Soil Quality Indices for Assessing the Forest Soil Health of Urban Forest Division, Srinagar

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Dedicated

To my
Beloved
Parents

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Natural Resource Management,
Faculty of Forestry, Benhama, Ganderbal

Certificate – I

This is to certify that the thesis entitled, **“Soil Quality Indices for Assessing the Forest Soil Health of Urban Forest Division, Srinagar”** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Forestry) Forest Resource Management**, to the **Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Ubaid Munawar Mir (Regd. No. MSF-2021-141)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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ABSTRACT

The present investigation entitled "Soil Quality Indices for Assessing the Forest soil Health of Urban Forest Division Srinagar" was carried out during the year 2021 and 2023. In this research, forest soil quality of Urban Forest Division, Srinagar were assessed under 3 experiments, for identifying causative parameters and prioritizing forest areas to facilitate adaptation and planning. In first experiment, forest soil health was checked based on 10 soil quality indicators which are grouped into Physical (Bulk density, Porosity and Aggregate stability), Chemical (pH, Total Nitrogen, Available phosphorous, Available potassium and Cation exchange capacity) and Biological (Soil organic carbon and Microbial biomass carbon) indicators. Significant variations were observed in soil properties across different blocks, including Bulk density, soil aggregate stability, and total porosity exhibited significant variations among blocks. Bulk density ranged from 1.06 g/cm^3 to 1.49 g/cm^3, with the highest recorded in Basiwan and the lowest in Nishat and Kralsangri. Soil aggregate stability ranged from 24.03 mm to 36.05 mm, with Hariparbat showing the highest stability. Total porosity ranged from 43.85% to 45.15%, with Shankarachariya exhibiting the highest value. Soil pH, Nitrogen, Phosphorus, Potassium, and Cation Exchange Capacity varied significantly across blocks. Soil pH ranged from 6.22 to 6.51, with Basiwan having the highest pH. Nitrogen content ranged from 451.9 kg/ha^{-1} to 512.6 kg/ha^{1} Nishat having the highest value. Available phosphorus ranged from 15.25 kg/ha^{-1} to 20.47 kg/ha^{-1} with Chashmashahi having the highest value. Available potassium ranged from 220.86 kg/ha^{-1} to 242.80 kg/ha^{-1}, with Nishat exhibiting the highest value. Cation exchange capacity ranged from 17.10 cmol(+)kg^{-1} to 20.82 cmol(+)kg^{-1}, Chashmashahi having the highest value and lowest was recorded in Nishat. Soil organic carbon and microbial biomass carbon varied significantly among blocks. Soil organic carbon ranged from 7.90g/kg to 8.93g/kg, Hariparbat exhibiting the highest value and lowest in Shankarachariya. Microbial biomass carbon ranged from 173 µg/kg to 188 µg/kg, with Hariparbat showing the highest value. Further, an integrated soil quality index was computed using principal component analysis (PCA) and weighted factor analysis. Four principal components (PCs) explained 73.5% of the total variance. The selected attributes for SQI included Microbial Biomass Carbon, Available Potassium, and Cation Exchange Capacity. Weighting factors ranged from 0.15 to 0.37, with PC1 having the highest weight.

The SQI provides a comprehensive assessment of soil quality. Weighted factor analysis reveals the relative importance of each soil function in enhancing soil sustainability and quality. The research underscores the importance of considering multiple soil parameters and their interactions to assess soil health comprehensively. The developed SQI provides a valuable tool for policymakers and land managers to monitor and improve soil quality in the Urban Forest Division Srinagar, thereby promoting sustainable land management practices.

Key words: Soil quality indices, Forest soil health, Urban Forest Division Srinagar, Physical indicators, Chemical indicators, Biological indicators, Principal Component Analysis, sustainability, land management

Signature of Student　　　　　　　　Signature of Major Advisor

Dated____________　　　　　　　　Dated _________________

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LIST OF ABBREVIATIONS

Food and Agriculture Organization	FAO
Inter-governmental Panel on Climate Change	IPCC
Soil Quality Indicators	SQI
Soil Health Index	SHI
Principal Component Analysis	PCA
Soil Organic Carbon	SOC
Nitrogen	N
Phosphorus	P
Potassium	K
Microbial Biomass Carbon	MBC
Minimum Data Set	MDS
Bulk Density	BD
Aggregate Stability	AS
Total Porosity	TP
Cation Exchange Capacity	CEC
Pair wise Comparison Method	PWCM
Tukey’s Honestly Significant Difference	HSD
Geographical Information System	GIS
Pearson’s Correlation	PC

Chapter-1

INTRODUCTION

The concept of a ‘soil quality indicator’ (SQI) is an appropriate means to determine and establish a soil quality baseline including functional ability, from which changes canbe observed as a result of pressures exerted on the soil. The soil quality concept has been adopted in several countries, including the USA, New Zealand Europe and the UK. Nevertheless, it has been challenged vigorously by some. In the UK, a consortium led by the Environment Agency recently commissioned research on the identification and development of a set of national SQIs, to be applied across all land uses, including forestry). Inevitably, there is a danger that in focusing in on one component of the ecosystem, a more holistic approach to sustainability will be endangered. Possibilities and practicalities of using SQIs as a quantitative tool is used in measuring the sustainable use of UK forest soils, as part of a wider set of indicators which attempt to quantify forest ecosystem quality and sustainable development (Loveland and Thompson, 2002).

Soil forms a thin layer over the surface of the earth that performs many processes essential to life. It serves as a substrate supporting plant growth, as a nutrient reservoir and as the site for many biological processes involved in decomposition and recycling of plant and animal products. Soils influence air quality through interactions with the atmosphere and as a storage and purification medium for water as it passes through the soil profile. The importance of soils to humankind is documented by the many ancient civilizations that have collapsed or relocated because mismanagement destroyed the soils on which they depended (Weinhold *et al*., 2004).Soil quality indicators are useful only if they can be linked to the concept of soil function and detection of change is likely in an appropriate time-scale. These precepts require understanding of:

- How soil systems work under optimal circumstances, i.e., what are the target values for an indicator which represent optimal function;

- What happens to the system and its functions and how this is reflected invalues of the indicator when perturbation occurs.
- How far a system can be perturbed before change is irreversible. This isan estimate of resilience for forestry, relevant soil functions include:
- Biomass production (timber, above and below ground macro- and microflora and fauna).
- Filtering, buffering and transforming substances (pesticides, industrialemissions, wastes – beneficial or otherwise).
- Supporting biodiversity (links to biomass through above and below ground macro- and micro-flora and fauna).
- Catching and releasing water to surface and groundwater (interception ofprecipitation).
- Preserving heritage (archaeological and geological materials).
- Carbon sequestration.
- Providing a surface for multifunctional forestry activities, e.g., visitor access, forestry operations

It is highly desirable that indicators can be fitted into a formal framework, in which to identify what shapes a system, what state or condition it is in and how it might respond to an adjustment. This minimizes the development and use of indicators in an unstructured and/or divergent way.

One framework, the D (river) –P (ressure) –S (tate) – I (mpact) –R (esponse) (DPSIR) model has been used recently by the European Environment Agency for its value as the basis for the development of SQIs in the UK in the Environment Agency study. However, much of the work on soil indicators refers, inevitably, to their ‘state’ only, i.e., their properties measured at some point in time or changes in state over a period of time. There is a strong need to move beyond this point and examine whether potential soil indicator data can be used to inform debate about function and the direction of policy on soil management (Maff, 2000).

Assessing the quality of soil resources has been stimulated by increasing awareness that it is an important component of the earth's biosphere, functioning not onlyin the production of food and fiber but also in ecosystems services and the maintenance of local, regional and global ecological balance. Soil quality primarily describes the combination of chemical, physical and biological characteristics that enables soils to perform a wide range of ecological functions The functions largely include, sustaining biological activity and diversity; regulating and partitioning water and solute flow; filtering, buffering, degrading, immobilizing and detoxifying organic and inorganic toxic materials; storing and cycling nutrients in soil-plant-atmospheric continuum and providing support of socio-economic treasures. In other way, quality of a soil is an assessment of how it performs all of its functions now and how those functions are beingpersuaded in future (Karlen *et al.*, 1997).

Soils contribute a lot to ecosystem services and may be categorized in the form ofprovisional, regulating and cultural services (Palmer *et al.*, 2017; Robinson *et al.*, 2014). Soils facilitate the growth of trees which in turn contribute to provisional ecosystem services (food for humans, energy in the form of fuel wood and bio-fuels, fodder for cattle, etc.). The regulating services of soils include carbon sequestration, supply of nutrients and their storage, mitigation of foods, etc. Even in November 2017, countries across the world united at 23rd Conference of Parties to the UNFCCC, acknowledged thebasic importance of soil carbon, soil fertility and soil health in response to the climate change (FAO, 2018).

Soil quality is important for two reasons. First, unscientific use of soil can damage itself and the ecosystem; therefore, there is a need to match the management of land to the soil's capability. Second, there is need to establish a baseline understanding about soilquality so that we can recognize changes as they occur. Therefore, the ultimate purpose of assessing soil quality is to protect and improve long-term agricultural productivity, water quality and habitats of all organisms including human being.

In recent years, soil quality research has focused on the linkages among the following i.e., management practices and systems; observable soil characteristics; and soil processes and performance of soil functions. Choosing the appropriate soil attributesto include in an index must include consideration of soil function and management goals that are site specific and user-oriented and must focus on sustainability rather than just crop yields. These indices would be useful in ascertaining the fragility of soil and for understanding how improved management might strengthen its resilience (Chaudhury *et al*., 2005). The testing of soil for routine analysis can only provide a snap shot on soil fertility which is not able to identify the production constraints because of deterioration of other soil properties. Therefore, assessing soil quality is advantageous for its holistic way to judge the management-induced changes. This capacity of the soil to function can be assessed by physical, chemical, and/or biological properties, which is termed as soil quality indicators (Wander and Bollero, 1999). Individual soil properties/processes may not provide an adequate measure of soil quality and integrated soil quality indicators based on a combination of soil properties can better reflect the status of soil quality than individual parameters. Soil quality changes with time can indicate whether the soil condition is sustainable or not (Arshad and Martin, 2002; Doran *et al.,* 2002). Soil quality cannot be measured directly however; it can be inferred by measuring soil physiochemical and biological properties that serve as quality indicator. Therefore, an integrated 'soil quality index' based on the weighted contribution of individual soil property to maintain the soil quality may serve better indicator of soil quality for differentland uses (Brejda *et al*., 2000, Diack and Stott, 2001).

1.1 Soil Health

The concept of soil health dates back to ancient civilizations. It has been considered more or less synonymous to soil quality, defined as “The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health” (Doran and Zeiss,1996). Soil health can be considered a subset of ecosystem health. A healthy ecosystem is characterized by integrity of nutrient cycles and energy flows, stability and resilience to disturbance or stress (O’Neill *et al.*, 1986). Thus, soil health may be associated with biological diversity and stability. Plant and animal disease outbreaks can be considered as indicators of instability and poor ecosystem health. Therefore, there is likely also a link between soil health, the ability of the biological community to suppress plant pathogens, the population density of plant pathogens in soil and ultimately disease incidence and severity (Van Bruggen and Grunwald, 1996).

Soil quality and soil health are referred many times as same concept. However, there are differences. Few points are listed here. Soil health refers to the biological, chemical and physical features of soil that are essential to long-term, sustainable agricultural productivity with minimal environmental impact. Thus, like soil quality, soil health also provides an overall picture of soil functionality. Similarly, it cannot be measured directly, soil health can be inferred by measuring specific soil properties (e.g., organic matter content) and by observing soil status e.g., fertility (Arias *et al.,* 2005).

Soil quality, soil health and soil quality/health assessment are highly contentious within the soil science community, because many believe those terms have generalized and oversimplified the collective knowledge and wisdom developed through several centuries of intensive, in depth, global studies of soil resources. Critics cite writings on sustainability by Cato during Roman times, prominent scientists and politicians from the 19th and 20th centuries, Nobel Laureates and other prestigious global award winners in support of their arguments. A common theme is that soil quality/health assessments are impossible and meaningless because of the complexity of soil resources. They suggest research and education should be focused on developing quality soil management practices rather than on soil quality or soil health. Proponents of soil quality argue that although soil scientists have long recognized the many unique and important properties and processes provided by fragile soil resources, outside the agricultural community, soils remain largely an under-valued resource The assessments are viewed as tools intended toalert users, in a manner analogous to a “consumer price index,” that soil resource problems have or may be occurring (Karlen *et al.,* 2008).

Soil quality influences basic soil functions, such as moderating and partitioning water and solute movement and their redistribution and supply to plants; storing and cycling nutrients; filtering, buffering, immobilizing and detoxifying organic and inorganic materials; promoting root growth; providing resistance to erosion. The capacityof soil to function can be reflected by measured soil physical, chemical and biological properties, also known as soil quality indicators (SQIs). There is a need to develop SQI in such a way so that they: (i) integrate soil physical, chemical and/or biological properties and processes (ii) apply under diverse field conditions (iii) complement either existing databases or easily measurable data and (iv) respond to land use, management practices,climate and human factors. Depending upon their temporal variability, SQI can be classified as static or dynamic. Monitoring changes in the key SQI with time can determine if quality of a soil under a given land use and management system is improving, stable or declining. Soil quality concept is both advocated and criticized in the literature (Shukla *et al.,* 2006).

Properties affecting soil ecological functions and quality, for example soil bulk density, water infiltration and holding capacity, total organic C and N, electrical conductivity, pH, plant-available nutrients and measures of microbial biomass andactivity. Although these properties may be useful as indicators for soil quality, they are not necessarily associated with soil health and the maintenance of essential soil ecological functions. The general approach to measure as many variables as possible and relate them to different uses (natural versus agricultural soil) or soil management practices (such as conventional versus alternative practices in terms of tillage, plant nutrition, or pest control) has not resulted in indicators that are consistently correlated with soil health (Doran *et al.* (1996).

1.2 Indicators for Soil Health

Physical indicators of soil health generally include simple, fast and low-cost methodologies. Moreover, such indicators like texture, bulk density, porosity and aggregate stability are also correlated with hydrological processes like erosion, aeration, runoff, infiltration rate and water holding capacity (Schoenholtz *et al.*, 2000). In general, a soil is considered physically poor when it shows low rates of water infiltration, enhanced surface runoff, poor cohesion, low aeration and root density and difficulty for mechanization (Dexter, 2004). Soil texture is an important factor affecting the balance between water and gases, but it is very stable along time, independently on the soil management. Therefore, bulk density and total porosity can better represent the effects of soil use and management on the water/air relationships (Beutler *et al.*, 2002). Lower bulk densities have been generally observed in soils under less anthropogenic interferences like native forests (Bini *et al*., 2013), where the greater levels of soil organic matter permit a better aggregation of soil particles, improving the soil structure. As a result, an increase in soil macro porosity improves the soil permeability not only for water, but also for air and roots (Tejada *et al.*, 2006). The total soil porosity can be classified as textural, depending on the proportion of soil particles and structural, depending on bio pores and as macrostructure. The second one is easily affected by soil use and management (Dexter, 2004), which may change the characteristic soil water retention curve based on structural pores.

