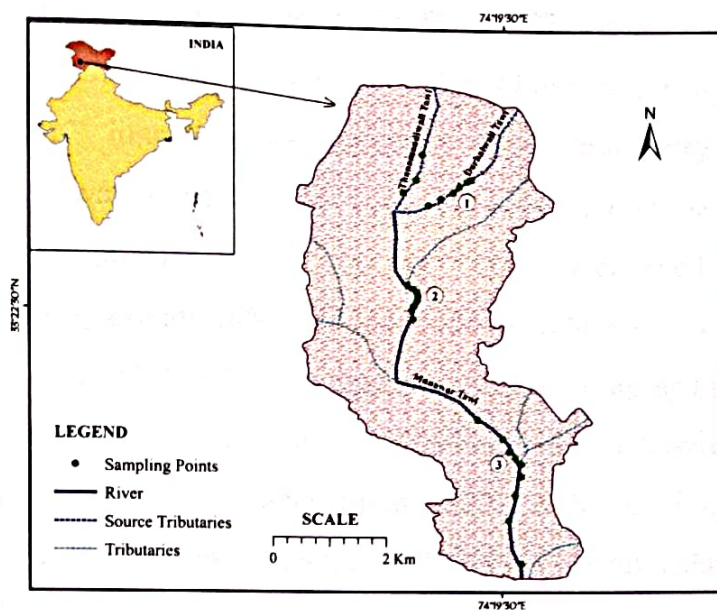


Fig. 5.1 Rajouri town with its periphery; samples collected from location one (upstream) two (highly populated area) and three (downstream)

from each bank and centre of the flow) and analyzed. Sampling was done twice from each site, in January representing winter and June representing summer flow. Although Munawar Tawi lacks specific discharge data, it would be highest in June and lowest during November to February similar to other rivers originating from Himalayas [218–220, 213]. Samples were collected between 11:00 and 14:00 in two liter polyethylene bottles, pre-cleaned with concentrated HNO_3 , rinsed with distilled water, and then once with the river water before collecting the water sample. Samples were taken holding the bottle mouth open against the flow at 10 to 15 cm below the surface. The samples were stored at $0^\circ C$ for two days and then transported to the Environmental Impact Assessment (EIA) laboratory at SACON. In the laboratory, the samples were stored at $4^\circ C$ until analysis. All samples were analyzed within ten days of reaching the laboratory. Samples, after filtering through $<0.45\mu m$ filter paper to separate suspended solids, were analyzed following the methods as per Federation and APHA [221], Tandon et al. [222]. The physico-chemical parameters analyzed include hydrogen ion concentration (pH), electrical conductivity (EC), turbidity, total dissolved solids (TDS), total hardness (TH as Calcium Carbonate), total alkalinity (TA as Calcium Carbonate), cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+), and anions (HCO_3^- , Cl^- , NO_3^- , SO_4^-). Of these, pH, EC and TDS

were measured directly on site using digital pH, EC and TDS meters. TH was determined by EDTA (0.01M) titration using ammonium buffer solution and Eriochrome black-T as indicator. Na^+ and K^+ ions were determined by flame photometry (Systronics Flame Photometer-128). TA was determined by Sulphuric acid titration using phenolphthalein and methyl orange as indicators. Ca^{2+} and Mg^{2+} were determined by EDTA (0.01M) titration with sodium hydroxide (8%) and murexide as indicator. HCO_3^- was estimated from the $CaCO_3^-$ levels [223]. Cl^- was determined by titrating against $AgNO_3^-$ (0.02N) using potassium chromate (5%) as indicator. Turbidity was determined using standard turbidity suspension using Nephelometer (model-335). NO_3^- and SO_4^- were determined by Spectrophotometer (Perkin Elmer Lambda-35 UV/VIS). Instrumental measurement was routinely checked by analyzing blanks, duplicates and standards and by ensuring ion balances for quality control. The water quality was also compared with Indian standards (ISI) and international standards by World Health Organization (WHO) for domestic use. Fitness of water for irrigation usage was checked based on EC as per US Department of Agriculture classification (USDA), Sodium in % (%NA), Sodium absorption ratio (SAR), residual sodium carbonate (RSC), Magnesium absorption ratio (MAR), Kelly Index (KI) and permeability Index (PI). AquaChem 2014.2 trial version was used to illustrate the hydro-geochemical characters as ternary plots for cations and anions [Ternary plot, Piper plot, Ludwig-Langelier plot and Schoeller plot]

5.3.1 Statistical analysis

To see the difference in each parameter of the samples collected during January and June Wilcoxon signed-rank test was used. Water samples were classified into three groups based on its location, viz. samples collected from the town, its upstream and downstream locations. We used Kruskal-Wallis test to analyze the difference in the samples from upstream, town and downstream in both January and June separately. All the analyses were conducted using R (3.1.2). A correlation matrix [224] among different water quality parameters was also prepared.

5.4 Results and discussion

5.4.1 River water quality

A summary of the physico-chemical characteristics of the water in Munawar Tawi collected from three locations during January 2014 and June 2014 is presented in Table 5.1. In January, pH of water was alkaline and it was slightly higher in the downstream location. It was 8.2-8.4 in the upstream location, 8.3-8.4 in the town and 8.2-8.6 in the downstream location. In June, pH was 6.3-6.4 in the upstream, 6.7-7 in the town and 6.8-7 in the downstream. The pH, slightly acidic in June, gradually grew higher towards downstream. Increase in pH towards downstream would be due to sewage and domestic waste flowing into the river. It would be also for the dissolution of limestone and dolomite-rich lithology in the flow path and drainage basin liberating Ca^{2+} , Mg^{2+} and aluminosilicates into solution [225, 226]. TDS in the water was 40-60 mg/l in January while it was 75-112 mg/l in June, an increase similar to that reported from River Jhelum's tributaries [213]. Higher water flow in June, probably hastens weathering of the substratum and erosion, which might be leading to the TDS increase. In June, the water flow is high from monsoonal rainfall and ice melt in the basin. Similar rise in TDS was also reported from River Lidder [212].

EC was 220-280 $\mu\text{s/l}$ in January and 149-218 $\mu\text{s/l}$ in June. EC, reflecting the amount of inorganic chemicals in the water [227, 228], is higher in January possibly due to proportionately higher sewage entry. Higher EC could be also attributed to release of dissolved solids from upland areas through rainwater and from effluents [229]. TA (as $CaCO_3$) was 103.1-130.7 mg/l in January and 85-136.67 mg/l in June, closer in range during the former month than during the later month. Alkalinity in aquatic environment cushions against rapid change in pH, harmful to aquatic life. Na^+ , essential for regulating fluid level and neural conduction in animals, varied between 10.4-15.5 mg/l in January and 8.1-14.2 mg/l in June. Concentration of Na^+ was in the order City > Downstream > Upstream in both the seasons. K^+ , essential for muscle contraction in animals, was 2.1-3.5 mg/l in January, the values

Table 5.1 Physico-chemical quality of water in Munawar Tawi from upstream, city (Rajouri town) and downstream locations in January and June 2014 in contrast with Desirable limit (DL) and Permissible limit (PL)

Month-Parameter	Location -Upstream				Location -City				Location -Downstream				WHO level (2011)				ISI level (2004)	
	Range	AVG	STD	Range	Range	AVG	STD	Range	Range	AVG	STD	DL	PL	DL	PL	DL	PL	
pH	8.2-8.4	8.3	0.1	8.3-8.4	8.4	0	8.2-8.6	8.4	0.2	7-8.5	6.5-9.2	6.5-8.5	8.5					
TDS (mg/l)	40-45	41.7	2.5	50-55	51.7	2.5	50-60	53.3	5	500	1500	500	2000					
EC (μ S/cm)	220-250	234.4	13.3	250-260	256.7	5	250-280	262.2	12	-	1600	800	4800					
TA $CaCO_3$ (mg/l)	117.7-122.4	120.5	1.8	103.1-106.4	105	1.3	122.1-130.7	126.7	3.5	-	-	-	600					
HCO_3^- (mg/l)	143.5-149.2	146.9	2.2	125.7-129.7	128	1.6	148.9-159.4	154.5	4.3	-	-	-	-					
Na^+ (mg/l)	10.4-12	11.2	0.6	14.6-15.5	15.1	0.4	12-13.5	12.7	0.6	-	200	-	-					
K^+ (mg/l)	2.1-2.9	2.5	0.3	3-3.5	3.3	0.2	3.3-3.5	3.4	0.1	-	12	-	-					
Ca^{2+} (mg/l)	45.4-47.9	46.8	1	53-57.7	55.3	1.8	60.8-64.8	63	1.5	75	200	75	200					
TH (mg/l)	127.1-141.4	135.3	6.1	146.3-152.3	149.6	2.5	163.1-167.6	165	1.9	-	-	200	600					
Mg^{2+} (mg/l)	14.2-23.7	18.4	4	7.1-13.9	11.5	3.2	1.3-13.8	6.4	5.5	>30	150	30	100					
Cl^- (mg/l)	25.7-27.3	26.6	0.7	31.1-31.9	31.5	0.4	34-35.1	34.7	0.5	200	250	250	1100					
TU (NTU)	4.2-4.6	4.4	0.1	3.3-3.9	3.6	0.2	3.2-3.6	3.4	0.2	-	-	1	5					
NO_3^- (mg/l)	4-4.5	4.3	0.3	4.2-5.3	4.7	0.5	3.2-9.4	6.1	2.7	-	50	45	100					
SO_4^{2-}	7.7-9.4	8.6	0.6	12.1-15.4	13.7	1.2	12.1-14.4	13.5	0.7	200	400	150	400					
pH	6.3-6.4	6.3	0.1	6.7-7	6.8	0.1	6.8-7	6.9	0.1	7-8.5	6.5-9.2	6.5-8.5	8.5					
TDS (mg/l)	75-85	80.2	4.1	85-112	102.1	11.7	99-106	102.6	2.5	500	1500	500	2000					
EC (μ S/cm)	149-161	154.7	4.8	203-212	206.8	3.4	207-218	212.7	4.4	-	1600	800	4800					
TA $CaCO_3$ (mg/l)	85-97.3	91.7	4.6	100-111.7	105.6	3.9	123.3-136.7	129.4	4.6	-	-	-	600					
HCO_3^- (mg/l)	103.6-118.7	111.8	5.6	121.9-136.1	128.7	4.8	150.4-166.6	157.8	5.7	-	-	-	-					
Na^+ (mg/l)	8.1-9.4	8.8	0.5	13.3-14.2	13.7	0.4	10.1-12.3	11.4	1	-	200	-	-					
K^+ (mg/l)	0-0	0	0	0-0	0	0	0-0	0	0	-	12	-	-					
Ca^{2+} (mg/l)	42.1-46.3	45	1.4	48.2-51	49.6	1	51.3-62.2	56.6	4.3	75	200	75	200					
TH (mg/l)	113.3-129.3	122.4	5.8	130-136.7	133	2.2	140-166.7	153.1	10.5	-	-	200	600					
Mg^{2+} (mg/l)	6.1-10.6	7.8	1.6	7.3-11.6	9.1	1.3	10.7-13.3	11.9	0.8	>30	150	30	100					
Cl^- (mg/l)	11.4-16.5	14.8	2.4	18.7-21.8	20.6	1.4	18.7-21.7	20.6	1.3	200	250	250	1100					
TU (NTU)	4.1-4.3	4.2	0.1	3.1-4.4	3.7	0.5	3.5-4.2	3.8	0.3	-	-	1	5					
NO_3^- (mg/l)	1.1-1.7	1.4	0.3	1.3-1.5	1.4	0.1	1.4-1.9	1.7	0.2	-	50	45	100					
SO_4^{2-}	1.7-6.9	5.3	1.6	5.6-8.1	6.9	0.7	4-6.5	5.3	0.7	200	400	150	400					

January

June

Table 5.2 Classification of water for its suitability for drinking 1) based on TDS into fresh, brackish, saline and brine water as per Carroll (1962), and 2) excellent, good, fair, poor and unacceptable as per [232, 233] and Total hardness (TH) as $CaCO_3$ as per [231]

Parameters	Range	Class	January samples in %	June samples in %
TDS (mg/l)	<1,000	Fresh water	100.0	100.0
	1,000-10,000	Brackish water		
	10,000-1,00,000	Saline water		
	>1,00,000	Brine		
TDS (mg/l)	<300	Excellent	100.0	100.0
	300-600	Good		
	600-900	Fair		
	900-1200	Poor		
	>1200	Unacceptable		
TH	<75	Soft	48.1	77.8
	75-150	Moderately		
	150-300	Hard		
	>300	Very hard		

increasing in downstream direction. K was absent in June. Ca^{2+} , another vital element for life, was 45.4-64.8 mg/l in January. Its concentration varied in the order upstream > city > downstream. In June, Ca^{2+} was 43.1-62.2 mg/l, varying in the order upstream > downstream > city. Another biologically essential element, Mg^{2+} was 1.32-23.66 mg/l in January and 6.1-13.3 mg/l in June, falling in concentration towards downstream. TH ranges from 127.1-167.6 mg/l in January and 113.1-166.6 mg/l in June, increasing towards downstream. The hardness could be attributed to the presence of rich deposits of limestone, and evaporation in the catchment [230]. The water in the river in terms of hardness falls under the moderate class (Table 5.2, [231]). HCO_3^- is the dominant anion, in the range of 125.7-159.4 mg/l in January and 103.6-166.6 mg/l in June. Chloride in the water was in the range of 11.4-21.8 mg/l in June and 25.7-35.1 mg/l in January, increasing towards downstream. Increase in chloride towards downstream could be attributed to the inflow of domestic waste. SO_4^{2-} ranges between 7.72-15.39 mg/l in January and 1.72-8.08 mg/l in June. Turbidity was in the range of 3.2-4.6 NTU in January and 3.1-4.4 NTU in June. The

turbidity of water is high, although close to permissible limit, possibly due to faster water flow, as the area is steep slope. Rajouri is a mountainous region and many locations are prone to land slide and soil erosion, which also cause the water to be turbid. Nitrate, a key nutrient released through sewage, was 5.4-10.8 mg/l in January and 1.1-1.9 mg/l in June. Nitrate showed increase towards downstream in both the seasons. Geological formations of Rajouri district vary from older metamorphic and crystalline in upper north to Murree group and Siwalik towards south (Figure 2.3 under study area); in Rajouri city and its surroundings, it is predominantly Murrees. In overall, the present study (Table 5.1) shows that, except pH in June, all other water quality parameters were within the permissible limit as per both WHO and Indian standards [233–235, 232].

Considering all cations, their concentrations in January were in the order $Ca^{2+} > Mg^{2+} > Na^+ > K^+$; in the city and the downstream locations, the order was $Ca^{2+} > Na^+ > Mg^{2+} > K^+$. In June the order is $Ca^{2+} > Na^+ > Mg^{2+}$ in the upstream and the city, whereas it was $Ca^{2+} > Mg^{2+} > Na^+$ in the downstream. The order of anions was $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ in both January and June; Ca^{2+} was dominant among cations (Figure 5.2a) and HCO_3^- was dominant among anions (Figure 5.2b). To find the dominant hydro-chemical

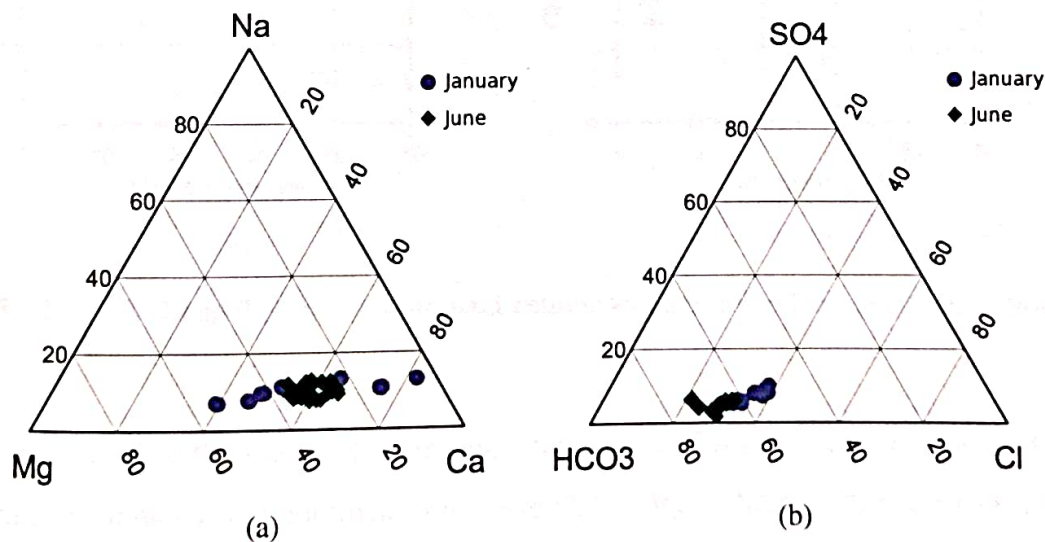


Fig. 5.2 Ternary plot showing a) cations and b) anions composition in Munawar tawi water in January and June

type of water in Munawar Tawi, the data was plotted on Piper diagram ([236, 237] Figure

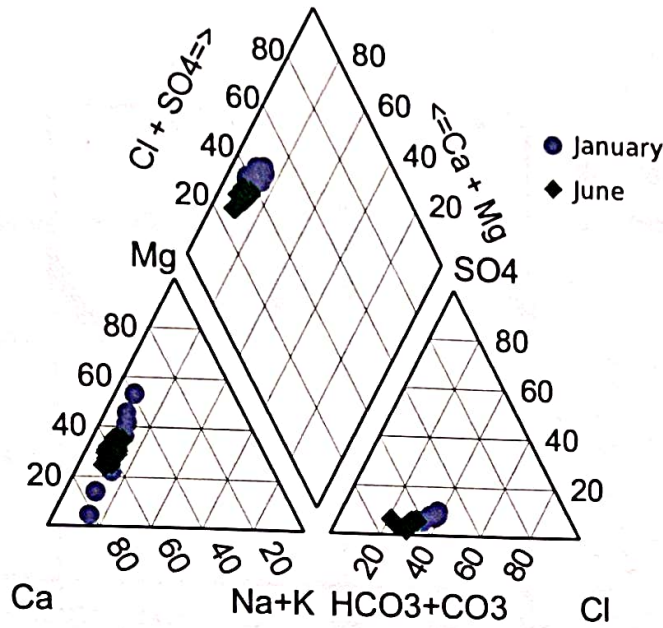


Fig. 5.3 Piper diagram showing hydro-chemistry of Munawar tawi in January and June

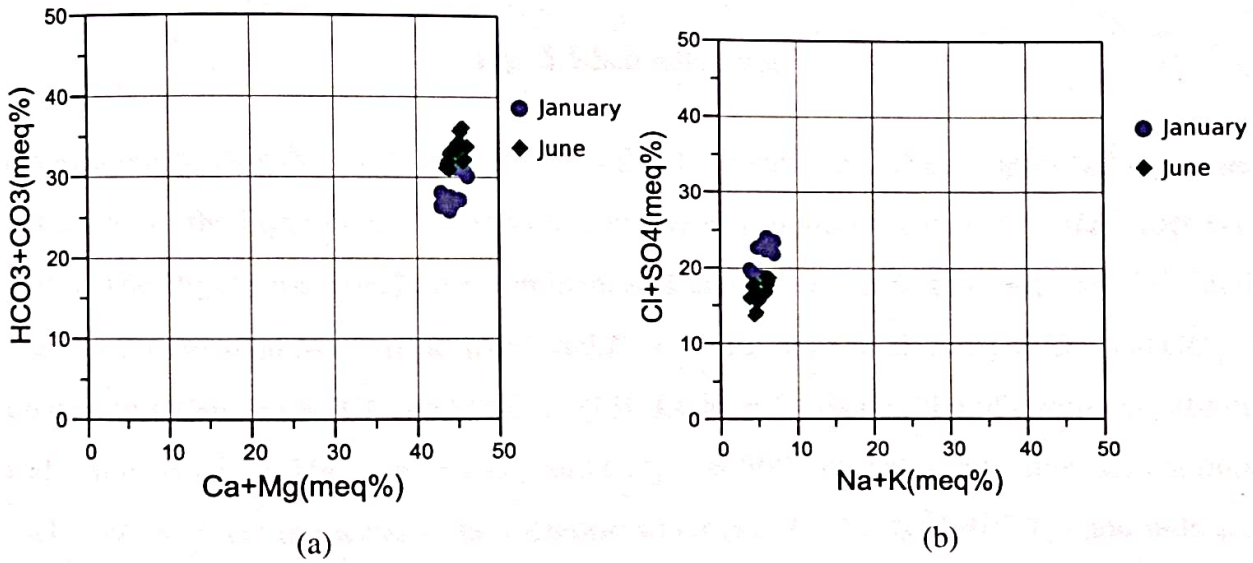


Fig. 5.4 Ludwig- Langelier plot a) dominant cations and anion b) Other available cations and anions

5.3). According to the ionic concentrations, four types of water could be identified in the samples. In January, the dominant ions were $Ca^{2+} - Mg^{2+} - HCO_3^-$, Ca^{2+} , HCO_3^- , $Mg^{2+} - Ca^{2+} - HCO_3^-$ and $Ca^{2+} - Mg^{2+} - Na^+ - HCO_3^-$. In June, only two types ($Ca^{2+} - Mg^{2+} - HCO_3^-$ and $Ca^{2+} - Mg^{2+} - Na^+ - HCO_3^-$) are found. $Ca^{2+} - Mg^{2+} - HCO_3^-$ is the dominant water type in both the seasons. Recent studies in River Jhelum and Wular Lake [215, 213]