Chemical attributes of soil health are correlated with the capacity to provide nutrients for plants and/or retaining chemical elements or compounds harmful to the environment and plant growth. Soil pH, cation exchange capacity (CEC), organic matter and nutrient levels are the main chemical attributes used in soil health assessment, especially when considering the soil capacity for supporting high yield crops (Kelly *et al.*, 2009). Chemical attributes have been correlated with plant yields and thus the variations of a particular indicator are easily interpreted and allow a quick improvement of the soil chemical properties by liming and/or fertilization. These soil chemical indicators can also be useful in considering the soil's capacity for sustaining forest production and sustainability, maintaining nutrient cycling, plant biomass and organic matter (Schoenholtz *et al.,* 2000).

The complex interrelationships between biological, physical and chemical components can be better achieved when studying the origins of natural processes and their fate in nature. For example, by means of photosynthesis, plants fix and transfer carbon as carbohydrates to the food web, which is the most important biological process on earth. Along their lifecycle and especially at the end, animal and plant debris are constantly deposited into the soil. Organic carbon and immobilized minerals must be recycled in the ecosystem before being utilized by new organisms in a continuous and sustainable life-cycle (Schjønning *et al.*, 2004). Thus, biological processes are essential for keeping the soil capacity for recycling carbon to the atmosphere and assure the continuance of photosynthesis, concomitantly with nutrient mineralization for plant and microbial nutrition. Healthy soils have the capacity to keep these processes working in a sustainable way indefinitely.

1.3 Soil Quality Indices

Soil quality indices are used to quantify the overall health and fertility of soil, incorporating various physical, chemical and biological parameters. These indices provide a valuable means of evaluating the suitability of soil for agricultural purposes and environmental sustainability. Parameters such as soil texture, organic matter content, nutrient levels, microbial activity and pH are often included in the calculation of these indices. The integration of multiple factors allows for a more holistic understanding of soil quality, facilitating informed land management decisions. Several well-established soil quality indices, such as the Soil Quality Index (SQI), the Soil Health Index (SHI) and the Global Soil Health Assessment Framework, offer standardized approaches for evaluating soil health on regional and global scales (Doran and Parkin, 1994; Karlen *et al.*, 2003; FAO, 2019).

1.4 Urban Forest and Soil

Urban forests play a vitol role in building soil organic carbon pool in urban areas. In many cases urban forests are constructed on land previously used for agriculture, parks and buildings. However, it is still being determined whether historical land use affects soil organic carbon (SOC) stock in these forests. Soil is an essential part of the urban ecosystem in maintaining stability and mitigating climate change. Urban soils have versatile functions especially the ability to buffer and purify pollutants. Urban forests are exposed to a variety of deleterious environmental conditions such as soil compaction, air pollution, deicing salts and heat loads along with impacts from constructions, buildings and vehicle debris. Understanding soil characteristics is of crucial importance to determine the best practices and growth conditions for tree health in urban environment (Yang *et al.*, 2015).

Need and Importance of Study

The ultimate purpose of assessing soil quality is to protect and improve long-term forest productivity, water quality and habitats of all organisms including human being. In recent years, soil quality research has focused on the linkages among the following:

1. Management practices and systems; observable soil characteristics; and soil processesand performance of soil functions.
2. Choosing the appropriate soil attributes to include in an index must include consideration of soil function and management goals that are

site specific and user oriented and must focus on sustainability. These indices would be useful in ascertaining the fragility of soil and for understanding how improved management might strengthen its resilience (Chaudhury *et al*., 2005)

3. Assessing soil quality is advantageous for its holistic way to judge the management induced changes. This capacity of the soil to function can be assessed by physical, chemical, and/or biological properties, which is termed as soil quality indicators (Wanderand Bollero, 1999).

This study aims to make credible assessment of forest soil quality in urban forest division Srinagar for identifying causative parameters and prioritizing forest areas assessing the current soil quality index to facilitate adaptation and planning keeping in view the proposed research problem entitled, ‘Soil Quality Indices for Assessing the Forest soil Health of Urban Forest Division Srinagar (J&K) is contemplated with following objectives.

1. To assess forest soil health on selected physical, chemical and biological soilquality indicators.
2. To compute an overall integrated soil quality index (SQI) of urban forestryDivision Srinagar.
3. Generation of soil quality index maps of Urban Forest Division Srinagar.

Chapter 2.

REVIEW OF LITERATURE

Review of related studies helps us to mull over our research argument and to put down research methodologies. Usually, the ensuring section gives a brief account or idea of various studies conducted at national and international levels relating to the title. The outcome of previous studies forms the base for further scientific enquiry and identifies inconstancies and the relationship of works in context of its contribution to the topic and to other works. In this chapter, an intensive exploration of past published research works related to the present study entitled "Soil Quality Indices for Assessing the Forest Soil Health of Urban Forest Division Srinagar (J&K)" have been presented as given below.

Taghipour *et al.* (2022) studied the Assessing changes in Soil Quality between protected and degraded forests using digital soil mapping for semi-arid oak forests, Iran. This study calculates a soil quality index (SQI) from an integrated suite of soil biological, physical and chemical properties and compares the SQI between a paired degraded/deforested area and a protected forested area in Iran using a digital soil mapping (DSM) approach via geostatistical and machine learning techniques. Here, 50 soil samples were acquired for each of the degraded/deforested and protected forested areas, whereby 14 soil attributes were measured. Results showed that the soil organic carbon, total nitrogen, available potassium, cation exchange capacity, pH, clay, saturated water content and basal respiration in the protected area were significantly higher than the degraded forest area. Furthermore, the soil quality in the protected area was substantially higher than the degraded area. By comparing the SQI maps between the degraded/deforested and protected forested areas, the soil quality was substantially higher for the protected areas. This study demonstrates a framework for assessing the impacts of deforestation on the spatial patterns of soils using DSM techniques, which will facilitate effective land use planning and sustainable forest resource management strategies.

Recha *et al.* (2022) examined soil quality indicators across six climate-smart land uses in East African Climate-Smart Villages. Notably, grasslands in Kenya and Tanzania displayed high bulk density at deeper depths (1.47 g/cm^3 and 1.50 g/cm^3, respectively), while Ugandan grasslands showed lower bulk density. Agroforestry had the highest soil pH (6.67 ± 0.67), while grasslands had the lowest (6.27 ± 0.85). Positive correlations were found between silt % and pH, sand and Ca and EC and pH. The study suggests that certain land use systems lead to improvements in soil properties and increased soil nutrients.

Yinga *et al.* (2022) studied the influence of land use pattern on soil quality in a steeply sloped tropical mountainous region, India. The study investigates the effect of various existing hill land-use practices on soil quality. The land-use types were selected for the analysis was based on common land-use types practices in the area. Soil samples were collected from different land-use types and analyzed for bulk density (BD), clay, sand, silt content, soil organic carbon, total nitrogen, available phosphorus, microbial biomass carbon and nitrogen (MBC and MBN) and exchangeable cations. Further, the soil fertility index, soil evaluation factor and Principal Component Analysis suggest PC1 accounts maximum variance (41.6%) followed by PC2 (19.7%), PC3 (13.5%), PC4 (12.4%) and PC5 has least variance (10.4%). Weighted soil quality index (SQI) was computed based on SQI the majority of land use samples show a moderate quality of soil except samples of CJ (SQI = 0.75) which is in good category.

Nunes *et al*. (2020) studied the soil health assessment protocol and evaluation applied to soil organic carbon. In this study Soil Health Assessment Protocol and Evaluation (SHAPE) tool was proposed. The SHAPE was developed using 14,680 soil organic C (SOC) observations from across the United States and accounts for edaphic and climate factors at the continental scale. Data were compiled from the literature, the Cornell Soil Health Laboratory and the Kellogg Soil Survey Laboratory. In this approach, scoring curves are Bayesian.

Menta and Ramelli (2020) studied the Soil Health and Arthropods: From Complex System to Worthwhile Investigation. This study aims to evaluate and compare the use of different soil micro arthropod taxa in soil degradation/quality studies to highlight which groups are the most reported for soil monitoring and which are the most sensitive to soil degradation. They have decided not to include the two most present and abundant taxa, Acari and Collembola, in this paper in consideration of the vast amount of existing literature and focus the discussion on the other micro arthropod groups. They reported some studies for each taxon highlighting the use of the group as soil quality indicator.

Li *et al*. (2019) investigates the impact of different land-use types on soil microbial communities in the semiarid Loess Plateau region. By employing advanced molecular techniques, the research delves into the intricate relationships between soil chemical properties and microbial diversity and function. Through extensive field sampling and laboratory analyses, the study examines how various land-use practices, including agriculture, grazing and natural vegetation and influence soil microbial communities. The findings highlight significant shifts in microbial community composition and activity across different land-use types, emphasizing the pivotal role of human activities in shaping soil ecosystems in semiarid regions. Moreover, the research underscores the importance of understanding these ecological dynamics for sustainable land management and conservation efforts in vulnerable environments like the Loess Plateau.

Smith (2019) explores soil phosphorus characterization and analysis, aiming to facilitate sustainable management practices in agriculture. The book offers a comprehensive overview of soil phosphorus dynamics, covering various aspects such as its forms, transformations, availability and interactions with soil constituents. Through a synthesis of current research and practical insights, Smith provides valuable information for understanding the role of phosphorus in soil fertility and plant nutrition. Emphasizing sustainable phosphorus management strategies, the book discusses approaches for optimizing phosphorus use efficiency, minimizing environmental losses and ensuring long-term soil productivity. Smith's work serves as a vital resource for researchers, agronomists and policymakers seeking to address the challenges of phosphorus sustainability in agricultural systems.

Kováčik *et al.* (2019) delve into the impact of different agricultural practices on soil potassium content, aiming to elucidate the dynamics of potassium in agricultural landscapes. Through field-based investigations and soil analyses, the research explores how factors such as tillage, fertilization, crop rotation and irrigation influence potassium availability and distribution in soils. By assessing the interactions between farming practices and soil potassium dynamics, they provide valuable insights for optimizing potassium management strategies in agriculture. The findings contribute to a better understanding of the factors influencing soil fertility and crop productivity, thereby facilitating sustainable land management practices and ensuring adequate potassium supply for agricultural production.

Schlesinger (2019) likely provides a thorough examination of the fate of anthropogenic nitrogen, offering valuable insights into the environmental ramifications of nitrogen utilization in human activities. The work likely delves into the intricate pathways through which anthropogenic nitrogen enters ecosystems, undergoes transformations and eventually impacts ecological processes. By elucidating the various mechanisms involved in nitrogen cycling, Schlesinger's research likely sheds light on the critical need for sustainable nitrogen management practices to mitigate pollution and safeguard environmental health.

Jones *et al.* (2018) present a detailed overview of the European Union Soil Information System (EUSIS) and its associated input datasets, offering a comprehensive resource for soil management. The study discusses the development, structure and functionality of EUSIS, highlighting its role as a central repository for soil-related data across Europe. By integrating diverse sources of soil information, including field surveys, remote sensing and modeling, EUSIS provides valuable insights into soil properties, functions and threats at regional and continental scales. The research emphasizes the importance of accessible and standardized soil data for evidence-based decision-making in various sectors, including agriculture, environmental protection and spatial planning. Their work serves as a valuable reference for researchers, policymakers and stakeholders involved in soil management and conservation efforts in the European Union.

Gupta *et al.* (2018) explore the mechanisms of potassium-solubilizing microorganisms (KSMs) and their role in enhancing potassium solubilization in agricultural soils. The study investigates the diverse microbial taxa capable of mobilizing potassium from soil minerals and organic matter through various enzymatic and metabolic processes. By elucidating the interactions between KSMs and soil physicochemical properties. They provide insights into the potential of microbial interventions for improving soil fertility and crop nutrition. The research discusses strategies for harnessing KSMs in sustainable agriculture, including biofertilizer development, microbial inoculation and soil management practices. Their work contributes to a deeper understanding of the microbial drivers of potassium cycling in soils, offering innovative approaches for enhancing nutrient availability and agricultural productivity while reducing reliance on chemical fertilizers.

Brown *et al.* (2017) focus on the characterization and analysis of soil phosphorus, emphasizing sustainable nutrient management practices. The study examines the forms, distribution, cycling and environmental implications of phosphorus in soils, addressing key challenges related to nutrient availability, soil fertility and water quality. Through a synthesis of empirical research and theoretical frameworks, Brown *et al*. provide insights into phosphorus dynamics and transformations in agricultural and natural ecosystems. The research highlights the importance of adopting integrated approaches for phosphorus management, including soil testing, nutrient budgeting, precision agriculture and best management practices. By promoting sustainable phosphorus use. Their work contributes to mitigating the adverse effects of phosphorus pollution on aquatic ecosystems and human health while enhancing agricultural productivity and food security.

Gregory *et al.* (2017) contribute insights into the influence of well-developed root systems on total porosity in soils, elucidating the role of roots in soil structure and function. Through field observations, experimental studies and modeling approaches, the research examines how root growth and activity affect pore formation, distribution and connectivity in soil profiles. They demonstrate that the presence of roots enhances macro-pore creation, root material decay, water movement and aeration, ultimately leading to increased total porosity and soil productivity. The findings underscore the importance of promoting healthy root-soil interactions for sustaining soil health, water infiltration and nutrient cycling in diverse ecosystems. Their work provides valuable insights for soil management practices aimed at optimizing root development and maximizing soil porosity for improved plant growth and ecosystem resilience.

Karlen *et al.* (2017) explore the anthropogenic influences on soil properties and associated microbial communities in agricultural landscapes, providing a comprehensive understanding of human-induced changes in soil ecosystems. Through a multidisciplinary approach integrating soil science, microbiology, ecology and land use analysis, the research investigates the effects of agricultural practices, land management and environmental factors on soil health and microbial diversity. They highlight the complex interactions between human activities and soil biota, including alterations in soil physical, chemical and biological properties. The study emphasizes the importance of adopting sustainable land management practices that promote soil conservation, biodiversity conservation and ecosystem services provision. By elucidating the mechanisms underlying anthropogenic impacts on soil ecosystems, they work informs strategies for enhancing agricultural sustainability, resilience and productivity while minimizing adverse environmental effects.

Tang *et al.* (2017) investigate the intricate interplay between climate patterns, vegetation cover and soil potassium dynamics in semi-arid and arid regions. Through field surveys and laboratory analyses, the study examines how climatic factors such as temperature, precipitation and evapotranspiration, along with vegetation types, influence the distribution and availability of potassium in soils. By integrating ecological and geochemical approaches, they elucidate the mechanisms driving potassium cycling in water-limited environments, where soil nutrient dynamics are particularly sensitive to environmental changes. The research underscores the importance of considering both abiotic and biotic factors in understanding soil nutrient dynamics, highlighting the role of vegetation as a mediator of soil-plant-atmosphere interactions. Their findings contribute to a holistic understanding of soil-vegetation-climate interactions, essential for sustainable land management and ecosystem conservation in semi-arid and arid regions. Through their interdisciplinary approach, Tang *et al*. provide valuable insights into the resilience and adaptability of soil ecosystems to changing environmental conditions, guiding strategies for enhancing soil fertility, biodiversity and ecosystem services provision in water-limited environments.

Bhattacharyya *et al.* (2017) studied the soil quality under organic farming. Soil quality index is a useful tool to assess soil health and wellbeing. Few methods are available to estimate it. Among those PCA based scoring, ranking and weightage method gaining popularity. However, SQI assessment primarily depends on objectives of study or soil functions need to be addressed. Selection of MDS and its ranking play important role for determining SQI. As obvious organic farming has great influence on SQI. And more so inorganic and organic farming affect SQI differently. So, they need to be assessed in site specific conditions keeping the goal in mind. In nutshell, SQI is a tool to quantitative measure of “soil condition: both in medium and long term”. It has to be interpreted precisely, when comparing organic or inorganic farming keeping in view of spatial and socio-economic variations.

Gelaw *et al.* (2015) studied the Soil Quality Indices for Evaluating Smallholder Agricultural Land Uses in Northern Ethiopia. Integrated soil quality indices (SQI) within the surface 0-15 cm depth increment for 3 agricultural land uses: rain fed cultivation (RF) ; agroforestry (AF) and irrigated crop production (IR). Each land use was replicated 5 times within a semiarid watershed in eastern Tigray, Northern Ethiopia. According to study four soil functions regarding soil ability were used 1) accommodate water entry (WE) ; 2) facilitate water movement and availability (WMA) ; resist degradation (RD) ; and 4) supply nutrients for plant growth (PNS) were estimated for each land use. The study revealed that AF affected all soil quality functions positively more than the other land uses. Furthermore, the 4 soil quality functions were integrated into an overall SQI; and the values for three land uses were in order: 0.58 (AF) >0.51 (IR) >0.47 (RF).

Duval *et al.* (2013) investigated soil quality indicators across natural and cultivated systems in the Argentinean pampas. They sampled soils along a West-East transect, with three defined treatments: "Good agricultural practices" (GAP), "Poor agricultural practices" (PAP) and "Natural environment" (NE). Soil organic carbon (SOC) levels varied from 27.3 g/kg in Viale to 13.3 g/kg in Bengolea, correlated with rainfall and texture gradients. The SOC levels in agricultural soils were 16-44% lower than in natural environments. Carbon stocks per unit soil mass were significantly different ($p < 0.001$): NE (26.6 Mg/ha) > GAP (20.1 Mg/ha) > PAP (16.3 Mg/ha). Labile organic fractions, particularly POCf (53-100 mm) and total carbohydrates (CHt), proved to be sensitive indicators of short- and medium-term management effects.

Havlin *et al.* (2014) likely serves as a foundational resource in understanding soil fertility and fertilizer management. Their work probably offers a comprehensive overview of the principles governing nutrient dynamics in soils, providing essential knowledge for optimizing agricultural productivity while minimizing environmental impacts. By elucidating key concepts such as nutrient cycling, soil amendment strategies and fertilizer application techniques, there research likely serves as an invaluable introductory reference for students and practitioners in the field of soil science.

Marzaoili *et al*. (2010) assessed soil quality in a Mediterranean area of Southern Italy across various land use types. They analyzed physical, chemical and biological parameters on soil samples collected with seasonal frequency. A soil quality index (SQI) was calculated based on annual means of the data, with multivariate analyses used to distinguish soil quality classes. Results indicated varying soil quality levels: low ($SQI < 0.55$) in permanent crops, intermediate ($0.55 < SQI < 0.70$) in shrub lands, grazing lands, coniferous forest and middle-hill olive grove and high ($SQI > 0.70$) in mixed forests. Permanent crop management negatively impacted soil quality, while moderate grazing and crop management with herb cover had a lesser negative impact. Abandonment of cultivated lands led to soil quality improvement, suggesting soil's good recovery capacity.

Qi *et al.* (2009) assessed soil quality indices in Zhangjiagang County, Jiangsu Province, China, using the Integrated Quality Index (IQI) and Nemero Quality Index (NQI). They employed three indicator selection methods: Total Data Set (TDS), Minimum Data Set (MDS) and Delphi Data Set (DDS), incorporating 22 soil parameters. Anthrosols generally exhibited higher quality than Cambosols. Regression and correlation analyses favored IQI over NQI, with IQI's match analysis 9% higher. While TDS is the most accurate, IQI and MDS adequately represent it ($r^2 = 0.65$), saving time and resources.

Brady and Weil (2008) seminal work is likely regarded as a cornerstone in the discipline of soil science, offering a comprehensive exploration of soil properties, processes and management practices. Their comprehensive text likely provides a holistic understanding of soil formation, classification and fertility, drawing upon interdisciplinary insights to elucidate the intricate relationships between soils, plants and the environment. By synthesizing decades of research and practical experience, Brady and Weil likely offer a definitive resource for scholars, educators and professionals seeking to deepen their understanding of soil science.

Schindelbeck *et al.* (2008) conducted a study on soil quality assessment, analyzing 1500 samples from agricultural landscapes. They selected 4 physical and 4 biological indicators, along with 7 standard chemical indicators for soil fertility tests. Additional chemical indicators were considered for potentially contaminated sites. The study developed test reports for overall soil quality assessment and identification of specific soil constraints. They exemplified the use of this protocol in three scenarios: a vegetable farm, a town park and a vacant urban lot in New York State. This approach offers a comprehensive assessment of soil's environmental functions at a modest cost, aiding targeted management and remediation strategies.

Amacher *et al.* (2007) studied soil vital sign: a new soil quality index for assessing forest soil health. In this study new index of forest soil was developed, the soil quality index (SQI), that integrates 19 measured physical and chemical properties of forest soil into a single number that serves as a soils “vital sign” of overall soil quality. Regional and soil depth differences in SQI values due to differences in soil properties were observed. The SQI is a new tool for establishing baselines and detecting forest health trends. Model-based estimates of the conditional cumulative distribution function (CDF) for defined soil peer groups reflecting five soil texture and five soil suborder classes adjusted for mean annual temperature and precipitation. Specifically, SHAPE produces scores between 0 and 1 (0–100%) for measured SOC values that reflect the quantile or position within the conditional CDF along with measures of uncertainty. Herein, we focus on development of the SHAPE scoring curve for SOC with our case studies.

SHAPE is a flexible, quantitative tool that provides a regionally relevant interpretation of this key soil health indicator.

Shukla *et al.* (2006) conducted study on determining soil quality indicators by factor analysis Soil quality indicators (SQIs) can be used to evaluate sustainability of land use and soil management practices in agroecosystems. The objective of this study was to identify appropriate SQI from factor analysis (FA) of five treatments: no-till corn (*Zee mays*) without manure (NT), no-till corn with manure (NTM), no-till corn–soybean (*Glycine max*) rotation (NTR), conventional tillage corn (CT) and meadow (M) in Coshocton, Ohio. Soil properties were grouped into five factors (eigenvalues > 1) for the 0–10 cm depth as: (Factor 1) water transmission (Factor 2) soil aeration (Factor 3) soil pore connection 1 (Factor 4) soil texture and (Factor 5) moisture status. Factor 2 was the most dominant, with soil organic carbon (SOC) the most dominant measured soil attribute contributing to this factor. For the 10–20 cm depth, factors identified were: (Factor 6) soil aggregation (Factor 7) soil pore connection 2 (Factor 8) soil macrospore and (Factor 9) plant production. At 10–20 cm depth, Factor 6 was most dominant with SOC the most dominant measured soil attribute. Management × sample and slope position × sample interactions were significant among some factors for both depths. Overall, SOC was the most dominant measured soil attribute as a SQI for both depths. Other key soil attributes were field water capacity, air-filled porosity, pH and soil bulk density for the 0–10 cm depth and total N and mean weight diameter of aggregates for the 10–20 depth. Therefore, SOC could play an important role for monitoring soil quality.

Bronick and Lal (2005) contribute significantly to our understanding of soil structure improvement through the role of organic matter. Their research underscores the importance of organic matter accumulation, facilitated by vegetative cover, in enhancing soil structure. By acting as binding agents, organic materials promote the formation and stability of soil aggregates, which in turn increases soil porosity. This enhanced porosity allows for better water infiltration and retention, improved root penetration and enhanced microbial activity, all of which are vital for sustaining soil health and fertility. There findings emphasize the critical role of organic matter management in sustainable soil management practices, highlighting the importance of strategies such as cover cropping, compost application and reduced tillage to enhance soil structure and overall ecosystem functioning.

Six *et al.* (2004) likely presents a seminal contribution to the field of soil science by elucidating the intricate relationships between soil aggregates, biota and organic matter dynamics. Their research likely lays the groundwork for understanding the fundamental processes governing soil structure formation, microbial activity and organic matter decomposition. By highlighting the critical role of soil biota in mediating organic matter turnover and nutrient cycling.

Moffat (2003) studied the indicators of soil quality for UK forestry. The study examined that the use of soil quality indicators in forestry world-wide and makes recommendations for the utilization of direct and indirect (headline/surrogate/awareness) measures of soil or site quality suitable for use ina forestry context in the UK. It reviews the degree of forest soil monitoring in Great Britain and the problems posed by spatial and temporal variation associated with this activity. It identifies research needed to increase the ability to use more direct measures of soil function in the future.

Sun *et al.* (2003) investigated spatial and temporal changes in soil quality in a subtropical Chinese hill region using geostatistical analysis. They sampled soil from 105 locations on a 100 x 100 m grid over a 112-ha field in 1985 and 1997. Soil properties varied widely, with the highest coefficient of variation for available P and the lowest for soil pH. Over 12 years, soil organic matter decreased significantly in areas initially wasteland or paddy fields. Geostatistical analysis revealed spatial structure in soil properties and their changes, with strong spatial dependence for pH and moderate for other properties. Land use changes affected soil fertility, with soil properties showing spatial similarity. The study suggests geostatistical methods for monitoring soil quality changes at a farm scale.

Sainju *et al.* (2002) study likely offers valuable insights into the impact of agricultural practices on soil carbon dynamics, with a particular focus on carbon dioxide emission and carbon content. Their research likely provides empirical evidence to inform sustainable land management strategies aimed at enhancing soil carbon sequestration and mitigating greenhouse gas emissions.

Andrews and Carroll (2001) developed a soil quality assessment tool for sustainable agroecosystem management. They designed a framework to select representative indicators from existing data sets, combining them into location-specific indices of soil quality (SQI) for assessing agricultural practices. They illustrated this approach using poultry-litter management, comparing fresh vs. composted litter application at two sites with different soil types. Over 40 assays were analyzed, including organic C, nutrients, heavy metals, water availability, soil structure and microbial activity. Multivariate statistical techniques identified a minimum data set (MDS) of indicators explaining at least 85% variability. The MDS was used to calculate an additive SQI, showing significant differences between management treatments. The SQI effectively monitored sustainable management practices, with indices tailored to local conditions.

Wander and Bollera (1999) conducted study on Soil Quality Assessment of Tillage impacts in Illinois. The main objective of the study was to use a multivariate data set to determine whether recent adoption of no-tillage (NT) practices had altered soil quality in Illinois. In 1995 and 1996, we sampled thirty six farm fields under conventional tillage (CT) or NT practices and relatively non-disturbed (ND) areas. Soils were Mollisols or Alfisols. Tillage or region affected 20 of the 23 parameters characterized. Soil chemical parameters were less variable than biological or physical measures. Principal component analysis (PCA) was used to assess soil quality overall. Principal component 1 (PC1) scores, which explained 39% of the total variance of the overall data set, were affected by tillage

(ND > NT > CT) and increased with particulate and organic C and total N, biological activity, mineralizable N and wet aggregate stability and decreased with bulk density and dry aggregate mean weight diameter. The only significant factor contributing to PC2 was penetration resistance; PC2 explained 13% of the variance and decreased as follows: NT ≥ ND > CT. Multivariate assessment of soil quality indicated use of NT practices improved the biological and physical condition of the soil (0–15 cm) despite increased consolidation. It also showed that those biological and physical aspects of soils influenced by organic matter were the properties most altered by agronomic practices. Particulate organic matter (POM) was identified as a promising soil quality measure. A next step is to determine the biological and environmental relevance of a refined set of soil quality measures in conjunction with soil processes of regional concern.

Davidson *et al.* (1990) conducted a comprehensive review on methods for measuring nitrogen processes in soils. Their research encompassed key values such as gross nitrogen mineralization, immobilization and nitrification rates. Through meticulous analysis, they provided valuable insights into the dynamics of nitrogen cycling in terrestrial ecosystems. This review serves as a cornerstone for understanding and quantifying soil nitrogen processes, guiding nutrient management practices for sustainable agriculture.

Gillman and Sumpter (1986) introduced a significant modification to the compulsive exchange method, representing a notable advancement in soil science methodology. Their research focused on characterizing soil exchange characteristics, including nutrient availability and cation exchange capacity. By refining measurement techniques, their work enhances ability to assess crucial soil properties. This advancement informs agricultural management practices and soil conservation efforts, contributing to improved soil health and productivity.

Tisdall and Oade (1982) pioneering research likely provides foundational insights into the role of tree roots in enhancing soil aggregate stability through the binding of soil particles. Their work likely advances our understanding of the physical processes governing soil structure formation and stability, highlighting the importance of biotic interactions in shaping soil properties. By elucidating the mechanisms through which tree roots influence soil aggregation.

Baver (1972) seminal work likely offers valuable insights into the factors influencing soil porosity, with implications for soil structure and fertility. By examining the role of compacted soil layers, organic matter content and root development in shaping soil porosity. He provides foundational knowledge for understanding the physical properties of soils. His research likely informs soil management practices aimed at optimizing soil structure and fertility, thereby enhancing agricultural productivity and environmental sustainability.

Chapter-3

MATERIALS AND METHODS

3.1 Study area:

The proposed study was conducted in Urban Forest Division of Srinagar district of Union Territory Jammu and Kashmir, India, it is situated at 34°5' North Latitude and 74°47' East Longitude. The Urban Forest Division lies in central part of Kashmir province and the total area of the demarcated forest area is 1789.8 ha. The Urban Forest Division is divided into two ranges namely: Hariparbhat and Shankarachariya Park. Hariparbhat Range comprises of two blocks *viz.,*Hariparbhat and Nishat. The Shankarachariya Park (S Park) consists of 4 blocks *viz.*, S Park, Basiwan, Chashmashahi and Kralsangri. The climate of the area is temperate. The place is cooler than many other places of India. Winters are cool and the average temperate becomes 2.5 °C during day time in the month of January. At night, the temperature may reach below 0 °C. Summers are warm and pleasant. During July, the average temperature becomes 24.1 °C. The average rainfall in a year is 710 mm. The driest season of Srinagar is the autumn and the wettest season is the spring.

3.2 Soil Sampling:

Soil sampling was carried out in each forest block of the Urban Forest Division of Srinagar. Six sites were selected for soil sampling from each respective block of the Forest Division. Stratified random sampling were followed within selected forest blocks for sample collection. Pits of recommended size (i.e., 30 cm^3) were dig at each forest block. Top organic matter was isolated from each site and samples were scraped from soil depth of (0-30 cm). Within each site, five samples were randomly collected. Overall, 30 composite samples were selected from both forest ranges in the study area (Fig. 3.3). The soil samples obtained from each site in the replicates of three were then analyzed in the laboratory.