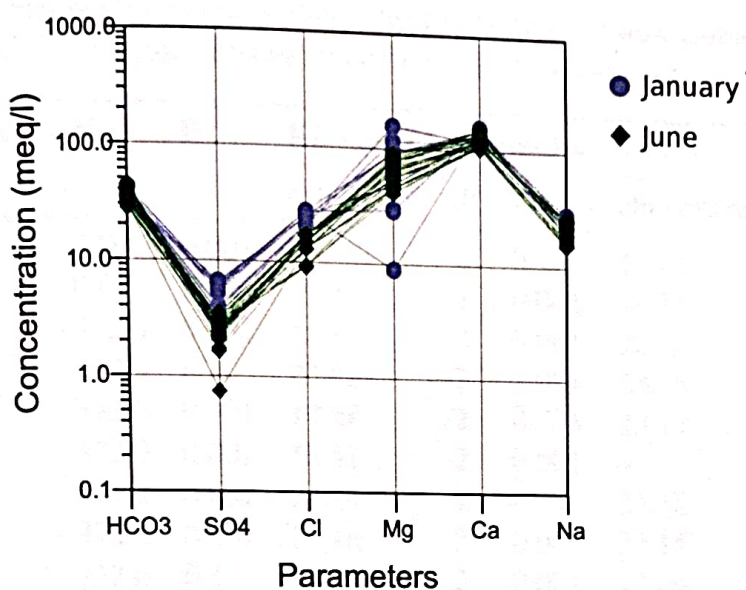


Fig. 5.5 Schoeller plot

report three types with Ca^{2+} and HCO_3^- as the dominant ions. The samples falling in the left corner of the Piper diagram shows that the water is dominated by Ca^{2+} , Mg^{2+} , HCO_3^- [215]. The Piper plot reveals the dominance of alkaline-earth metals (such as Ca^{2+} and Mg^{2+}) over the alkaline elements (Na^+ and K^+). It also show weak acid (HCO_3^- and CO_3^{2-}) exceeding strong acids (Cl^- and SO_4^{2-} , [213]. Ludwig-Langelier plot of dominant cations and anions ($Ca^{2+} + Mg^{2+}$ vs. HCO_3^- and CO_3^{2-}) at 50% ion balance (cations and anions each 50%) suggest the water to be meteoric water (i.e. $Ca^{2+}-Mg^{2+}-HCO_3^-$) and indicate carbon lithology as a dominant source of major ions (Figure 5.4a). A Ludwig-Langelier plot of other cations and anions (Na^+ and K^+ vs. Cl^- and SO_4^{2-}) shows slight increase towards Cl^- and SO_4^{2-} possibly indicating role of other sources in addition (Figure 5.4b, [215]). Schoeller plots (developed by Schoeller [238]) display the concentrations of major ions in Munawar Tawi, the higher concentration (in meq/l) of Ca^{2+} followed by Mg^{2+} among cations and HCO_3^- among anions (Figure 5.5).

Wilcoxon signed-rank test shows that of all the parameters in Table 5.3, TDS increases, while EC, Na^+ , K^+ , Ca^{2+} , TH, Cl^- , NO_3^- , and SO_4^{2-} significantly decreases from January

Table 5.3 Results of the Wilcoxon signed-rank test to examine significant difference in the parameters of the water samples collected in January and June and Kruskal Wallis (KS) test to examine the changes based on locations (upstream, city and downstream) (V = Wilcoxon signed rank test, df = Degree of freedom and P = significance).

Parameters	V	P<	KS - January samples			KS - June samples		
			chi-square	df	P<	chi-square	df	P<
pH	378.0	0.001	3.1	2	0.1	17.61	2	0.001
TDS	0.0	0.001	19.4	2	0.001	16.77	2	0.001
EC	378.0	0.001	15.14	2	0.001	20.82	2	0.001
$CaCO_3^-$	258.0	0.1	22.61	2	0.001	23.16	2	0.001
Na^+	372.0	0.001	10.68	2	0.001	23.19	2	0.001
K^+	378.0	0.001	18.51	2	0.001	0	0	0
Ca^{2+}	357.0	0.001	23.14	2	0.001	23.18	2	0.001
TH	378.0	0.001	23.16	2	0.001	23.15	2	0.001
Mg^{2+}	252.0	0.1	18.99	2	0.001	17.66	2	0.001
Cl^-	378.0	0.001	23.37	2	0.001	17.48	2	0.001
TU	110.0	0.1	19.78	2	0.001	9.71	2	0.001
NO_3^-	378.0	0.001	2.69	2	0.2	8.93	2	0.05
HCO_3^-	258.0	0.1	22.61	2	0.001	23.16	2	0.001
SO_4^{2-}	378.0	0.001	17.36	2	0.001	12.11	2	0.05

to June. In the case of TA, pH, HCO_3^- and Mg^{2+} , the seasonal changes are insignificant. With respect to locations towards downstream in January, Kruskal Wallis test shows pH and NO_3^- as insignificant. TDS, EC, K^+ , Ca^{2+} , TH and Cl^- increased significantly whereas Mg^{2+} and TU decreased significantly. TA and HCO_3^- is significantly less in the town and higher in the downstream. In June, Kruskal Wallis test shows Na^+ and SO_4^{2-} decreasing significantly towards upstream. All parameters, except the TU, increase significantly towards downstream (Table 5.3). In the case of TU, the highest was in the upstream possibly for the low flow in the river.

Correlation matrix of 13 variables for January and June is given in Table 5.4. TDS, EC, Na^+ , K^+ , Ca^{2+} , TH and Cl^- showed significant positive correlations with each other during both the seasons. On the other hand, TU and Mg^{2+} showed significant positive correlation with each other and negative correlation with the rest of the parameters, except HCO_3^- in January. There were also notable differences between seasons in the correlations among

Table 5.4 Correlation matrix of ionic content in water of Munawar Tawi during January and June

	pH	TDS	EC	HCO ₃ ⁻	Na ⁺	K ⁺	Ca ²⁺	TH	Mg ²⁺	Cl ⁻	TU	NO ₃ ⁻	SO ₄ ²⁻
January													
pH	1.0												
TDS	0.41	1.0											
EC	0.34	0.61	1.0										
HCO ₃ ⁻	0.2	-0.15	0.06	1.0									
Na ⁺	0.19	0.57	0.63	-0.7	1.0								
K ⁺	0.27	0.78	0.83	-0.08	0.65	1.0							
Ca ²⁺	0.29	0.7	0.74	0.27	0.38	0.74	1.0						
TH	0.23	0.73	0.58	0.25	0.28	0.66	0.95	1.0					
Mg ²⁺	-0.32	-0.44	-0.82	-0.28	-0.42	-0.67	-0.82	-0.61	1.0				
Cl ⁻	0.23	0.79	0.67	0.13	0.44	0.79	0.97	0.97	-0.7	1.0			
TU	-0.4	-0.76	-0.75	-0.05	-0.58	-0.7	-0.94	-0.86	0.82	-0.91	1.0		
NO ₃ ⁻	0.45	0.01	0.64	0.44	0.13	0.32	0.51	0.34	-0.71	0.31	-0.44	1.0	
SO ₄ ²⁻	0.27	0.69	0.67	-0.23	0.7	0.85	0.79	0.74	-0.65	0.84	-0.8	0.36	1.0
June													
pH	1.0												
TDS	0.76	1.0											
EC	0.94	0.86	1.0										
HCO ₃ ⁻	0.78	0.72	0.82	1.0									
Na ⁺	0.84	0.71	0.83	0.47	1.0								
K ⁺	0.0	0.0	0.0	0.0	0.0	1.0							
Ca ²⁺	0.69	0.66	0.8	0.85	0.4	0.0	1.0						
TH	0.67	0.62	0.78	0.85	0.38	0.0	0.99	1.0					
Mg ²⁺	0.73	0.6	0.7	0.78	0.43	0.0	0.75	0.77	1.0				
Cl ⁻	0.77	0.71	0.86	0.63	0.76	0.0	0.7	0.7	0.6	1.0			
TU	-0.42	-0.22	-0.4	-0.14	-0.33	0.0	-0.22	-0.21	-0.19	-0.07	1.0		
NO ₃ ⁻	0.42	0.38	0.34	0.56	0.03	0.0	0.57	0.52	0.58	0.32	0.15	1.0	
SO ₄ ²⁻	0.47	0.35	0.34	0.18	0.52	0.0	0.2	0.12	0.23	0.32	0.07	0.34	1.0

some of the parameters. In June, TU shows significant negative correlation with all the parameters except HCO_3^- , Cl^- , and SO_4^{2-} . In January, SO_4^{2-} shows significantly positive correlation with other parameters except pH and NO_3^- , while in June it did not show any correlation with any parameter except Na^+ . pH showed significantly positive correlation with TDS in January and with all other parameters except TU, NO_3^- and SO_4^{2-} in June. HCO_3^- shows significant negative correlation with Na^+ and positive correlation with NO_3^- in January. HCO_3^- in June shows significant positive correlation with all the parameters except TU and SO_4^{2-} . Overall, these correlation shows influence of sewage, domestic, agriculture activities and seasonal variations due to water flow. Moreover, this would also reflect variation in the source of each of the ionic content in water.

5.4.2 Water quality for domestic, livestock and irrigational purposes

To check the usability of the water in the Munawar Tawi, important water quality parameters were compared with WHO and ISI standards (Table 5.1). Except the pH in June, which is slightly acidic, other parameters were within the permissible limits. Based on the classification (in Table 5.2) by Carroll [239], Munawar Tawi falls in fresh water category. The water, which is having TDS <500 mg/l, is also fit for drinking [240]. Permissible quality of drinking water for livestock is similar to that for humans except that TDS and salinity could be a bit higher [229]. Australian and UNESCO standards approve TDS below 2900 mg/l for livestock [241]. In our study, the levels of TDS are below 300 mg/l in both the seasons (Table 5.2). In Rajouri, rain-fed agriculture is widespread, unlike in the plains where groundwater is also available for irrigation. People in the district are dependent on agriculture and allied sectors for livelihood. A large number of Kuhl (community managed traditional water harvesting and transport system) are constructed to supply irrigation water mainly for rice cultivation. As per USDA classification, the levels of EC, %Na, SAR, MAR, RSC, KI and PI are considered to decide the suitability of the water for irrigation.

5.4.3 Electrical conductivity (EC)

EC, a measure of salinity [242] and dissolved solids in water, when high in irrigation water raises the salinity of soils affecting the plants by limiting the uptake of water through a reversal in the osmotic process (Todd, 1980). Overall EC of Munawar Tawi was below $< 300 \mu\text{S/cm}$. As per the criteria by Wilcox [243] in terms of EC, 55% water samples of Munawar Tawi in January are found to be 'excellent' and 45% of 'good quality'. On the other hand, in June all samples fell in 'excellent' category (Table 5.5). EC in the city and downstream is $> 250 \mu\text{S/cm}$ in January, which can relate to the low water flow than in June; consequently lower dilution of dissolved ions.