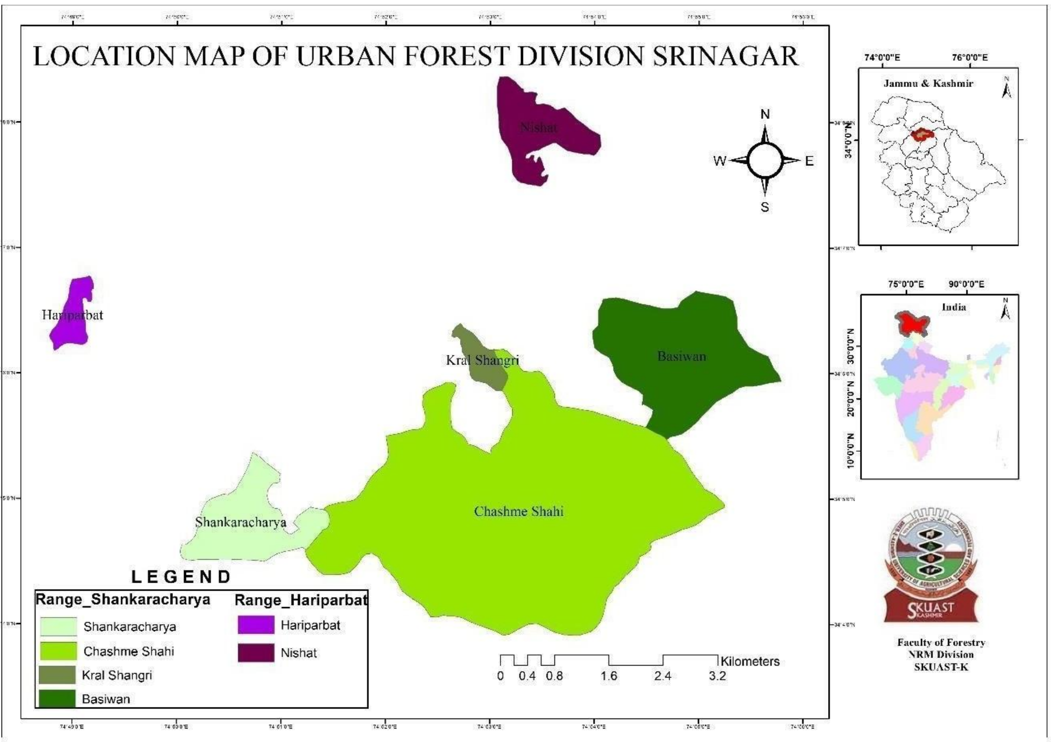


Fig. 3.1: Location map of Urban Forest Division Srinagar

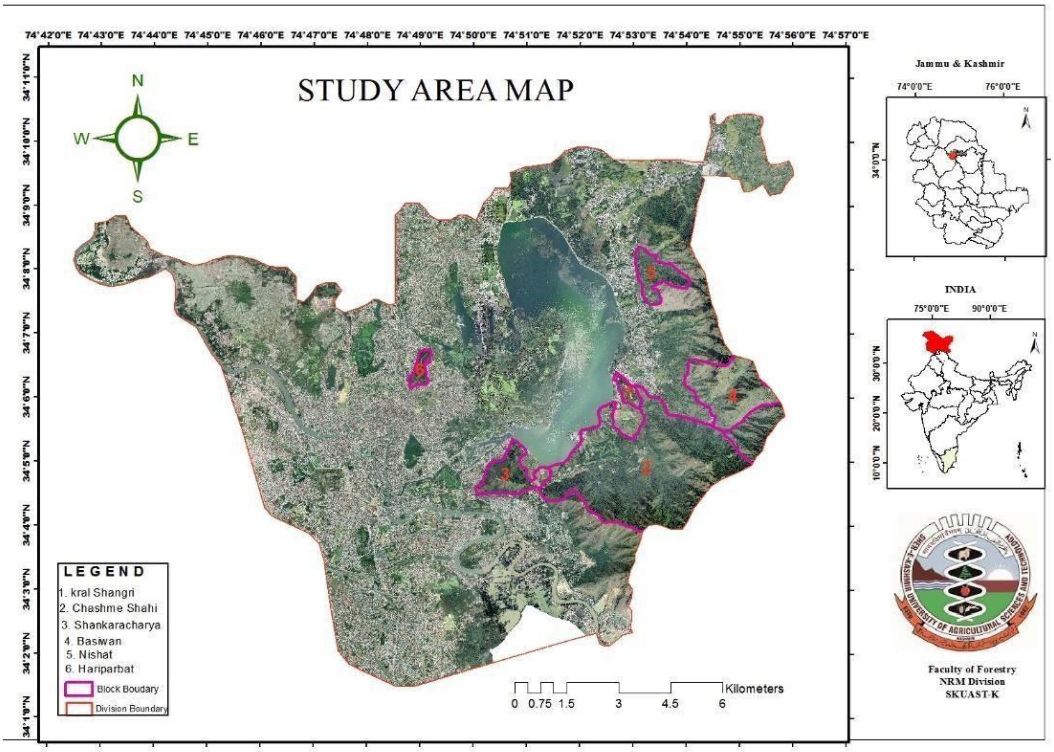
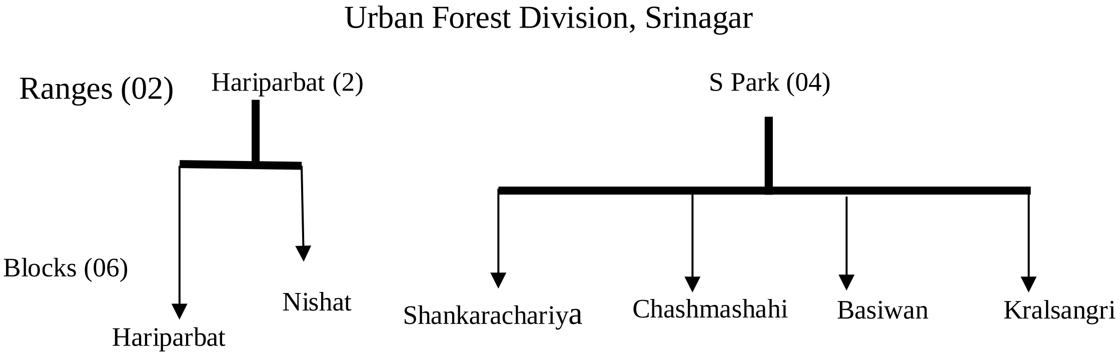


Fig. 3.2: Study Map of Urban Forest Division Srinagar

Stratified random sampling was followed within selected forest blocks for samplecollection.



Blocks : 6

Sites : 5

Replications : 3

Total samples : 6x5x3=90

3.3 Soil quality index (SQI) indicators recorded

Soils have physical, chemical and biological properties that interact in a complex way to give a soil its quality. Thus, soil quality cannot be measured directly, but must be inferred from measuring changes in its attributes or attributes of the ecosystem, referred to as indicators. Indicators are measurable properties of soil. Thus, broad soil quality indicators could be grouped, viz. (i) soil physical quality indicators and (ii) soil chemical quality (iii) soil biological quality indicators.

Following ten (10) indicators was used to assess soil quality index of Urban Forest DivisionSrinagar.

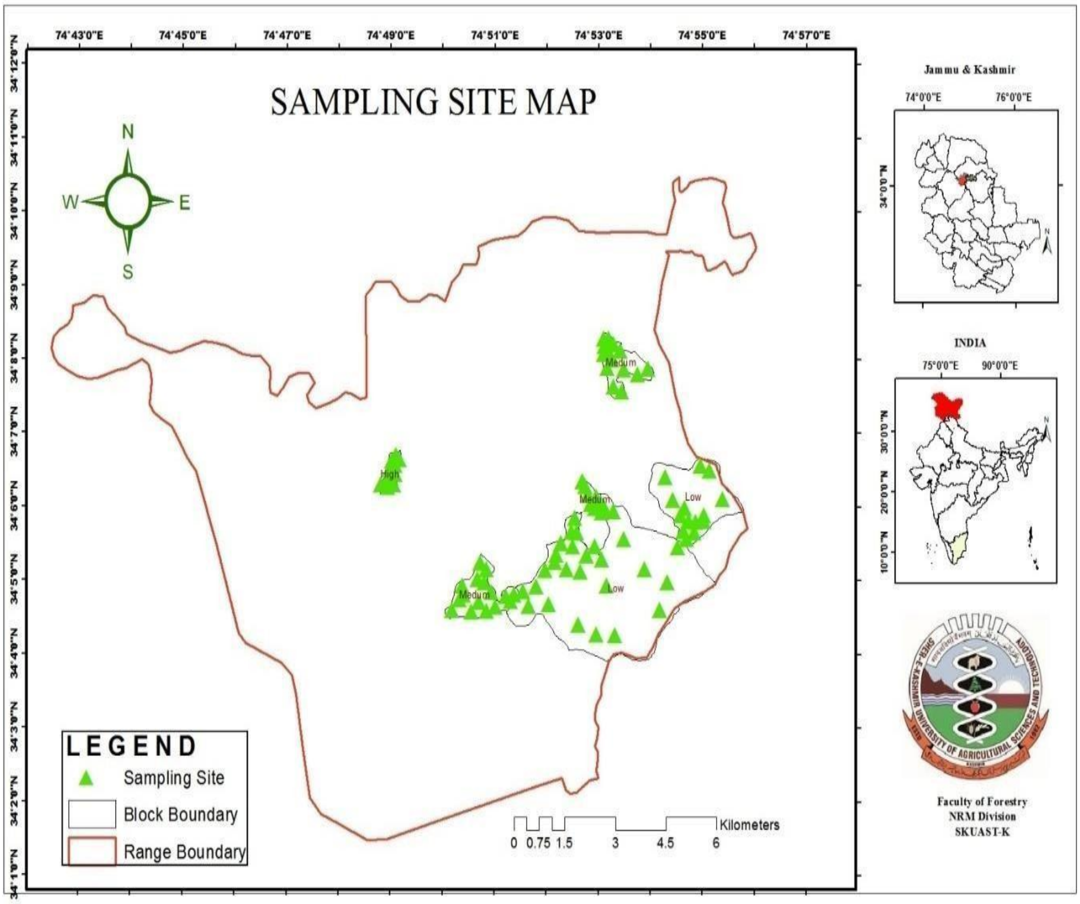


Fig. 3.3: Sampling Site Map of Urban Forest Division Srinagar

Table 3.1: List of indicators for soil quality indexing

S. No	Physical	S. No	Chemical	S. No	Biological
01	Bulk density	01	pH	01	Soil organic carbon
02	Aggregate stability	02	Total nitrogen	02	Microbial biomass carbon
03	Porosity	03	Available phosphorus		
		04	Available potassium		
		05	Cation exchange capacity		

3.4 Methodology

Assessment of Soil quality indexing was examined by using indicator-based approach. In determining soil quality index (SQI), four main steps were followed (Fig. 3.4)

a) Formulation of appropriate goals for desired outcomes of soil functions,

b) Selection of a minimum data set (MDS) of indicators that best represent soilfunction,

c) Scoring the MDS indicators based on their performance of soil function

d) Integration of the indicator scores into a comparative SQI

(Nayak *et al*., 2016)

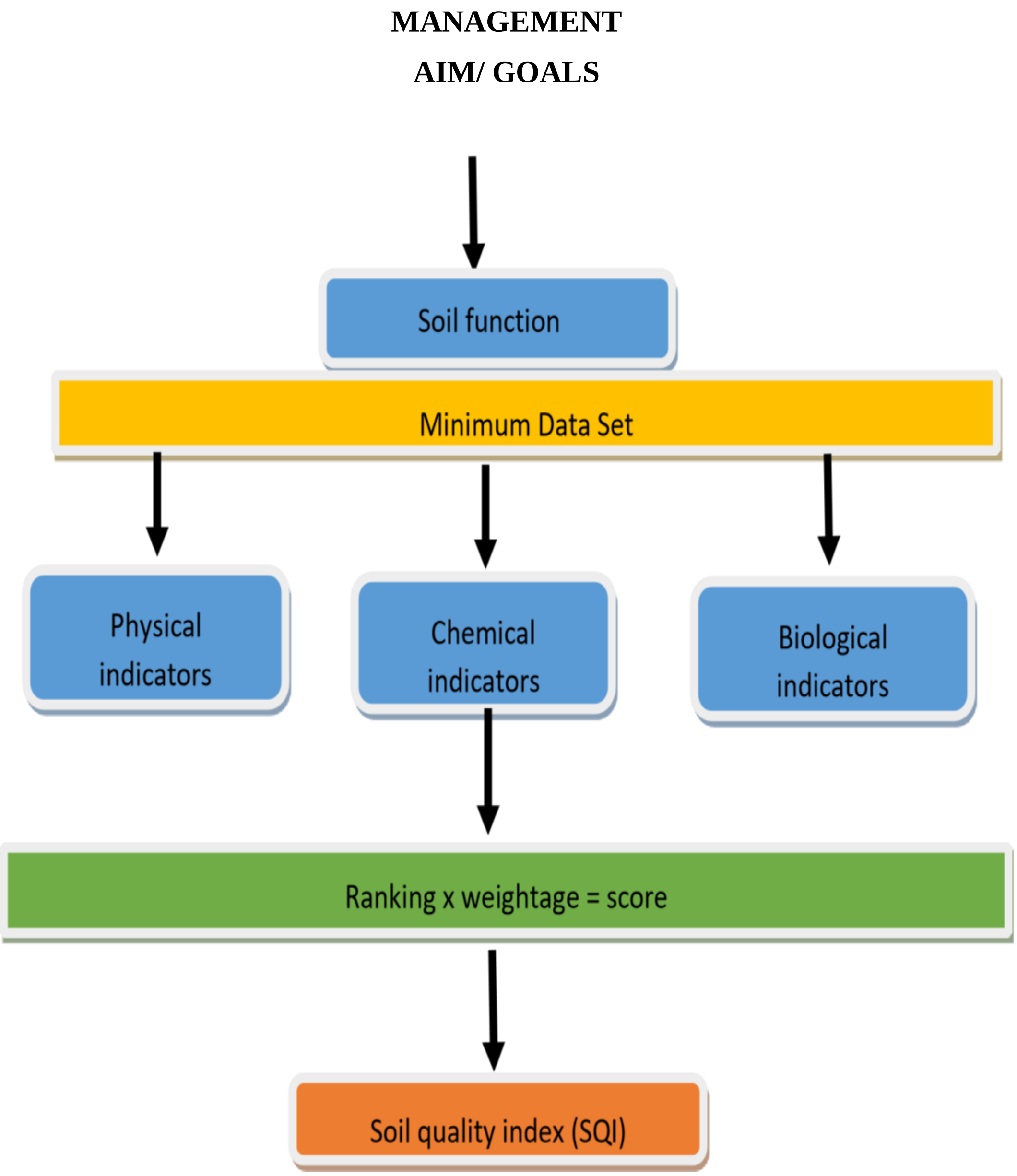


Fig. 3.4: A generalized framework for developing soil quality indices

Objective 1: To assess forest soil health on selected physical, chemical and biological soilquality indicators.

A. Physical Indicators

1. Bulk density (g cm^{-3})

The bulk density of soil was estimated by using the weighing bottle method asdescribed by (Jalota *et al.* 1998).

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Dry weight of soil sample}}{\text{Volume occupied by the same soil sample (cm}^3\text{)}}$$

2. Aggregate stability (>0.25mm)

It was calculated by aggregate stability measure the number of stable aggregatesagainst flowing water. The aggregate stability was calculated as per the standard method followed by NRCS.Soil survey laboratory, this procedure involves repeated agitation of distilled water. (Zezhou *et al.* 2022). Water stable aggregates (% of soil less than 0.25mm = weight of dry aggregates –sand).

3. Total porosity (%)

The porosity were calculated with the following formula (Sahai, 1999)

$$\text{Porosity} = 100 - \frac{Bulk\ density}{Particle\ Density}$$

Since % pore space + %solid space =100

$$\%\text{Solid space} = \frac{Bulk\ density}{Particle\ density} \times 100$$

$$\text{Porosity (\% pore space)} = 100 -- \frac{Bulk\ density}{Particle\ density} \times 100$$

B. Chemical indicators

1. pH (1:2:5)

The pH of soil sample analysis was determined in 1:2.5 soil: water suspension with the help of glass electrode pH meter as described by Jackson (1973).

2. Total Nitrogen (kg ha^{-1})

Available nitrogen was estimated by alkaline permanganate method as given by Subbiahand Asija (1956).

3. Available Phosphorus (kg ha^{-1})

The available phosphorus was extracted by Oslen's extractant (0.5N NaHCO3 at pH. 8.5) and color developed by stannous chloride was measured with the help of spectrophotometer at 660 nm wave length (Olsen, 1954).

4. Available Potassium (kg ha^{-1})

The available potassium were extracted by 1N ammonium acetate at pH 7and then determined with the help of flame photometer using k-filter (Jackson, 1973).

5. Cation exchange capacity (CEC (cmol (+) kg^{-1})

Cation exchange capacity were estimated by centrifuge method using sodium acetate solution (pH) for leaching and then sodium ions will be replaced by ammonium ions using neutral normal ammonium acetate and extracted sodium concentration was measured by flame photometrically which serves the measure of total CEC of the soil (Baurah and Barthakur,1999).

C. Biological indicators

1. Soil organic carbon (gkg^{-1})

Soil Organic carbon were estimated by (Walkey and Black's method, 1934)

The Van Bemmelen factor of 1.724 was used for conversion of organic carbon content to organic matter content (%).

$$\text{Organic matter Content (\%)} = \text{organic carbon} \times 1.724$$

The soil organic carbon density was then determined as per procedure followed by(Jianzhong *et al.* 2006).

$$CS = 100 \sum (DdO) /1.724$$

Where,

CS = soil carbon density (tons ha^{-1} or Kg $tree^{-1}$)

D = soil depth (cm)

d is soil bulk density (g cm^{-3})

O is soil organic matter content (%)

2. Microbial biomass carbon (μgkg^{-1})

The soil microbial biomass carbon were determined by chloroform fumigation extraction method prescribed by Vance *et al.* (1987). Soil microbial biomass carbon will be estimated by taking five sets of 10g of soil for each sample. One set will be kept in moisture box after taking weight of the empty box and placed in the oven at 100°C for 24 hours or until a constant oven dry weight was achieved. Out of the four remaining sets of the soil, two sets were placed in 50 ml glass beakers with ethanol free chloroform for fumigation. Samples designated for fumigation were placed in the vacuum desiccators. The desiccator will be sealed, placed in a laboratory hood and evacuated, allowing the chloroform to boil for approximately five minutes. Samples were fumigated for 24 hoursin the dark at 25° C. After removal of chloroform, soils were transferred to 250 ml conical flasks where 25 ml of 0.5 M K_2SO_4 was then added. At the same time, remaining two unfumigated soil samples were placed in the conical flasks and treated in the same way. All the conical flasks will be shaken for 30 minutes on a reciprocating shaker and supernatants were filtered through watman no.1 filter paper (Plate-3).

Microbial biomass carbon was measured in 10 ml of aliquots of K_2SO_4 extracts after oxidation with 2 ml of 0.2 N $K_2Cr_2O_7$, 10 ml of H_2SO_4 and 5 ml of orthophosphoric acid at 100° C for 30 minutes and back titrated with ferrous ammonium sulphate.

Microbial biomass Carbon was calculated by measuring the difference in extractable organic C between the fumigated and unfumigated soils which was simply formulated with the equation put forth by (Vance *et al.* 1987).

$$\text{MBC } (\mu g\ g^{-1}) = 2.64 \times \text{Ec}$$

Where,

Ec refers to difference in extractable organic carbon between the fumigated and unfumigated treatments, 2.64 is the proportionality factor for carbon biomass released by fumigation extraction.

Objective 2: To compute an overall integrated Soil Quality Index (SQI) Urban Forest Division Srinagar.

1. Soil Quality Indexing

Soil quality assessment tools needs to be flexible in terms of selection of soil function to be assessed and indicators to be measured to ensure that assessment are appropriate for specific management goals. The conceptual soil quality index framework model was used to determine soil quality indices of Urban Forest Division Srinagar as described by Karlen and Stott (1994). It uses selected soil functions which are weighted and integrated according to the following expressions:

$$\text{SQI} = \text{WE (wt)} + \text{WMA (wt)} + \text{RD (wt)} + \text{PNS (wt)}$$

Where,

WT is numerical weighting for each soil function

WE is Accommodate water entry

WMA is Facilitate water movement and availability

RD is Resist degradation

PNS is supply nutrients for plant growth

2. Soil Quality Indicators scoring function values and references

The soil quality indicators, scoring function values and references to be used for evaluating the Soil Quality Indices in Urban Forest Division Srinagar adopted from (Masto *et al.*, 2007) are as follows.

Table 3.2: Soil quality indicators and their soil function

Indicator	Scoring function	Lower Threshold	Upper Threshold	Soil function
Physical indicators				
Bd (gcm^{-3})	Less is better	1.0	2.0	Accommodate water entry
Water stable	More is better	0.0	40.0	
aggregates (>0.25mm)				Accommodate water entry.Facilitate water movement and availability. Resist surface structure degradation.
Total Porosity (%)	Optimum	20.0	80.0	Accommodate water entry Facilitate water movement and Availability
Chemical indicators				
pH	More is better	0.0	14.0	Supply plant nutrients
Total Nitrogen ($kgha^{-1}$)	optimum	3.0	9.0	Supply plant nutrients
Available Phosphorus ($kgha^{-1}$)	More is better	600	1200	Supply plant nutrients Resistsurface structure
Available potassium ($kgha^{-1}$)	More is better	25	50	Supply plant nutrients
CEC (cmol (+) kg Ha^{-1})	More is better	0.0	18.0	Supply plant nutrients
Biological				
SOC (g/kg^{-1})	More is better	0.0	10.0	Accommodate water entry, Facilitate water movement and availability, Resist surface structure degradation Supply plant nutrients.
MBC (μgkg^{-1})	More is better	0.0	300.0	Supply plant nutrients

3. Assigning weights to the indicators

Weights was assigned to each indicator according to their importance in determining soil quality index in Urban Forest Division Srinagar to get reliable result. The score for each indicator was calculated after establishing the baseline, the lower and the upper threshold values (Table 3.2). Threshold values are soil property values where the score equals one (upper threshold) when the measured soil property is at the most favorable level; or equal zero (lower threshold) when the soil property is at an unacceptable level. Baseline values were generally regarded as minimum target values. These are two baseline for "Optimum curves", lower baseline and upper baseline, which corresponds to 0.5 score of the growth and death curves, respectively

Pair wise comparison method (PCM) were employed for selected indicators to assign the weights (Saaty, 2008). It were ensured that the weight or proportion assignedto all indicators add upto 1.

4. Statistical analysis

Soil quality indicators, functions and integrated quality indices were subjected toone-way ANOVA. Excel spreadsheet were used for transforming soil quality indicator values into unit-less scores. Differences between means of parameters were considered significant at the 0.05 level using the Tukey's student zed (HSD) test. The data were analyzed using R version 3.02 software package.

All the data obtained were subjected to the statistical analysis as per procedure given byGomez and Gomez (1984) using R- software.

Objective 3: Generation of soil quality index maps of Urban Forest Division Srinagar.

The obtained soil quality index (SQI) was represented with the help of tables, charts and spatial maps using MS excel and Arc GIS software with respect to their respective level degree of quality of indicators and index, all the spatial composite units will be categorized into three categories for distinguishing the level of soil quality index.Low, medium and high.

Chapter-4

EXPERIMENTAL FINDINGS

The results emerged out with respect to different parameters of the study entitled **'Soil Quality Indices for Assessing the Forest Soil Quality Health of Urban Forest Division Srinagar"** have been discussed in this chapter under the following headings listed below:

4.1 Soil Physical indicators

4.2 Soil Chemical indicators

4.3 Soil Biological indicators

4.4 Soil Quality index

4.1 Soil Physical indicators

4.1.1. Bulk density (gcm^3)

The perusal of data presented in the table 4.1 revealed that the soil bulk density was significantly influenced under different blocks and was in the range of 1.49 gcm^{3}to 1.06 gcm^3.The bulk density was recorded highest in Basiwan (1.49 gcm^3) followed by Chashmashahi (1.41 gcm^3), Shankarachariya (1.13 gcm^3) and was recorded lowest in Nishat (1.06 gcm^3) and Kralsangri (1.06 gcm^3).The Harpiarbat and Shankarachariya not at par with each other,Nishat and Kralsangri were also at par to each other However remaining two blocks (Basiwan and Chashmashahi) were significantly different from others.

4.1.1 Soil Aggregate stability (mm)

Data presented in table 4.1 also revealed that the soil aggregate stability is significantly influenced under different blocks and was in the range of 24.03 mm to 36.05 mm. The aggregate stability was recorded highest in Hariparbat (36.0) followed byShankarachariya (31.9 mm), Nishat (31.4 mm), Chashmashahi (27.7 mm), Basiwanwan (24.5 mm) and least was recorded in Kralsangri (24.0

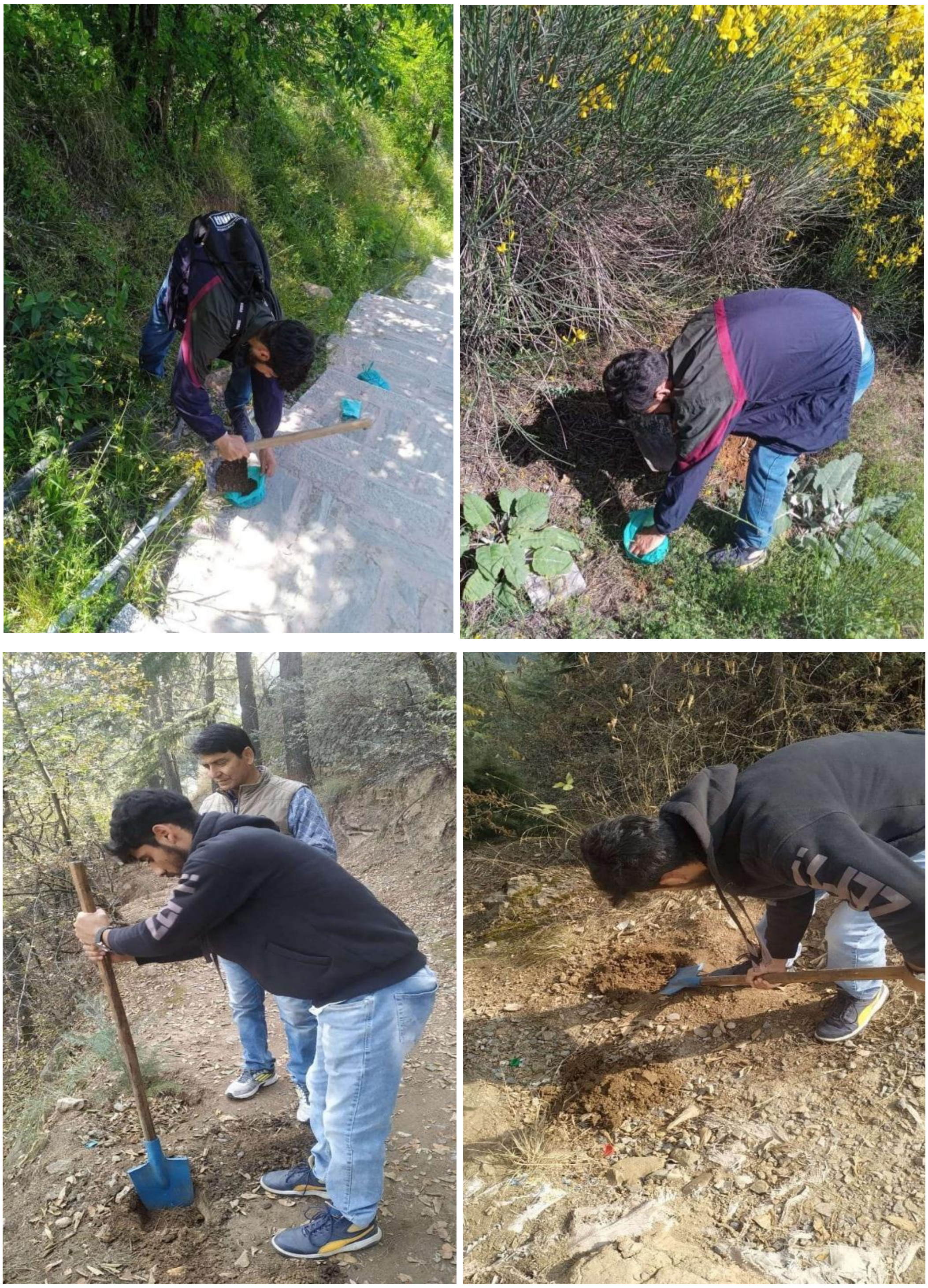


Plate 1: Collection of soil samples from different blocks.

mm).The Shankarachariya and Nishat were at par with each other, However the remaining four blocks were significantly different (Hariparbat, Chashmashahi, Basiwan and Kralsangri).

4.1.2 Soil Total Porosity (%)

The perusal of data presented in the table 4.1 shows significant variation in the soil total porosityand varied significantly under different blocks and was in the range of 48.5% to 43.85%. The total porosity was found highest in Shankarachariya (48.5%) followed by Kralsangri (47.7%), Nishat (45.5%), Hariparbat (45.2%), Basiwan (45.1%) and least was recorded at Chashmashahi (43.9%).The Hariparbat,Basiwan and Chashmashahi were at par with each other. However, the remaining two blocks were different (Shankarachariya,Kralsangri).