5.4.4 Sodium percentage (%Na)

Sodium percentage (%Na) is a common index used for assessing the suitability of irrigation water. It is defined by Wilcox [243] as follows.

$$\%Na = (Na^+ + K^+) * 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$$

Higher %Na in irrigation water is known to reduce the permeability of soil and hence is important for deciding the suitability of water for irrigation. The impact of high %Na is higher on the soil with coarser texture and higher organic matter. %Na in water of Munawar Tawi varies from 11.25 to 17.96 (mean = 14.73) in January. In June, it ranges from 9.78 to 16.38 (mean = 12.96). Basing on the criteria by Eaton [247] and Wilcox [243], % Na in the water in the river falls in 'excellent' class (Table 5.5).

5.4.5 Sodium adsorption ratio (SAR)

Water having high Na^+ and low Ca^{2+} favors saturation of the binding sites in the soil with Na^+ by ion exchange and destroys soil structure [248] resulting in fall in productivity [249]. Soil permeability decreases due to increase in Na^+ in relation to Ca^{2+} and Mg^{2+} content and inhibits water intake by crops. SAR was estimated using the formula [250] given below.

Table 5.5 Classification of water based on its suitability for irrigation usage; EC and %Na after Wilcox [243] ; SAR and RSC after Richards [244]; MAR by Paliwal et al. [245] and KI after Kelley [246]

Parameter	Range	Class	January samples in %	June samples in %
EC	<250	Excellent (C1 ^a)	55.6	100.0
	250–750	Good (C2 ^a)	44.4	
	750–2000	Permissible (C3 ^a)		
	2000–3000	Doubtful (C4 ^a)		
	>3000	Unsuitable (C4 ^a)		
Na%	<20	Excellent	100.0	100.0
	20–40	Good		
	40–60	Permissible		
	60–80	Doubtful		
	>80	Unsuitable		
MR	<50	Suitable	100.0	100.0
	>50	Unsuitable		
RSC	<1.25	Safe	100.0	100.0
	1.25–2.5	Marginally suitable		
	>2.5	Not suitable		
SAR	<10	Excellent (S1 ^a)		33.3
	10–18	Good (S2 ^a)	100.0	66.6
	18–26	Permissible (S3 ^a)		
	>26	Doubtful (S4 ^a)		
KI	<1	Suitable	100.0	100.0
	>1	Unsuitable		

S1: low; S2: Medium; S3: High; S4 very high for sodium hazard. C1: low; C2: Medium; C3: High; C4 very high for salinity hazard; SAR: Sodium adsorption ratio; RSC: Residual sodium carbonate and MAR: Magnesium adsorption ratio.

^aClassification of irrigation water based on US salinity diagram

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

The SAR levels, expressed in meq/l, range from 10.36 - 16.26 (mean = 13.11) in January, while in June the range was 9.44 - 15.56 (mean = 12.1). In the present study, with respect to SAR based on WHO [251] classification, 33.3% water samples in June fell in 'excellent' category, while the rest of the samples in June and all samples in January fell under 'good' category (Table 5.5). On comparing the data of both the months with US salinity laboratory diagram USSL Richards [244], also known as Wilcox diagrams, to find the suitability of river water for irrigation, it was found that 100% of the water samples of June fall in C1 class indicating low salinity. Only 33.3% fell in S1 class and 66.6% in S2 class indicating low to medium sodium hazard (Table 5.5). In January, 55.6% water samples fall in C1 class and 44.4% in C2 class indicating low to medium salinity. In January, 100% of the samples fall in S2 group indicating medium sodium hazard. In short, in terms of SAR, the water from Munawar Tawi is suitable for irrigation.

5.4.6 Residual Sodium Carbonate (RSC)

An excess amount of HCO_3^- and CO_3^{2-} over the sum of Ca^{2+} and Mg^{2+} also influence the suitability of groundwater for irrigation as these ions cause damage to soil texture by dissolving organic matter in the soil [252]. This excess of HCO_3^- and CO_3^{2-} over Ca^{2+} and Mg^{2+} is called RSC. Adsorption ratio of sodium increases with an increase in RSC value in the soil Eaton [247]. RSC is calculated using the following formula [253].

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

RSC, expressed in meq/l, ranged from -1935.67 to -701.4 (mean = -1393) in January. The values were -1587.15 to -763.42 (mean = -1125.22) in June. Based on the classification by Richards [244], all water sample are 'safe' (Table 5.5) for irrigation.

5.4.7 Magnesium adsorption ratio (MAR)

In water Ca^{2+} and Mg^{2+} always maintains a state of equilibrium [250]. Excess Mg^{2+} in water increases the alkalinity of soil that results in a decrease in crop productivity [252]. Magnesium hazard ratio, proposed by Szabolcs and Darab [254], is calculated by the formula [245] given below.

$$MAR = (Mg^{2+}) * 100 / (Ca^{2+} + Mg^{2+})$$

MAR, expressed in percentage in January ranged from 1.97 – 33.51 (mean = 17.98). In June, the values were in the range of 12 - 19.39 (mean = 15.86). Therefore, water of Munawar Tawi fall within the permissible limit of MAR (Table 5.5) which affirms its suitability for irrigation purposes.

5.4.8 Kelly Index

Kelley [246] introduced sodium measurement against Ca^{2+} and Mg^{2+} to calculate Kelly's ratio. Kumar et al. [252] opines that SAR is a better measure for the purpose. Nevertheless, we estimated KI to evaluate our sample using the formula given below.

$$KI = Na^+ / (Ca^{2+} + Mg^{2+})$$

In the case of the water samples in the present study, KI expressed in meq/l ranged from 0.11 – 0.20 (mean = 0.15) in both January and June. Thus, as per KI the water in the river falls in the suitable category (Table 5.5) for irrigation.

5.4.9 Permeability Index (PI)

Generally, long-term irrigation altered soil permeability due to accumulation of Na^+ , Ca^{2+} , Mg^{2+} and HCO_3^- contents in the soil due to inadequate drainage over a period. To assess suitability of water for irrigation, Doneen [255] evolved an index estimated using the formula

given below.

$$PI = (Na^+ + \sqrt{HCO_3^-} * 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K))$$

The PI, expressed in meq/l, in the present study ranged from 10.98 – 17.23 (mean = 14.05) in January. PI for the June samples were 10.88 – 17.59 (mean = 14.2). The entire sample values fell in Class 1 of Doneen's chart [256] indicating suitability of the water for irrigation.

5.5 Conclusion

The study examined the water quality of Munawar Tawi flowing through Rajouri town. Water collected from three locations, viz. the town, its upstream and downstream, was alkaline (pH 8.3) in January. It turned slightly acidic (pH 6.7) in June. Wilcoxon signed-ranks test shows TDS significantly higher in June than in January, which can be due to higher flow during the latter month. pH, EC, Na^+ , K^+ , Ca^{2+} , TH, Cl^- , NO_3^- and SO_4^{2-} significantly lower in June than January can be due to dilution. The study also found that all the parameters, except TU and Mg^{2+} , were significantly higher in town and downstream locations, perhaps for sewage and domestic flow from the town. Piper plot and Schoeller plot shows Ca^{2+} among the cations and HCO_3^- among anions as dominant ions. Ionic chemistry reveals the water meteoric. Hydro-chemical analysis of Munawar Tawi shows the concentration of major ions to be within permissible limit as per WHO, ISI and UNESCO standards, indicating that water is suitable for humans and livestock uses. Based on EC, %Na and SAR, the water falls in 'excellent' to 'good' category and considering RSC, MAR, KI and PI water fall under 'safe and suitable' category for irrigation. We suggest that the smaller rivers in the Himalayas need to be studied intensively and extensively, and more frequently as that would contribute towards the database for use in the context of interpreting imminent climate changes.

Chapter 6

SOIL CHARACTERISTICS IN THE FLOODPLAINS OF MUNAWAR TAWI IN RAJOURI

6.1 Introduction

Agriculture plays a key role in economy and overall social well-being of India [257]. Growing population in the country demands a yield of 5 metric tons (MT)/year compared to the earlier average productivity of 3.1 MT/year during 1968-2008 to meet the future needs [258]. That requires improvement in the soil quality, the key element in sustainable agriculture [259]. Ecosystem function, process and attributes of soil are described by its quality [260–262]. Yield efficiency of soil can be based on availability of nutrients and categorizing soil accordingly is important for agricultural use [263]. During 1970 to 2000, increase in the yield is reported worldwide due to intensified crop management, improved germplasm, higher fertilizer inputs and cultivation of two or more crops per year [264]. In India with the arrival of high yield varieties, addition of macronutrients such as N, P and K fertilizers raised productivity by four folds, which however in turn led to deficiency of micronutrients in most of the soil [258]. Agriculture globally and even in India is vulnerable

to climate change [265]. In India, prediction of loss in crop productivity ranges from 10 to 40% during 2080-2100 due to global warming [266–268, 265]. A significant loss of pulses, tomatoes, onions, garlic, cereals [269], especially 4-5 million tons of wheat, is estimated with 1°C rises in temperature [270, 271]. The Himalayas are recognized as highly vulnerable to climate change due to its special ecosystem features, geological specificities, ecological fragility, harsh living conditions and economic marginality [31, 101]. More than 85% of the population in the Himalayas depends on agriculture and allied sectors. Impacts of climate change tend to be severe on people relying on rain-fed agriculture for a living [158]. Since, agriculture based livelihood of people is vitally linked with essential nutrients in the soil it is important to estimate requirement of fertilizers to make a balanced nutrient management in the agriculture field [222, 272]. Studies from north-western Himalayas particularly from Jammu & Kashmir (J&K) on its agriculture with respect to nutrients, yield of major crops, fertilizer inputs and climate change are scarce. Therefore, for the present study aiming essentially to create baseline information on the soil characteristics of the area, we explored soil texture, type, lime status, pH, EC, essential nutrients such as OC, Na, Mg, Ca, N, P, K, Cu, Zn, Fe and Mn from paddy-wheat fields in the flood plains of Munawar Tawi flowing through Rajouri, Western Himalayas, India. We also examined the relations with respect to the area among land under rice, wheat and maize cultivation, input of inorganic fertilizers and yield.

6.2 Study area

The study area is described in detail in chapter 2.

6.3 Methods

Croplands along the banks of Munawar tawi in Rajouri town, its upstream and downstream locations was selected for sampling soils (Figure 6.1). Soil samples were collected from three sites in the crop fields using a scoop. From each site, nine samples were collected from the corner and centre of the field. Samples, each 0.5 kg, were collected in triplicates from a depth of 0.1-0.2 m, packed in zip lock bag (airtight polyethylene bags) and transported to

the laboratory for processing. The collections were done between 11:00 and 15:00 hours in January representing post harvesting period and June representing sowing period. In the lab the soil samples were air dried at room temperature [273], mildly ground using a mortar and pestle and strained using a 2 mm sieve [222]. Then the soil material, less than of 2 mm size, were stored in acid-washed labelled plastic containers until further analysis.

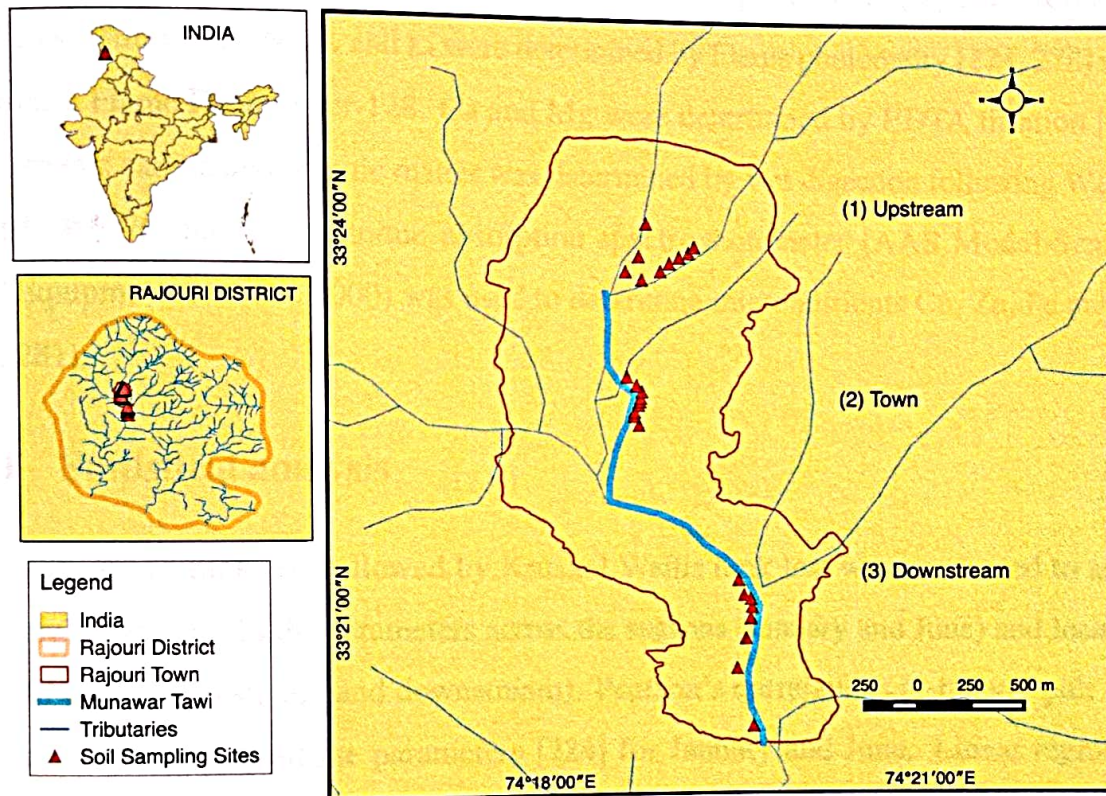


Fig. 6.1 Soil sampling sites in floodplain agricultural fields in Rajouri town, its upstream and downstream locations

Soil texture was determined by particle fractionation - BS 1796:1962 [274]. Soil type was determined by colour matching the samples spread in a plastic tray taking the Munsell soil colour chart as reference and noting down the colour codes. Lime status was estimated by determining organic matter content following the method of Bailey [275]. A calibrated pH meter (Digital Electronics-7007) was used to record the pH and a calibrated Digital Conductivity Meter (DI-9009) was used to record the EC [222]. To estimate N, P, K, Na, Ca, Mg, Li, Cu, Zn, Fe and Mn samples were extracted with 1 M neutral ammonium acetate solution [276]. The extractions were made by stirring 10gm of air-dried soil samples in 100 ml of the extractant for 20 to 30 minutes, filtered and the filtrate was stored in pre-cleaned

plastic vials. All the reagents were prepared using double distilled water and AnalaR grade chemicals.

Of the available primary macronutrients, N was determined by Micro-Kjeldahl method (Jackson, 1973) using micro-Kjeldahl KEL PLUS (Model Kes06L) and P was determined by stannous chloride method [277] using UV-VIS Spectrophotometer (Model: Lambda 35 UV/VIS spectrometer). Na, K and Li were determined by Flame photometry [274, 278] using Systronics Flame Photometer-128. Ca and Mg were determined by EDTA titration [274]. Total organic carbon and organic matter was determined by wet digestion following Walkley and Black [279] method. Atomic absorption spectrophotometer (AAS Model-SenSAA GBC Equipment GBCHG 3000) was used to determine micronutrients Cu, Zn, Fe and Mn [280, 281].

6.3.1 Statistical analysis

Wilcoxon signed-rank test followed by Kruskal Wallis rank test was conducted to assess the overall variations in the parameters across the seasons (January and June) and locations (Rajouri town, its upstream and downstream). Pearson's correlations (2 tailed), pair wise, was performed among all the parameters [224] for January and June. Linear regression was performed on the area under crop, yield and fertilizer inputs in rice, wheat and maize cultivation during 2000-2012. A correlation matrix was prepared on area vs. yield (in rice, wheat and maize cultivation), and yield vs. inputs of N, P, and K fertilizer.

6.4 Results

The concentrations of both macro and micronutrients in the soil under agriculture along the banks of Munawar Tawi in Rajouri town, its upstream and downstream locations during January and June 2014 is presented in Figure 6.2. The soil is clay loam, black and non-calcareous. It is acidic; the pH ranging from 4.8-5.7 in January and the range was wider in June. EC ranges from 0.05- 0.29 dS/m. Organic carbon and organic matter were in range of 4.1- 5.2 and 5.0- 9.0 %. Na in soil was in the range of 0.09-0.4 mg/g. Mg and Ca ranges from

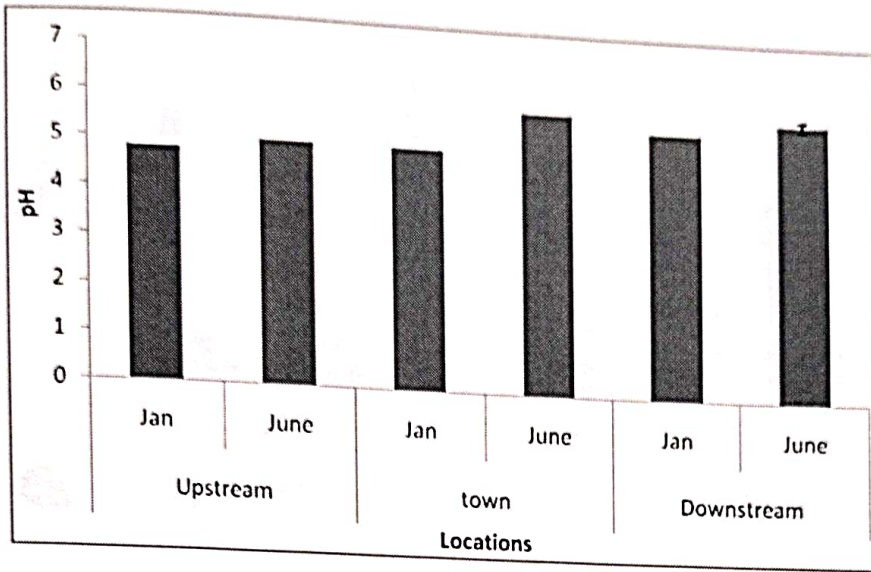
0.49-7.4 and 1.6-9.8 mg/g respectively. The range in concentration of primary macronutrients N, P, K were 212- 451, 30-99 and 85-250 kg/ha respectively. The micronutrients Cu, Zn Fe and Mn ranged from 3.4-8.5, 1.0-3.0, 2.0-3.0 and 9.0-17.7 ppm respectively.

Table 6.1 Results of the Wilcoxon signed-rank test to examine significant difference in the parameters of the soil samples collected in January and June and Kruskal Wallis test to examine the significant differences based on locations - upstream, town and downstream (KS = Kruskal Wallis test, V = Wilcoxon signed rank test, df = Degree of freedom and P = significance).

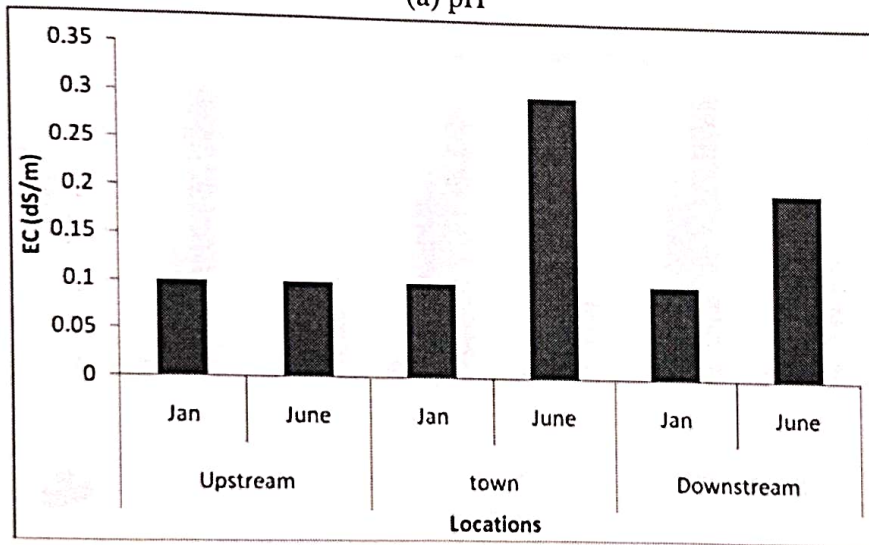
Parameters	V	P<	KS-January samples			KS - June samples		
			chi-square	df	P<	chi-square	df	P<
pH	0.0	0.01	23.1782	2	0.01	18.0717	2	0.01
EC (dS/m)	21.0	0.01	22.2753	2	0.01	17.7693	2	0.01
OC %	361.0	0.01	13.7402	2	0.01	17.9528	2	0.01
N (kg/ha)	317.0	0.01	23.1499	2	0.01	20.7723	2	0.01
P (kg/ha)	0.0	0.01	20.8954	2	0.01	19.5916	2	0.01
K (kg/ha)	74.5	0.05	20.8954	2	0.01	23.2564	2	0.01
Na (mg/g)	292.5	0.01	0.868	2	0.1	16.3159	2	0.01
Mg (mg/g)	378.0	0.01	13.7311	2	0.01	12.8907	2	0.01
Ca (mg/g)	378.0	0.01	7.0301	2	0.05	8.5446	2	0.05
Cu (ppm)	346.5	0.01	22.254	2	0.01	23.2208	2	0.01
Zn (ppm)	27.0	0.01	18.0717	2	0.01	23.285	2	0.01
Fe (ppm)	83.5	0.01	11.6722	2	0.01	23.1924	2	0.01
Mn (ppm)	0.0	0.01	21.1022	2	0.01	23.2066	2	0.01

Of all the parameters given in the Table 6.1, Wilcoxon signed-rank test showed significant rise in pH, EC, P, K, Zn, Fe and Mn while N, Cu, Ca, Mg, OC and Na fell significantly from January to June. With respect to locations towards downstream in January, Kruskal Wallis test showed increase in pH, EC, Fe and Mn. Ca was significantly high in downstream location whereas N, K, Cu, Zn, Mg, OC and Na were high in town. P was significantly higher in upstream. In June, Kruskal Wallis test showed pH, N and Ca increasing while P, Mg and OC decrease significantly towards downstream. In June, EC, K, Cu Zn, Mn and Na were significantly higher in town and Fe in upstream.