Table 4.1: Effect of different Forest blocks on physical parameters for Soil quality index

Range	Block	BulkDensity (gcm$^{3)}$	Aggregate (≥0.25mm) Stability	Total Porosity (%)
Hariparbat	Hariparbat	1.10^{c}	36.05^{a}	45.19^{c}
	Nishat	1.06^{d}	31.42^{b}	45.52bc
Shankarachariya	Shankarachariya	1.13^{c}	31.94^{b}	48.52^{a}
	Basiwan	1.49^{a}	25.43^{d}	45.15^{c}
	Kralsangri	1.06^{d}	24.03^{e}	47.69^{ab}
	Chashmashshi	1.41^{b}	27.71^{c}	43.85^{c}
Lsd ($p \leq 0.05$)		002	1.22	2.41

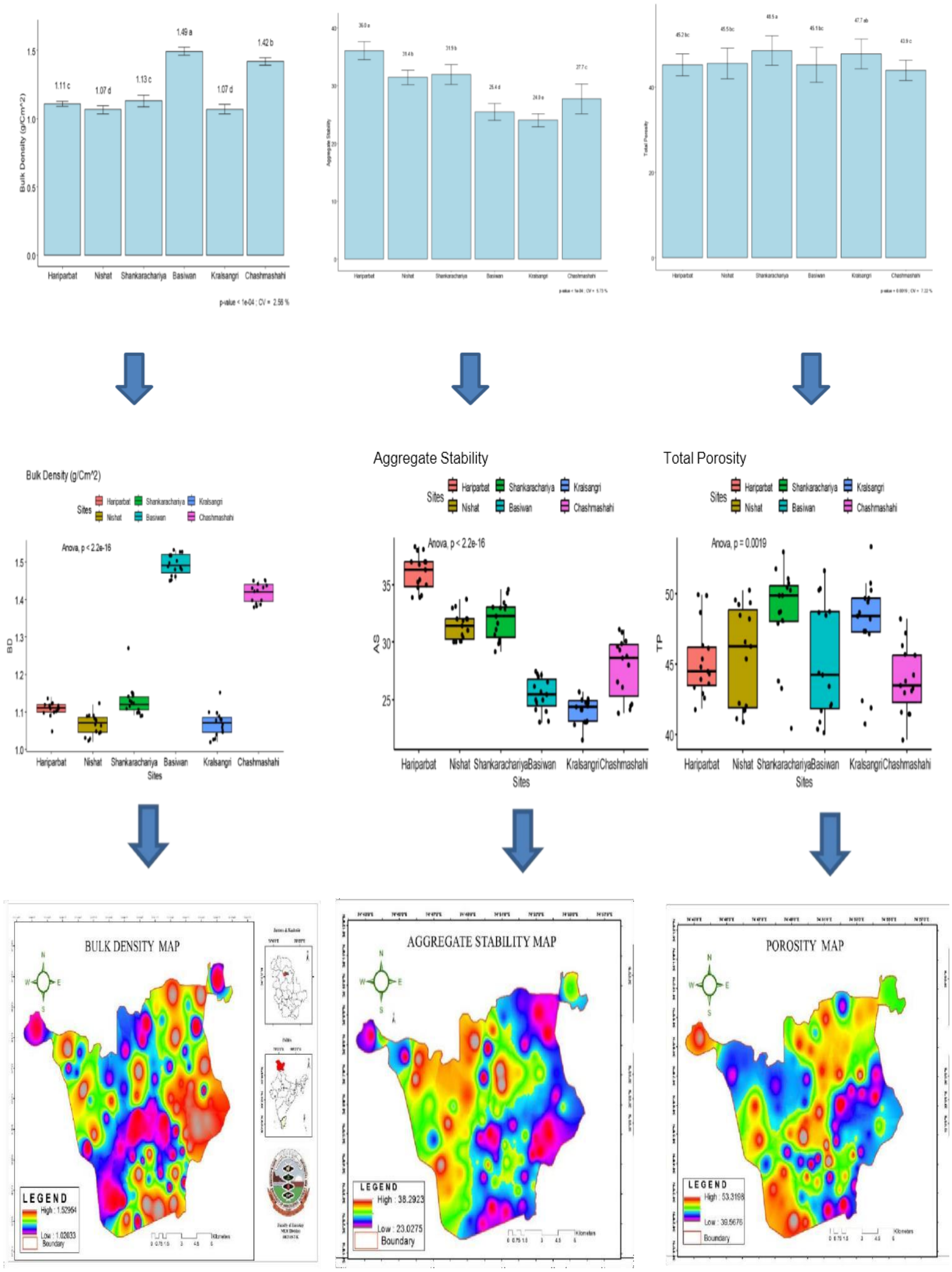


Fig. 4.1: Graphical Representation of Soil Physical Parameters:

Plate 2: Analysis of Soil Physical Parameters

4.2 Soil Chemical indicators

4.2.1 Soil pH

The perusal of data presented in the table 4.2 indicates significant variation in the pH and varied significantly underdifferent blocks and was in the range of 6.50 to 6.22. pH was recorded highest in Basiwan (6.51) followed by Chashmashahi (6.46), Kralsangri (6.45), Chankarachariya (6.43), Nishat (6.31) and least was recorded in Hariparbat (6.22).The four blocks viz,Chashmashahi, Kralsangri, Shankarachariya and Basiwan were at par with each other, however Nishat and Haripabat are significantly different from these blocks.

4.2.2 Soil Nitrogen (kg ha^{-1})

It is evidently clear from the data presented in the table 4.2 that Soil Nitrogen was significantly influenced by the average effects under different blocks and was in the range of 512.6 (kg ha^{-1}) to 451.9 (kg ha^{-1}). Total nitrogen was registered highest in Nishat (512.6kg ha^{-1}) followed by Shankarachariya (511.7kg ha^{-1}),Hariparbat (510.7kg ha^{-1}), Kralsangri (498.7kg ha^{-1}), Chashmashahi (476.5kg ha^{-1}) and least was recorded in Basiwan (451.9kg ha^{-1}).The Hariparbat,Nishat and Shankaracharia were at par with each other,however Basiwan,Kralsangri and Chashmashahi were significantly different from others.

4.2.3 Soil Phosphorous (kg ha^{-1})

The data presented in table 4.2 indicates no significant variation in the available soil phosphorousamong different blocks ranging from 20.47 (kg ha^{-1}) to 15.25 (kg ha^{-1}). The highest available phosphorous was recorded in Chashmashahi (20.5), Shankarachariya (19.8), Kralsangri (18.8), Hariparbat (16.6), Nishat (16.4) and least was observed at Basiwan (15.3).

4.2.4 Soil Potassium (kg ha^{-1})

The perusal of data presented in the table 4.2 also reveals that available soil potassium is significantly varied under different blocks and was in the range of 220.86 **(**kg ha^{-1}) to 242.80 **(**kg ha^{-1}). The available potassium was found highest in Nishat (242.8 kg ha^{-1}) followed by Hariparbat (240 kg ha^{-1}), Shankarachariya (239 kg ha^{-1}), Basiwan (238 kg ha^{-1}), Kralsangri (227 kg ha^{-1}) and least was found in Chashmashahi (221 kg ha^{-1}). The Nishat, Hariparbat and, Shankarachariya, Basiwan and Kralsangri were at par with each other,However the Chashmashshi was found different from rest of these blocks.

4.2.5 Cation exchange capacity (cmol (+) kg^{-1})

It is apparent from the data in the table 4.2 that available soil exchange capacity was significantly under different blocks and was in the range of 20.82 cmol (+) kg^{-1}) to 17.10 **(**cmol (+) kg^{-1}). The CEC was found highest in Chashmashahi (20.8 cmol (+) kg^{-1}) followed by Kralsangri (20.5 cmol (+) kg^{-1}), Hariparbhat (20.4 cmol (+) kg^{-1}),Basiwan (19.7 cmol (+) kg^{-1}), Shankarachariya and least was found in Nishat (17.1 cmol (+) kg^{-1}).

Table 4.2: Effect of different blocks on soil chemical parameters

Range	Block	Ph (1:2.5)	Total nitrogen (kgha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kgha^{-1})	Cation exchange capacity (CEC (cmol (+) kg^{-1}
Hariparbat	**Hariparbat**	6.22^{c}	510.7^{a}	16.57^{a}	240.20^{a}	20.42^{a}
	Nishat	6.30^{bc}	512.6^{a}	16.44^{a}	242.80^{a}	17.10^{b}
Shankarachariya	**Shankarachariya**	6.42^{ab}	511.7^{a}	19.77^{a}	238.86^{ab}	19.56^{a}
	Basiwan	6.50^{a}	451.9^{d}	15.25^{a}	238.00^{ab}	19.66^{a}
	Kralsangri	6.44^{ab}	498.7^{b}	18.91^{a}	227.26^{ab}	20.45^{a}
	Chashmashshi	6.46^{b}	476.5^{c}	20.47^{a}	220.86^{b}	20.82^{a}
Lsd ($p \leq 0.05$)		0.17	5.825	6.60	18.01	1.41

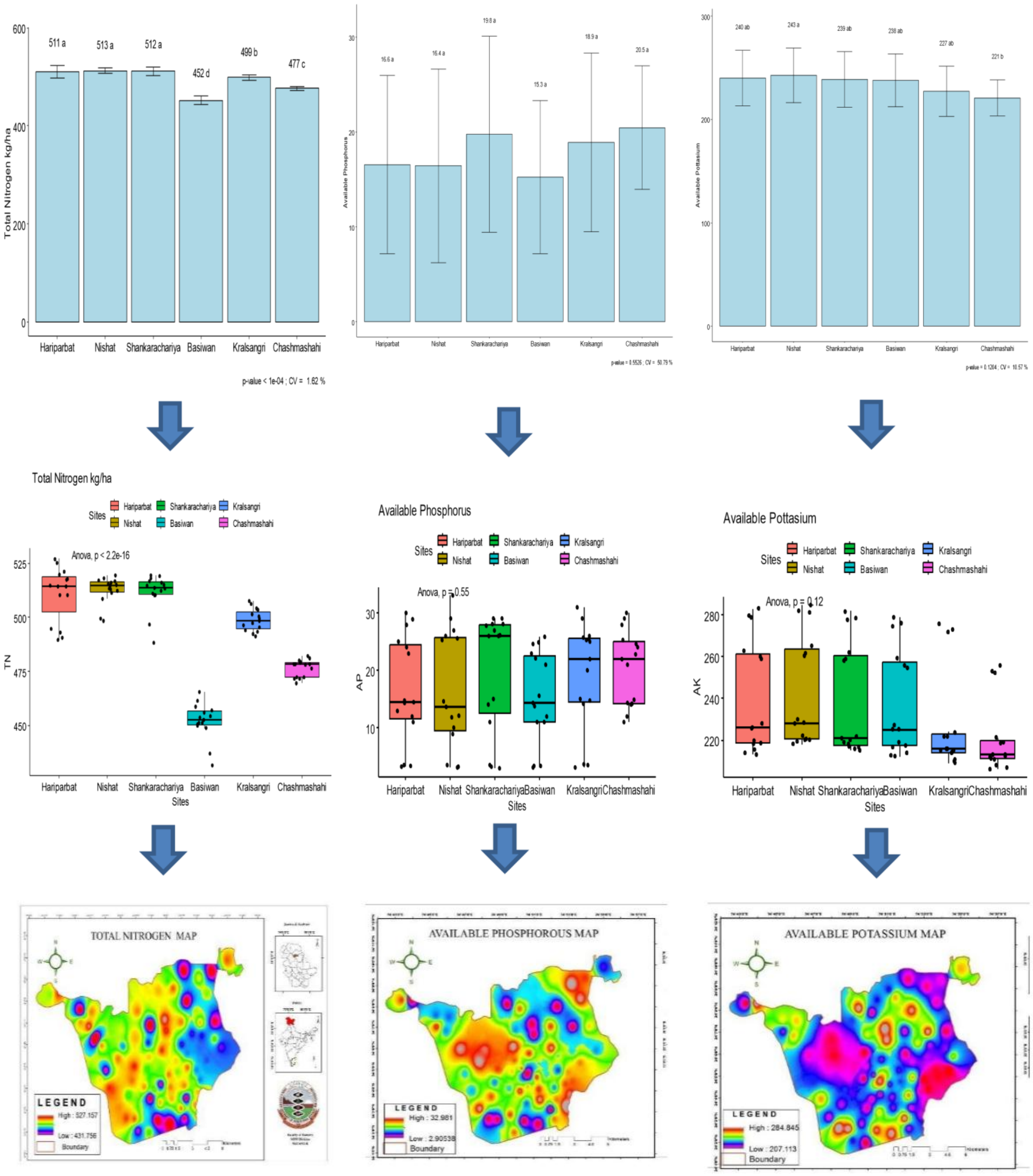


Fig. 4.2a: Graphical Representation of Chemical Parameters of Soil

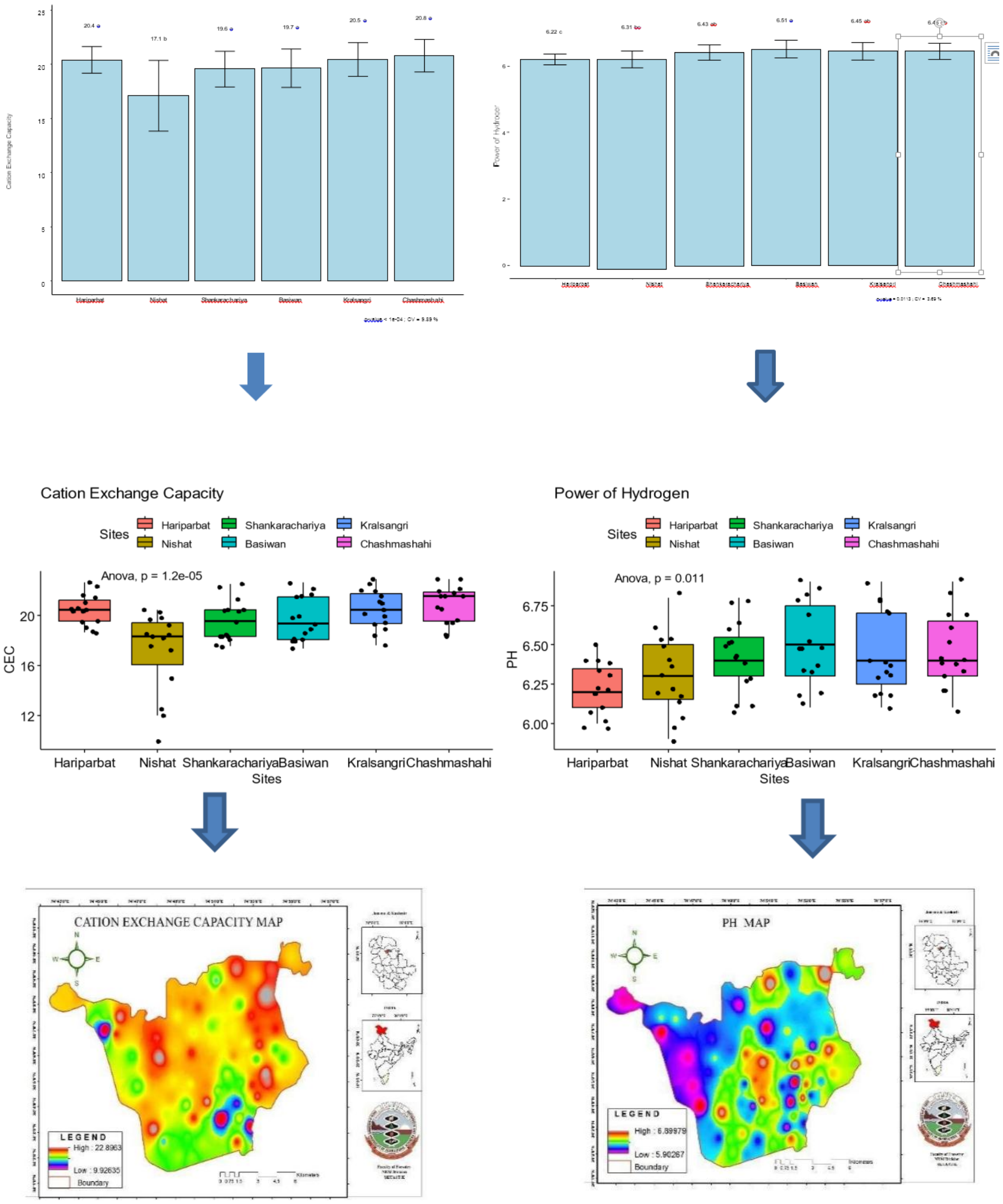
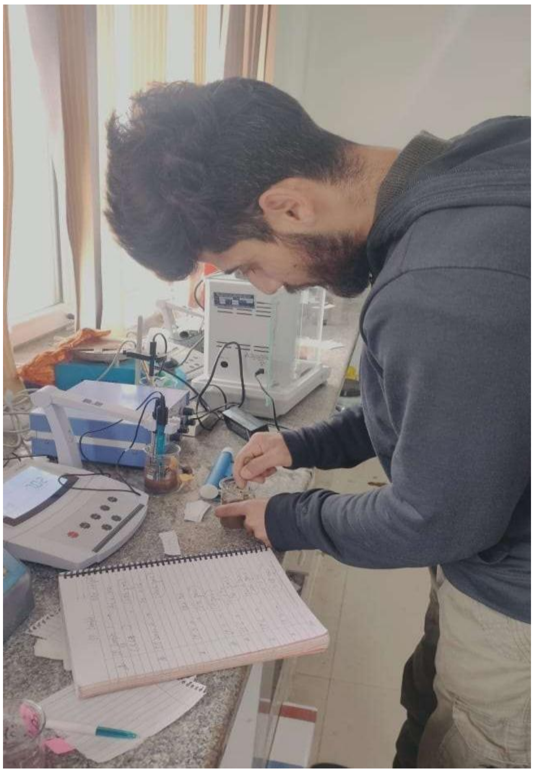


Fig. 4.2b: Graphical Representation of Chemical Parameters of Soil



Calculating pH

Calculating total Nitrogen

Calculating available Phosphorous

Plate 3: Analysis of Chemical Soil Quality Indicators.

4.3 Soil Biological Indicators

4.3.1 Soil organic carbon (g/kg)

The perusal of data in the table 4.3 indicates significant variation in the soil organic carbon and varied significantly under different blocks and was in the range of 7.90 g/kg to 8.93 g/kg The soil organic carbon was found highest in Hariparbat (8.73g/kg) followed by Nishat (8.45g/kg), Chashmashahi (8.31g/kg), Kralsangri (8.00g/kg) and least in Shankarachariya (7.90g/kg).Hariparbat and Nishat were at par to each other. However the remaining blocks (Shankarachariya, Basiwan Kralsangri and Chashmashahi were significantly different from others.

4.1.3.2 Microbial biomass carbon (µgkg^{-1})

It is apparent from the data in the table 4.3 that microbial biomass carbon was significantly affected under different blocks and was in the range of 172.70µgkg^{-1} to 187.75µgkg^{-1}. Themicrobial biomass carbon was found highest in Nishat (187.75µgkg^{-1}) followed by Hariparbat (187.7µgkg^{-1}), Shankarachariya (179.05µgkg^{-1}), Kralsangri (175.41µgkg^{-1}), Chashmashshi (173.7µgkg^{-1}) and lowest was recorded in basiwan (172.7µgkg^{-1}) Nishat and Shankarachariya were at par to each other. However the remaining blocks (Hariparbat,Basiwan, Kralsangri and Chashmashshi were significantly different.from each other.

Table 4.4 shows the statistical characteristics of the measured properties of the 90 samples in the study area, the samples exhibited a large variation in the most of the soil properties. The normal distribution was tested based on the komogorov-smirnov method and the value of the kurtosis and skewness. The pH and MBC,s coefficient of variation (CV%) and standard of deviation had the lowest and second lowest values, respectively which can be related to dominant parent material in the study area, where as the high CV% in bulk density and phosphorus indicated the strong spatial variations of their content in the study area.These strong variations may be due to variations in land use,soil type and the effect of management factors such as applying fertilizers in the field,topographic changes and the drainage conditions in the study area.

Table 4.3: Effect of different blocks on soil Biological indicators

Range	Block	Soil organic carbon (g/kg)	Microbial biomass carbon (µgkg-1)
Hariparbat	Hariparbat	8.72^{a}	187.7^{a}
	Nishat	8.45^{a}	187.75^{b}
Shankarachariya	Shankarachariya	7.90^{d}	179.05^{b}
	Basiwan	8.28^{bc}	172.70^{d}
	Kralsangri	8.00^{cd}	175.41^{e}
	Chashmashshi	8.30bc	173.70^{c}
Lsd ($p \leq 0.05$)		0.32	1.88

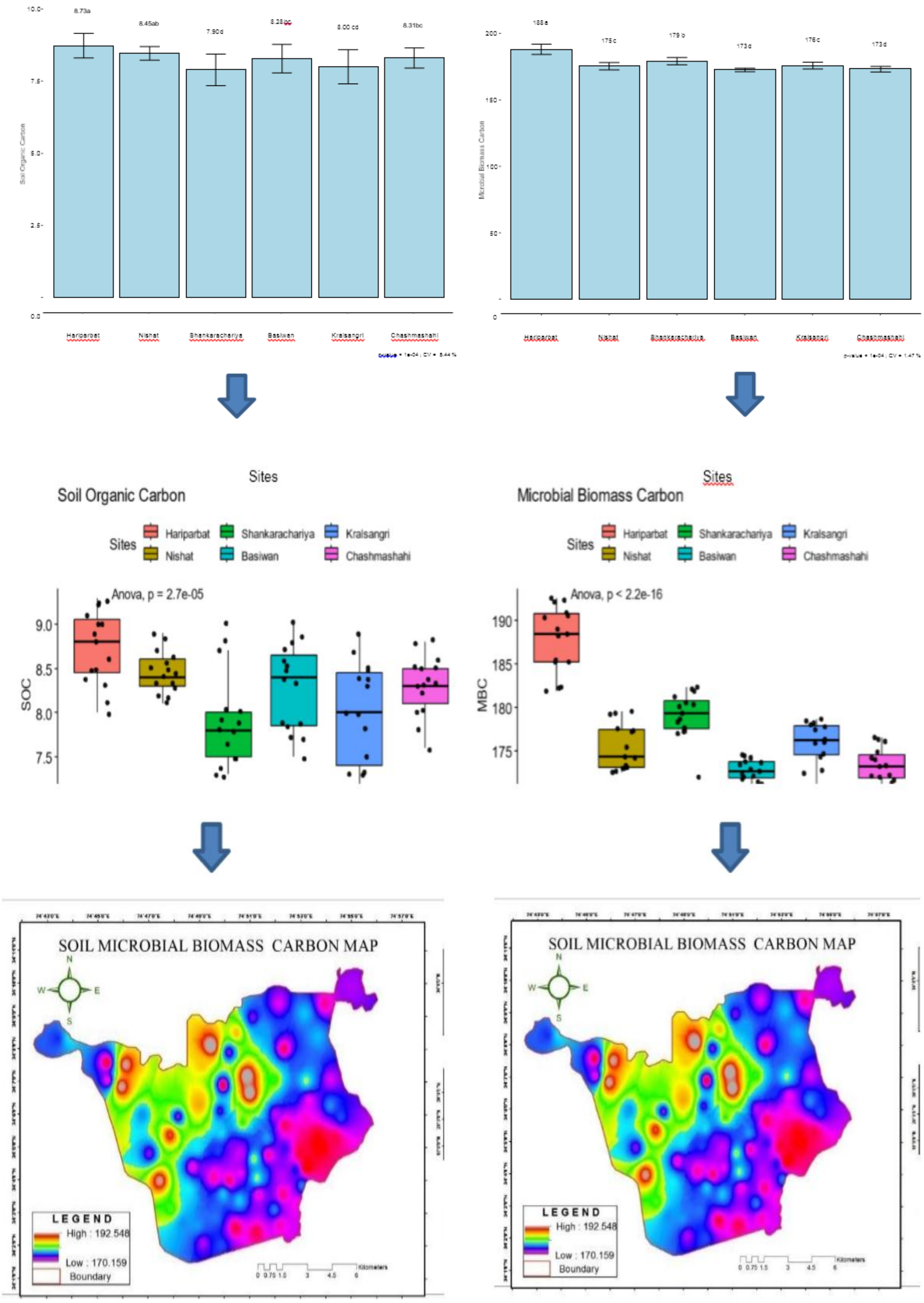


Fig. 4.3: Graphical Representation of Biological Parameters Of Soil

Calculating Soil organic carbon

Plate 4: Analysis of Soil Biological Parameters

Table 4.4: The statistical characteristics of the 90 samples in the study area

Variable	Min	Max	Mean	Standard deviation	CV%	Kurtosis	Skewness
Bulk Density	0.156	0.959	0.493	0.28	56.7	-1.64	0.121
Aggregate Stability	21.43	38.3	29.43	4.46	15.15	-1.05	0.15
Total Porosity	39.56	53.34	45.99	3.60	7.82	-1.25	0.022
pH	5.9	6.9	6.39	0.24	3.75	-0.63	0.34
Available P	2.9	33	17.90	9.04	50.50	-1.20	-0.29
Available K	206	285	234.66	25.36	10.80	-1.00	0.799
Total N	508.5	744.6	571.00	49.99	8.75	3.63	1.89
CEC	9.9	22.9	19.67	2.25	11.43	4.72	-1.60
SOC	7.1	9.3	8.27	0.51	6.16	-0.60	-0.30
MBC	170.14	192.56	177.32	5.71	3.22	0.64	1.15

4.4 Computation of overall integrated soil quality index (SQI) of Urban Forest Division Srinagar.

The figure 4.5 (Table 4.7) depicts the relation between Eigen value and PC in the form of a scree plot, with an increase in PC resulting in a decrease in Eigen value. For example, when the PC number increasesfrom PC1 to PC4, there was a steep decline in Eigen value (2.623 to 1.075). The PCA and communalities to evaluate SQI are given in table 4.5. Four PC's have been extracted which had Eigen values greater than 1 and these four PC's can explain 73.5 percent of total variances. As the PC number increased from PC1 to PC4 Eigen values decreased from (2.623 to 1.075) similarly, explained variance decreased from 26.22 to 10.74 percent. The four retained PC's of the data under difficult land uses were then subjected to varimax rotation, which resulted in the maximumrelationship between interdependent variables by distributing the variance of each PC.PC1 displayed an Eigen value of 26.22, it explained approximately 26.22% of the variance, which included microbial biomass carbon (MBC) with positive factor loading (.875), AS **(.**849), TN (.629).PC2 explained approximately (23.8) percent of variance and had an Eigen value of (2.309). PC2 included Available potassium with a positive loading factor of 0.785 and available phosphorus (0.763). PC3 which explained (13.50) variance with Eigen value (1.351) which included cation exchange capacity with loading factor (0.620) and total porosity (0.529). PC4 included only cation exchange capacity (0.668), PC4 explains about 10.74 percent variance and had Eigen value 1.075communalities indicate the relative importance of each soil attribute in terms of its contribution to all extracted PC's. All of the soil attributes that were explained in terms of communalities contributed to the improvement of soil quality.

Based on the effects of indicators on the soil quality, they were scored as 'more is better' for one with positive effect on soil quality 'less is better 'for one with negative effects and 'optimum 'for one which can have positive effects on increasing part and negative effect on decreasing part. In this study the bulk

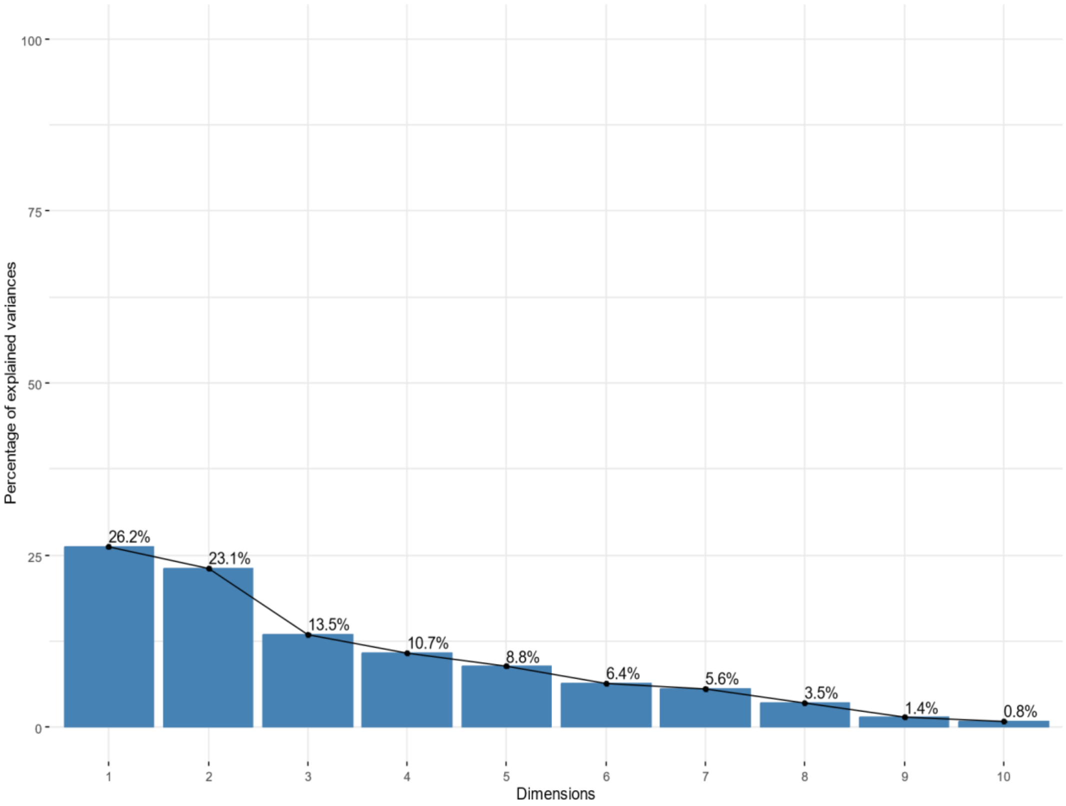


Fig. 4.4: Scree Plot of Percentage of Varience

density was scored as ‘less is better’, porosity was scored as ‘optimum, while as rest of the indicators maintained in the MDS were scored as ‘more is better’. The slope of the equation was set as -2.5 for more is better and 2.5 for less is better and for optimum functions followed by Askari and Holden, 2014.