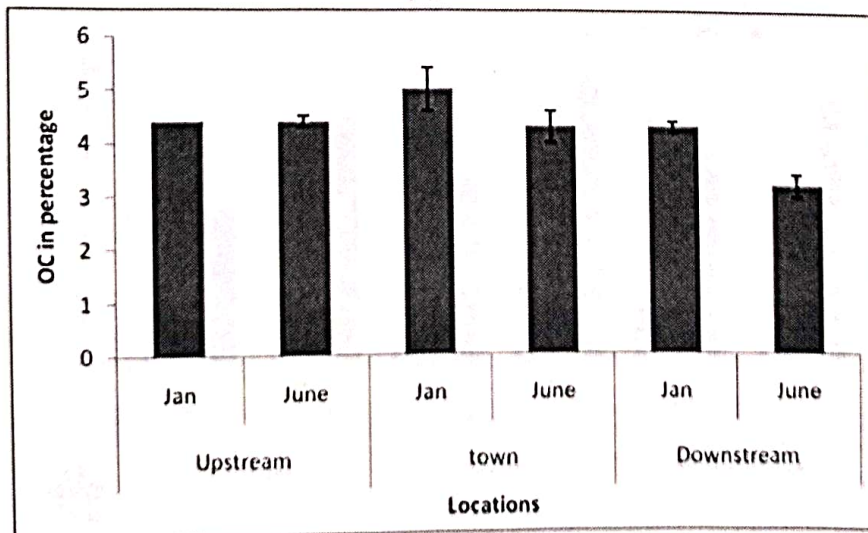
The matrix of correlation among the 13 variables for January and June is given in Table 6.2. In January and June pH and EC, showed significantly positive correlations with each other and with K and Mn, while the correlation was negative with P. Mg and Fe showed



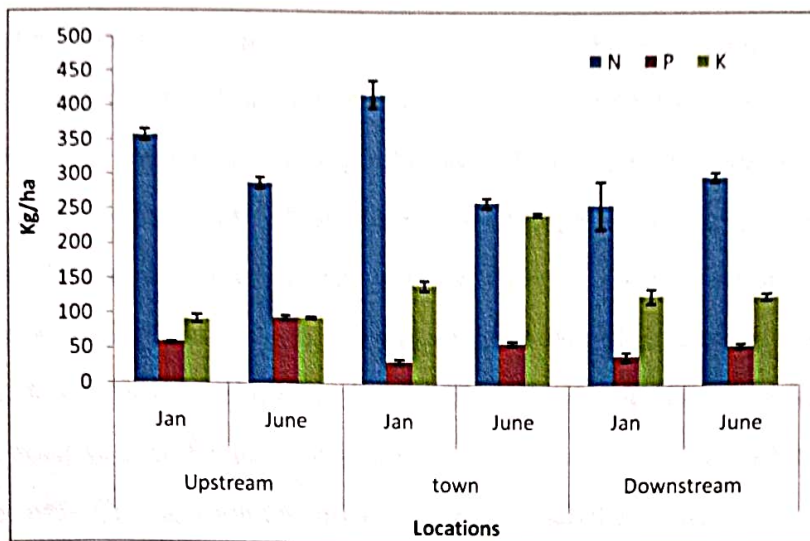
(a) pH



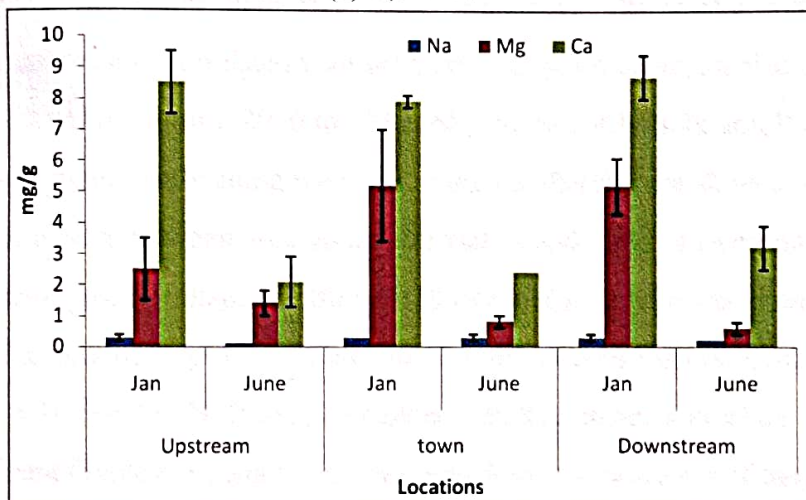
(b) EC



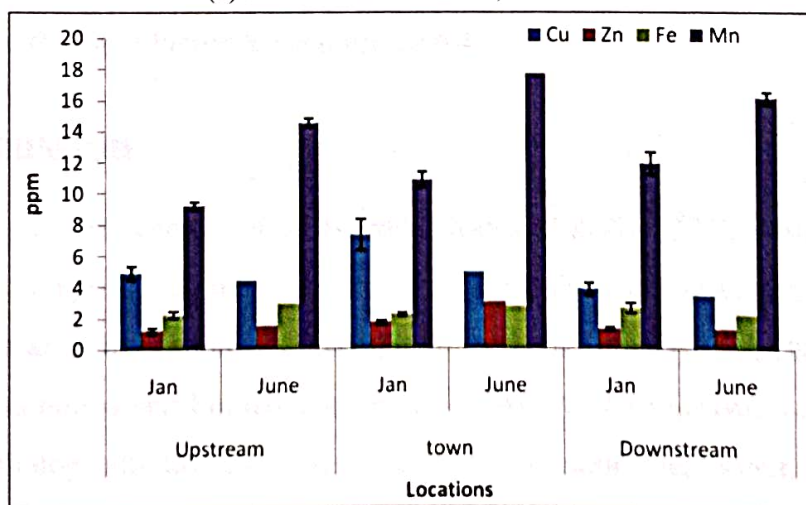
(c) OC



(d) N, P and K



(e) Alkaline elements Na, K and Ca



(f) Micronutrients

Fig. 6.2 Soil characteristics in floodplain agriculture field along the Munawar Tawi from upstream, town and downstream locations in January and June 2014

positive correlation with pH in January and negative in June. EC showed negative correlation with N both in January and in June. OC was positively correlated with Mg, Cu and Zn and negative with Ca. OC showed interesting relation with N and P in January, N positive and P negative, and vice versa in June. N in June showed negative correlation with K, Na and micronutrients while as in January it was positive with Cu, Zn and negative with Fe only. P was negative with K, Na and Mn in both the season though it was opposite in the case of Mg and Ca. K was positive with Cu, Zn and Fe and opposite with Mg from January to June. Mg was positive with Fe and negative with Ca. Ca was negative with Cu, and among micronutrients, only Cu was found positive with Zn in both the seasons.

During 2000 to 2012, area under rice, wheat and maize cultivation and their respective yields were insignificantly correlated with year. Average yield of rice, maize and wheat was 1.8, 2.07 and 1.7 MT/ha during 2000 to 2012 [65]. Inputs of both N and P fertilizer were found increasing significantly along the years, unlike K that did not show any such change. The correlation matrix between area under cultivation and yield of rice, maize and wheat showed significant positive relation in the case of rice, negative with wheat and insignificant with maize indicating perhaps the flawed dataset published by the concerned government agency (Table 6.3). Input of N, P and K fertilizer with rice, maize and wheat yield was also found insignificant (Table 6.4), which further raises doubt on exactness of the dataset. Areas under rice, wheat and maize cultivation, its yield and fertilizer inputs in the district for the past decade are shown in Figure 6.3 and Figure 6.4.

6.5 Discussion

Soil fertility is a key component in its productivity and quality [282]. Despite agriculture being a prime component of Indian economy, regional database on essential nutrients in most of the areas in the country is incomplete. Soils in Himalaya are characterized by shallowness, stoniness and limited development. Massif of Himalayan region is young and geo-morphologically unstable and is the source of major river system of India [283]. Himalayas contributes mainly to runoff and sediment load in major rivers of South Asia. Of the sediments delivered to the world oceans, 80% comes from Asian towers wherein

Table 6.2 Correlation matrix of organic and inorganic contents in agricultural soil in the floodplains of Munawar Tawi during January and June 2014 (OC = Organic Carbon, EC = Electrical conductivity).

	pH	EC	OC	N	P	K	Na	Mg	Ca	Cu	Zn	Fe	Mn
pH	1												
EC	.845**	1											
OC	-0.297	-0.027	1										
N	-.754**	-.388*	.726**	1									
P	-.437*	-.709**	-.521**	-0.108	1								
K	.472*	.711**	.588**	0.173	-.890**	1							
Na	0	0.226	0.098	0.049	-.440*	0.125	1						
Mg	.507**	.556**	.432*	-0.172	-.757**	.629**	0.341	1					
Ca	0.178	0.151	-.389*	-0.293	.440*	-0.245	-0.189	-.426*	1				
Cu	-.473*	-0.104	.896**	.808**	-.509**	.436*	0.285	0.25	-.416*	1			
Zn	-0.104	0.286	.613**	.555**	-.641**	.612**	-0.044	0.326	-.405*	.693**	1		
Fe	.641**	.552**	-0.362	-.666**	-0.301	0.03	.450*	.591**	-0.037	-0.368	-0.175	1	
Mn	.858**	.889**	-0.002	-0.363	-.537**	.679**	-0.027	.466*	0.187	-0.209	0.141	.427*	1.0
pH	1												
EC	.470*	1											
OC	-.555**	0.297	1										
N	-0.166	-.762**	-.635**	1									
P	-.977**	-.414*	.562**	0.139	1								
K	.644**	.887**	0.245	-.815**	-.604**	1							
Na	.608**	.816**	0.154	-.589**	-.577**	.813**	1						
Mg	-.769**	-0.243	.504**	-0.055	.789**	-.395*	-0.37	1					
Ca	.450*	-0.186	-.610**	0.325	-.531**	-0.037	-0.208	-.770**	1				
Cu	-0.2	.664**	.871**	-.848**	0.25	.613**	.403*	0.272	-.523**	1			
Zn	0.346	.889**	.539**	-.911**	-0.289	.936**	.720**	-0.148	-0.26	.848**	1		
Fe	-.726**	0.194	.917**	-.475*	.766**	0.039	-0.082	.647**	-.650**	.811**	.384*	1	
Mn	.832**	.844**	-0.056	-.612**	-.781**	.925**	.826**	-.518**	0.084	0.334	.769**	-.252	1.0

* Correlation significant at the 0.05 level (2-tailed) ** Correlation significant at the 0.01 level (2-tailed)

Table 6.3 Correlation between the areas (in ha) under cultivation of rice, maize and wheat in (MT/ha) and their respective yields

Year 2000-2012		Area (ha)		
		Rice	Maize	Wheat
Yield	Rice	.853**		
	Maize		0.561	
	Wheat			-.677*

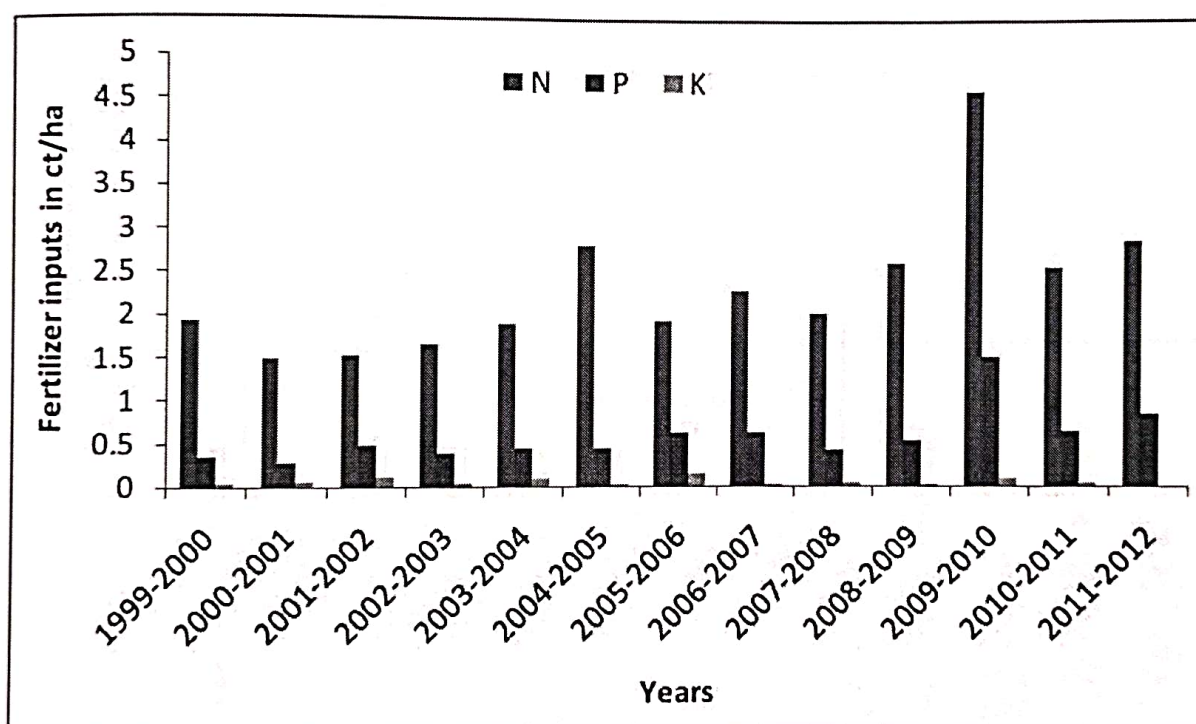


Fig. 6.3 Total Inputs of N, P and K fertilizers during 1999-2000 to 2011-2012 in Rajouri (Source - Digest of statistics, Jammu & Kashmir 2011-12)

Himalayan rivers contribute the most [284]. Compared to the geological past the rates of erosion have increased five times [285, 286]. Rajouri falls in Western Himalaya wherein agricultural fields are lying adjacent to the riverbanks and climate change has increased catastrophic flood in the region causing a rise in soil and nutrients loss [283, 155]. Rajouri also falls in high seismicity area; therefore, the problem of erosion is further acute. Erosion renders the soil unfavourable to crop cultivation hence establishing dataset on essential nutrients is vital to identify appropriate measures for sustainable agriculture. Land conversation from

Table 6.4 Correlation matrix between fertilizer input with yield of rice, maize and wheat in MT/ha

Year 2000-2012		Area (in ha)		
		Rice	Maize	Wheat
Fertilizer	N	-0.334	-0.01	-0.079
	P	-0.371	-0.122	-0.11
	K	0.15	-0.185	-0.229

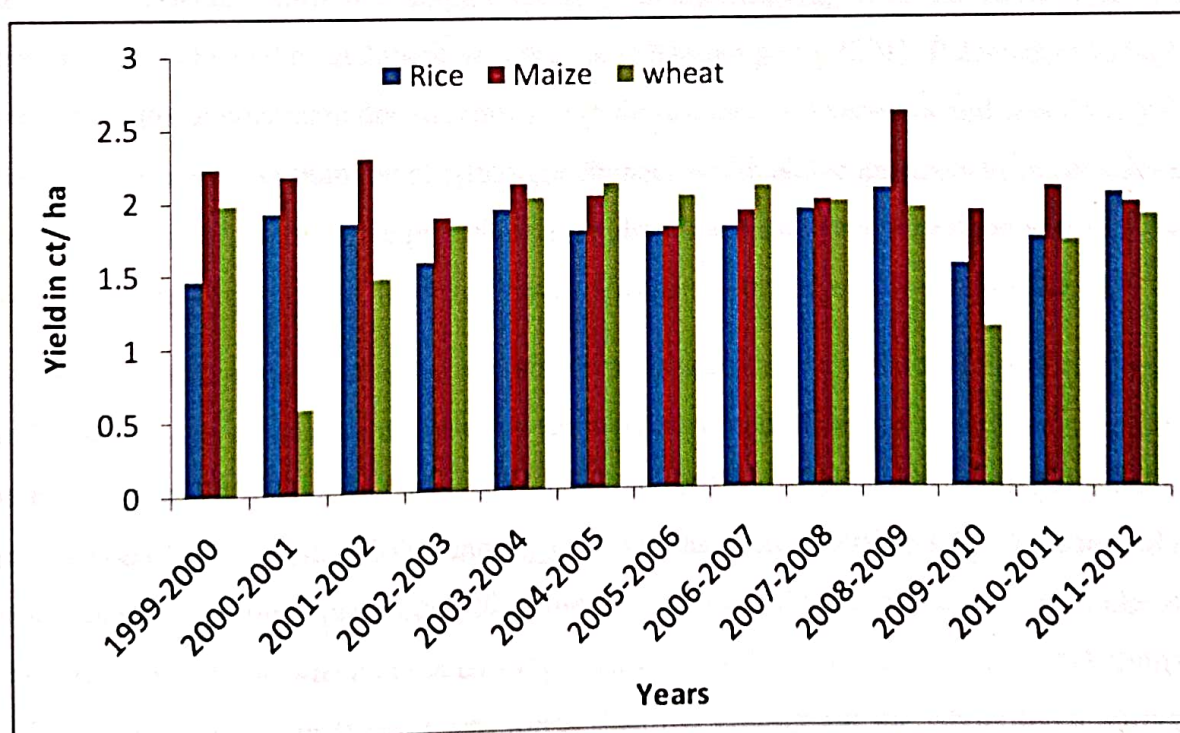


Fig. 6.4 Yield of rice, maize and wheat from 1999-2000 to 2000-2012 in Rajouri (Source - Digest of statistics, Jammu & Kashmir 2011-12)

forest to agriculture and then to housing or commercial sectors in Rajouri further degrades the available soil, its fertility and nutrient contents. In the present study, pH, EC, primary and secondary macro and micronutrients vary significantly across the season and locality. Similar observations have been reported from studies elsewhere [287, 288].

This can be due to difference in the uptake of nutrients during sowing, growing and harvesting periods, rate of fertilizer inputs and other natural seasonal variations [289, 290]. In January, the water flow of Munawar tawi is lower than in June. Increase in pH, EC, Fe and Mn towards downstream could be due to discharge of waste from town and adjacent areas. Higher amount of N, K, Cu, Zn, Mg, OC and Na in town could be mainly due to input of waste from anthropogenic source in the area. pH and Ca are higher in downstream in June as well, however higher flow of water could be leading to an increase in N from the agriculture field in downstream locations. For some of the elements, natural sources as well may be significant contributor, being released from the withering of the substratum and the banks. The rocks in the catchment area belong to Murree group [291]. P decreases in both seasons in the downstream due to reduction in the amount of detergents and wastewater in the downstream areas than town. Although changes in the above nutrients have been seen with seasons and locality in the present study, it does not allow specifying if the nutrients are varying due to crop rotation, fertilizer inputs, weather or any other physical processes.

A robust dataset on pedological aspects, crop yield and area under major crops cultivated in Rajouri can be valuable as the baseline for integrated methods to sustain nutrients balance in near future [292]. Rice is the staple food of about 50% of the world population with a production of 618.4 million MT annually [37]. Of this, Asia contributes 556.2 million MT annually in which India produces 140 million MT. Rice yield has increased and similar is the case of maize and wheat in the past reported worldwide for various reasons [293–296]. Average yield of rice in Rajouri was lower than the average for the whole India during 2000 to 2011 [66]. During 2011-2012, average yield of maize in Rajouri was higher than that of India [67], whereas average yield of wheat is lower than the Indian average [68]. In Rajouri, crop yield as well as area under cultivation showed insignificant change from

2000 to 2012. However, a correlation between area under cultivation and yield especially in the case of maize and wheat raise questions on the veracity of the official dataset. Wheat showed insignificant change with year, but with the increase in the area under cultivation the yield is declining significantly and that possibly points to the faulty dataset consolidated and published by the government agencies, and perhaps the lack of care in preparing such vital database. In order to improve and sustain the agriculture sector, a robust dataset is required. In Himalayas, despite increasing threats to agriculture sector due to changing land use practices, fertilizer consumption pattern and especially climate changes, the dataset published by government agencies is apparently inadequate.

Rice yield is declining in India [297] due to injudicious use of fertilizers [298]. In the case of Rajouri district, even after significant increase in addition of N and P, yields of rice, maize and wheat are insignificant. Incidentally, it is to be noted that higher addition of N and P could also lead to deficiency of K and micronutrients [258, 288]. It has been also reported that adding N, while it increases productivity in the early stages, later exhausts nutrients and hence cannot sustain yield by adding even P ([299, 300, 258]. Studies from north-western India also reports agriculture decline due to falling soil fertility, change in water table, rising salinity, resistance to pesticides and degrading irrigation water quality [42, 291].

Globally climate changes have grave implications on agricultural productivity, although the aggregate impact is not yet known [289]. Studies on agriculture in India also reported the impact of climate change to be uncertain. The impacts varies on crop productivity at local to regional scale depending on the climate scenarios such as variation in rising temperature, CO₂ and their interactions [257]. Change in temperature and precipitation patterns also influence soil water content, run-off, erosion, biodiversity, organic carbon and nitrogen [257]. Impact also varies based on crops, level of agronomic management, region and season [257, 301]. Globally growing competition for land, water and labour from non-agriculture sectors poses a threat to the agriculture [201]. Adoption of improved soil management practices and soil restoration in view of climate change is vital to achieve global food security [302]. Hence,

region-specific studies on soil problems, especially in vulnerable regions such as Himalayas are wanted.

6.6 Conclusion

The study presents baseline information on the soil characteristics in paddy - wheat fields in Rajouri town, its upstream and downstream locations. Soil in the area is clay loam, black, non-calcareous and acidic. Wilcoxon and Kruskal Wallis test shows nutrients varying across seasons and locations significantly. Linear regression showed changes in area and yield under rice, wheat and maize to be insignificant during 2000 – 2012 whereas inputs of N and P fertilizer increased during the same period significantly. High addition of N and P in near future may lead to a deficiency of micronutrients. The correlation matrix between areas under rice, wheat and maize with their respective yields gives contradictory results (significantly positive relation for rice and negative in the case of wheat), which raises doubt on the veracity of the dataset published by government agencies. Insignificant relation between increasing N, P fertilizer input and yield of rice, maize and wheat, contradicts with studies reported elsewhere and widely accepted conclusions, again casting doubt on official data. The present study highlight need for generating data on crops and yields that are more authentic. This is a study first of its kind providing baseline data on soil characteristics in Rajouri, Western Himalayas, a highly vulnerable region for climate change impacts.

Chapter 7

SUMMARY

Climate change is a global issue that poses serious threats to wide-ranging aspects in the biosphere of which ecological security, biodiversity and livelihood are the most explicit ones. The Himalayas, unique in terms of geological and environmental settings, habitats, ecosystems and cultural diversity, is identified as highly vulnerable to climate change [20]. According to the fifth assessment report of the Intergovernmental Panel on Climate Change, the average surface air temperature in the Himalayas over the past three decades has increased by 1.5°C, more than double the global average rise (0.6°C). Therefore, adaptation strategies to cope with the repercussions of climate change in the region are crucial.

In view of the reported rise in temperature in the Himalayas and gaps in related information, the present study was undertaken in Rajouri of Jammu region, Western Himalayas, India. The study explored global climate change, people's perception and engagement along with baseline study on vulnerable sectors such as water and agriculture in Rajouri district.

Temperature and rainfall (gridded, 0.5° × 0.5° spatial resolution) for 1901 to 2002 from Climate Research Unit (University of East Anglia), and ground data from Regional Agriculture Research Station (Rajouri and Jammu) were also examined (Temperature and rainfall for 2000 to 2014) to compare actual and perceived changes in climate. The perceptions of 630

rural and urban respondents (adult) on climate change, risks, reactive and proactive actions were elicited using a custom-made questionnaire.

Regression analysis showed clear trends in mean annual temperature and rainfall during 1901 to 2002. The mean temperature for February, March, April, November and December showed significant increase. The month of August, however, showed a significant fall. Mean monthly rainfall for March and November showed significant increase. In contrast, during 2000 to 2014, annual mean maximum temperature significantly decreased while minimum temperature and annual and monthly rainfall showed no significant changes.

The respondents observed increase in temperature, rainfall, wind speed, relative humidity, environmental pollution, traffic, crop varieties and deforestation over a thirty-year period. Ninety-one percent viewed climate change as a risk, 86.8% reported reactive actions and 82.8% reported proactive actions towards reducing the impacts. Our study shows that locals are cognizant about climate change, but confirming that their engagements are in the line of their statements need further investigation.

To make an informed contribution, under awareness the locals particularly the youth need to be aware of climate change and its implications. Hence, the level of awareness among school students, the future generation, and their participation in advocacy and actions concerning climate change were explored. The variations in the responses of students with respect to the schools (private versus public), location (urban versus rural), education level (secondary versus higher secondary), and gender were investigated. A questionnaire on awareness, advocacy and action, distributed among the students received 738 responses. The analysis was performed using LMs and GLMs. Among the students, 27.6% were highly aware of climate change, 60.2% were highly proactive towards advocacy and 88.2% were willing to be involved in actions concerning their environment. However, students who were found to be aware of through formal education system were not involved in adaptation actions. It seems current formal education system does not encourage many proactive actions towards environment-related issues or direct exposure to various scenarios. Nevertheless, the students show their willingness towards environment-friendly activities focusing on climate

change, possibly due to their exposure from the curricula as well as from other wider and informal means. It is felt that more attention be given to climate change in formal education with appropriate improvement in curricula and pedagogy, and with hands-on exposure to inspiring the students to become more proactive in adaptation and mitigation efforts.

Water and agriculture in the Himalayan region are severely vulnerable to climate change. The river flowing through Rajouri is Munawar Tawi, a tributary of Chenab. Most of the human habitations in Rajouri are close to the banks of the streams / river for easy access to fresh water. Growing urbanization poses major threat to water and agriculture by sewage and domestic waste being dumped in the rivers or their tributaries. Studies on river water quality in the Indian Himalayas are limited to a few larger ones; the smaller ones, although vital for a large section of people, mostly remain unexplored. In Rajouri, surface water is the main source of water for drinking, livestock and agriculture. The quality of the water is an increasing concern for the people residing downstream of Rajouri town, the most urbanized part in the district. Since there is no study on Munawar Tawi, it was vital to look at its quality, especially in view of its importance to the locals. Fifty-four water samples from twenty-seven sites from Rajouri town and its upstream and downstream locations were collected during January and June 2014. Fourteen water quality parameters that include major cations and anions were analyzed. Water quality indicators such as Sodium adsorption ratio (SAR), Sodium percentage (%Na), Residual sodium carbonate (RSC), Magnesium adsorption ratio (MAR), Kelly Index (KI) and Permeability Index (PI) were also calculated to determine suitability of water for irrigation. Piper plots identified four water types, of which $Ca^{2+} - Mg^{2+} - HCO_3^-$ were the dominant type in both the seasons. While in January water samples varied across all the four types, in June only two types were seen (i.e. $Ca^{2+} - Mg^{2+} - HCO_3^-$ and $Ca^{2+} - Mg^{2+} - Na^+ - HCO_3^-$). Ludwig-Langelier plot also showed $Ca^{2+} - Mg^{2+} - HCO_3^-$ type as the dominant water type. Wilcoxon signed-rank test showed most of the parameters, except TDS, significantly high in January than in June. Kruskal Wallis test showed significant variation in concentration among most of the parameters from upstream to the town and towards downstream. The water, with respect to the set standards (WHO, ISI, UNESCO), in both January and June, is found suitable for drinking and irrigation.

In Himalayas, particularly Jammu and Kashmir, 85% of population depends on agriculture or allied sectors. In Rajouri, as well, agriculture is the prime driver of economy. However, information on essential nutrients in the soil in the area is meagre. While the Himalayas contribute highest sediment deposit to the World Oceans, surface soil in the region is under threat due to erosion, and Rajouri is no exception. Along with the region being highly seismic, land use changes and additionally climate change further affect the soil fertility and nutrient contents. In the present study, soil texture, soil type, lime status, pH, EC and select nutrients in January (non-cropping season) and June (cropping season) in paddy / wheat fields in Rajouri town, and its upstream and downstream locations were explored. Area under major crops, yield and fertilizer inputs from 2000 to 2012 were also examined. Wilcoxon signed-rank test showed that pH, EC, K, Zn, Fe and Mn are higher in January than in June while OC, N, P, Na, Mg, Ca and Cu is vice versa. Kruskal Wallis test showed nutrients varying significantly from upstream to downstream in both seasons. Area and yield under rice, wheat and maize cultivation during 2000 to 2012 did not change significantly. During the same period, while significant increase in N and P input was seen, micronutrients remain neglected. Yield was significantly positively correlated in the case of rice with its area, but negatively correlated in the case of wheat. This possibly points to the drawback in dataset consolidated and published by the government agencies, and perhaps the lack of care in preparing such vital database. In order to improve and sustain the agriculture sector, a robust dataset is required.

The present study explores the impending climate change in the area and the perceptions of public as well as students on the same. It further discusses the characteristics of the soil and water in the context. It is a baseline study and an important attempt at local scale from western Himalayas, India. In general, it highlights the importance of global climate change and its importance at local to regional scale.

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Appendix A

Template of the questionnaire for the parents/Grand parents

Have you noticed any change in your environment / climate change over the past 10 to 40 years....Yes/ No. If Yes.

A.1 Section A

Abbreviation I = Increase, D = Decrease, E = Erratic and N = No change.

SI No	Part A	I	D	E	N
1	Rainfall				
2	Temperature				
3	Wind speed				
4	Humidity				
5	Pollution				
6	Trees				
7	Transportation				
8	Cultivation				
9	Crop varieties				

A.2 Section B

Sl No	Part B	
1	Do you think climate change poses a risk to you and your household?	Yes / No
2	Are you taking action in response to climate change that is now occurring?	None / Some / High
3	Are you taking action to reduce climate change that you expect to occur in the future?	Yes / No

A.3 Section C

- Action in response to climate change?
- Your perception about the above changes?
- Your view and suggestion for improving the environment/ overcome climate change in your village/area/ town?

Appendix B

Template of the questionnaire for the students

Name.....,Gender. Male / Female, Age.....,Class....., Roll no....., School name....., Village.....,(Tehsil).....

Abbreviation **A** = Agree, **NS** = Not Sure, **D** = Disagree, **AT** = All the time, **S** = Some time, **NT** = Not Sure, **Y** = Yes, **N** = No, **M** = May be

B.1 Section A

Exploring the level of awareness and participatory involvement in actions relating to climate change

SL No	What do you know about Climate Change?	A	NS	D
1	I look / read for information on climate change			
2	Climate change is a risk to me			
3	I try to do everything, I can to reduce my impact on climate change			
4	Climate change will harm other human beings			
5	Climate change will kill plants and animals			
6	I don't do anything to be climate friendly			
7	I've never noticed any information about climate change			
8	I'd like to do more to be climate friendly, but I don't know what to do			

B.2 Section B

Dealing with involvement in advocacy and promotion of social actions

S.No	How often do you encourage others to do?	AT	S	N
1	Buy locally grown fruit and vegetables when they are in season			
2	Grow their own food			
3	Think about how much packaging there is when buying food			
4	Think about whether something can be recycled when buying products			
5	Buy the goods by using carry bags (reusable) instead of polythene			
6	Find out about climate change from TV / books / talking to neighbors / teachers			
7	How much solid waste they can control			
8	Turn off the tap while cleaning teeth			
9	Switch off power when not used, stop using heaters, don't leave TV on standby etc.			

B.3 Section C

Exploring willingness to involve in action in environmental activities

SI No	Would you like to do this?	Y	N	M
1	Switch off electricity when not required			
2	Use minimum water for bathing, washing etc			
3	Don't throw out the wrapper of chocolate , biscuits and Kulfi etc in the street / roads / commercial market			
4	Plant at least one tree in a year as your friend			
5	Avoid using polythene bags in daily life			
6	Use cloth / jute bag instead of polythene for shopping			
7	Avoid wastage of the food			
8	Dumping of household waste (solid waste) without throwing it in open sewage / river / pond			