Table 4.5: Results of Principal Component Analysis (PCA) of Soil Quality Indicators based ondifferent Forest Blocks.

Soil attributes	**Components (Eigen vectors)**			
	PC1	PC2	PC3	PC4
Bulk Density	.298	**.592**	.314	.314
Aggregate Stability	**.849**	.216	.003	.212
Total Porosity	.180	.349	**.529**	**.535**
Total Nitrogen	**.629**	.534	.149	.275
Available Phosphorous	.347	**.763**	.313	.313
Available Potassium	.471	**.785**	.273	.131
CEC	.025	.075	**.620**	**.668**
pH	.449	.134	.393	.139
SOC	.269	.496	.408	.231
MBC	**.875**	.181	.260	.134

Table 4.6: Score of the Indicators

	BD	**AS**	**Porosity**	**pH**	**N**	**P**	**K**	**CEC**	**SOC**	**MBC**
Min	1.065	21.43	39.56	5.9	451.9	2.9	206	9.9	7.1	170.14
Max	1.493	38.3	53.34	6.9	512.6	17.90	234.66	2.25	9.3	192.56
Average	1.279	29.43	45.99	6.394	481.25	17.90	234.6	19.67	8.277	177.3
CurveType	Less is better	More is better	Optimum	More is better	Optimum	More is better	More is better	More is better	More is better	More is better
Weighting Factor	0.040	0.200	0.160	0.032	0.112	0.032	0.032	0.064	0.264	0.064
Slope	2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
Normalized Linear Eq	0..040 (x \1.493)	0.200 (x \38.3)	0.160 (x\53.34)	0.032 (x\6.9)	0.112 (x \512.6)	0.032 (x\17.90)	0.032 (x\234.66	0.064 (x\2.25)	0.24 (x\9.3)	0.064 (x\192.5)
Normalized Non Linear Eq	(1+ (x⁄ 1.279) $^{-2}$ 5)	(1+ (x⁄ 29.43) $^{-2}$ 5)	(1+ (x⁄ 45.99) $^{-}$2..5)	(1+ (x⁄ 6.394) $^{-}$ 2..5)	(1+ (x⁄ 481.25) $^{-2}$ ..5)	(1+ (x⁄ 1790) $^{-}$ 2..5)	(1+ (x⁄ 234.6) $^{-}$ 2..5)	(1+ (x ⁄ 19.67) $^{-}$2..5)	(1+ (x ⁄ 8.227) $^{-}$2..5)	(1+ (x ⁄ 177.3) $^{-}$2..5)

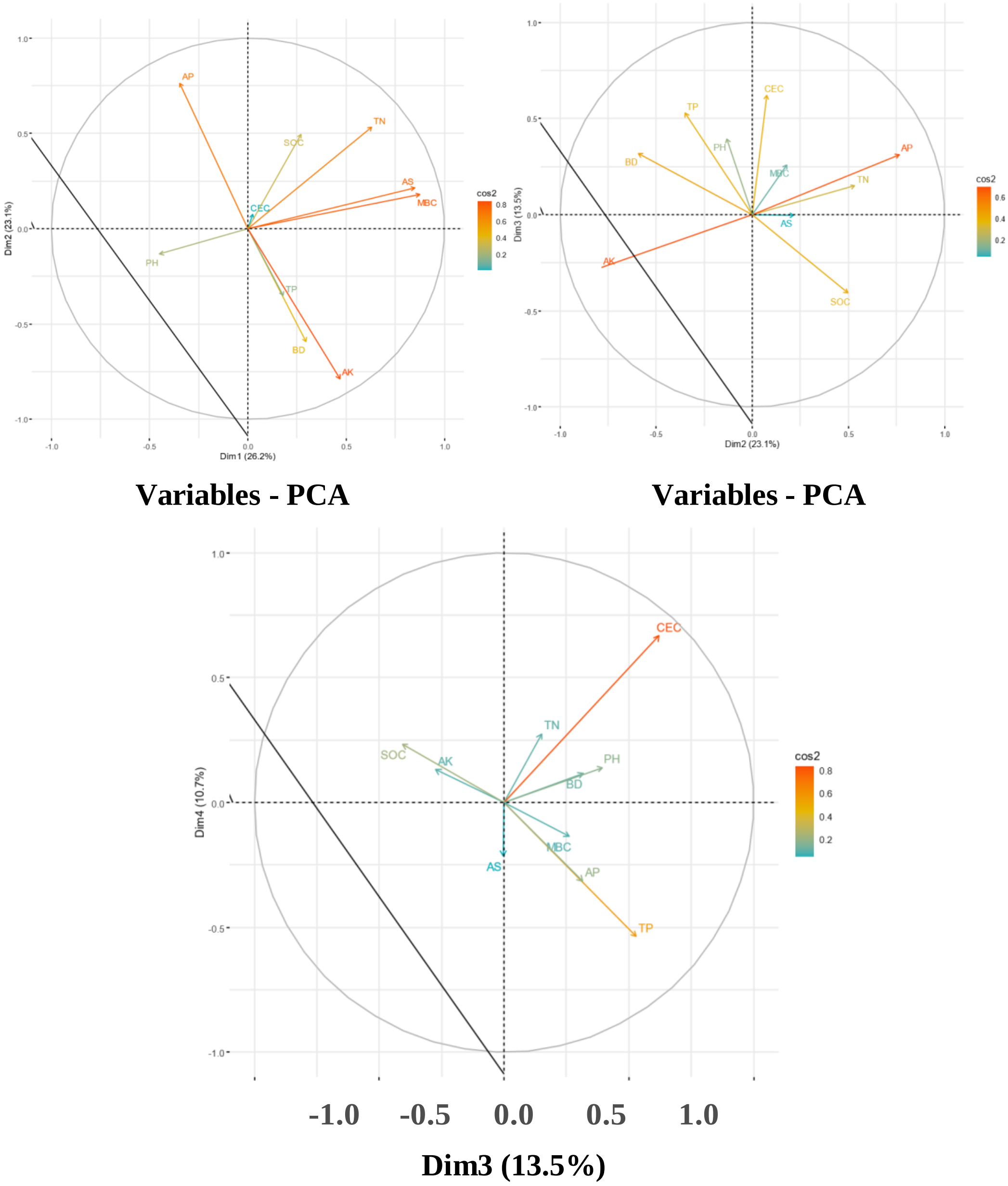


Fig. 4.5: Principle Component Analysis Of Different Variables

4.4.1 Selection of minimum data set attributes (MDS)

A Correlation matrix for highly weighted variables was computed separately for each PC and is shown in the table 4.6.The variables with the highest correlation sum were assumed to represent the best group, MBC was chosen for MDS as one of the five variables in PC1 because it had the highest correlation sum (3.39).AS (2.29) and TN (2.08), were dropped from PC1 because their sum of correlation was lower than MBC.In PC2 Available Potassium and Available Phosphorous have higher factor loading both the variables were highly correlated. Available Potassium was chosen for PC2.In PC3 the CEC and TP both shows higher factor loading, CEC was chosen from PC3.In PC4 CEC and TP showed higher factor loading and only CEC was retained for SQI.

The selected soil attributes, namely MBC, Available Potassium and Cation Exchange capacity. Demonstrate the important role in enhancing the sustainability of blocks and improve soil quality. Theremaining attributes were either less factor loaded or were not well correlated with one another, so they were eliminated.

Table 4.7: Correlation matrix of different blocks for highly weighted variable sunder PCA1 withhigh factor loading

	AS	TN	AP	CEC	MBC
AS	1.0000	0.492	-0.0434	-0.1038	0.8039
TN	0.4921	1.000	0.1323	0.2291	0.5934
AP	-0.0434	0.132	1.0000	0.0157	-0.0618
CEC	-0.1038	0.229	0.0157	1.0000	0.1077
MBC	0.8039	0.593	-0.0618	0.1077	1.0000

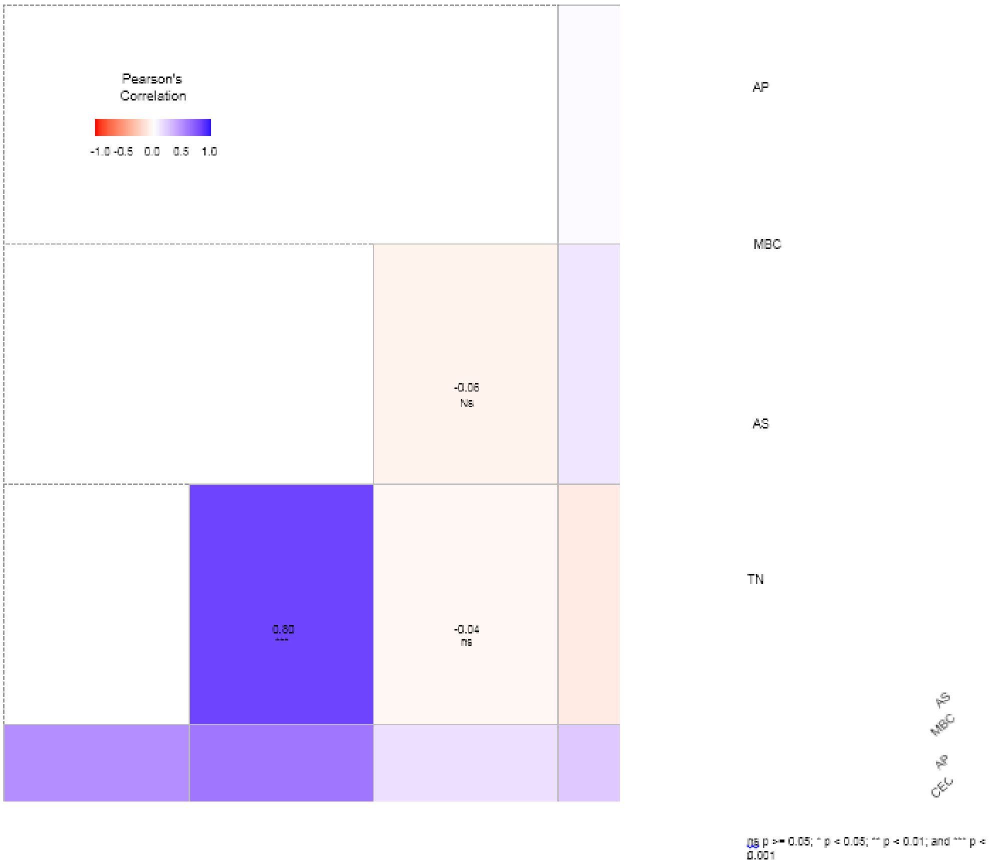


Fig. 4.6: Pearson's Correlation

4.4.2 Scoring of indicators

Selected indicators in MDS were scored in dimension less value ranging from 0 to 1 using linear scoring method (Liebig *et al.*,2001).Indicators were ranked in ascending or descending order depending on whether a higher value was considered " good or bad" in term of soil function. For the MBC (higher is better) indicator, each value of indicator was divided by the highest value such that the highest value received a score a value of 1.For indicators in which less is better the lowest value divided by each data value such that the lowest value received a score of 1.For indicators AK, CEC "optimum is better "threshold value considered. As the values of current study investigated that these indicators were in medium range, so it was" high is better "above the threshold (Andrews *et al* 2002). The weight of each PC in terms of variance to total variance ranged from 0.15 to 0.37 (Table 4.8).The MD's weighted factor shows the following pattern: PC1 (0.37) >PC2 (0.32) >PC3 (0.19) >PC4 (0.15).

Table 4.8: List of selected parameters for minimum data set (MDS) as effected by blocks.

PC number	Eigen value	Percent of variance	Cumulative Percent	Weight of each PC	Indicators selected For SQI
PC1	2.623	26.22	26.22	0.37	MBC
PC2	2.309	23.08	49.31	0.32	AK
PC3	1.351	13.50	62.82	0.19	CEC
PC4	1.075	10.74	73.56	0.15	CEC

Table 4.9: Relative importance of the different soil properties used for the soil quality indexing inUrban Forest Division Srinagar

SQI	Weight	Soil function
Bulk Density	0.040	Accommodate water entry
Aggregate Stability	0.200	Accommodate water entry Facilitate water movement and availabilityResist surface structure degradation.
Total Porosity	0.160	Accommodate water entry Facilitate water movement and availability
pH	0.032	Supply plant nutrients
Total N	0.112	Supply plant nutrients Resist surface structure degradation
Available P	0.032	Supply plant nutrients
Available K	0.032	Supply plant nutrients
CEC	0.064	Supply plant nutrients
SOC	0.264	Accommodate water entry Facilitate water movement and availabilityResist surface structure degradation. Supply plant nutrients
MBC	0.064	Resist surface structure degradation.Supply plant nutrients
Total	1.00	

4.4.3 Soil Quality Index (SQI)

The indicator score was then multiplied by the weighting factor derived from the PCA to obtainthe ultimate index for soil quality under different blocks.The weight of each PC on the basis of percentvariance ranged from 0.15 to 0.37 and is presented in table 4.7.

Relative importance of different soil properties used for the soil quality indexing is presented in table 4.8. The numerical weights were assigned to each soil function according to their importance in fulfilling the overall goals of maintaining soil quality under specific conditions of this study. According to Karlen and Stott (1994) the sum of weights for all soil functions must be equal to 1.0. They assigned equal weights to each soil function.For this study soil organic carbon was assigned with moreweight value (0.264) than other indicators because soil organic carbon has all the four soil functions i.e.

Accommodate water entry, Facilitate water movement and Availability, Resist surface degradation and supply plant nutrients,followed by Aggregate stability (0.200) which has three soil functions. Porosity (0.160) and Total nitrogen (0.112) having two functions each. The microbial biomass carbon and cation exchange capacity were assigned (0.064) weight value. Available phosphorus, potassium and pH were assigned (0.032) weight value which have only one soil function i.e. supply plant nutrient.

Data presented in table 4.10 revealed that different forest blocks had a significant effect on the soil quality index.The descending order of the mean SQI as effected by different forest blocks was Hariparbat (1.00) >Shankarachariya (0.42) >Kralsangri (0.20) >Nishat (0.18) > Chashmashshi (0.03) >Basiwan (0.01).The Hariparbat recorded maximum SQI.

As depicted in soil quality index map of Urban Forest Division Srinagar (Fig. 4.7), Hariparbat shows highest composite index while as Basiwan and Chashmashahi has low Soil Quality Index.

Table 4.10: Soil quality index affect by different forest block systems

Blocks	**SQI**
Hariparbat	1.00
Nishat	0.18
Shankarachariya	0.42
Basiwan	0.01
Kralsangri	0.20
Chashmashshi	0.03

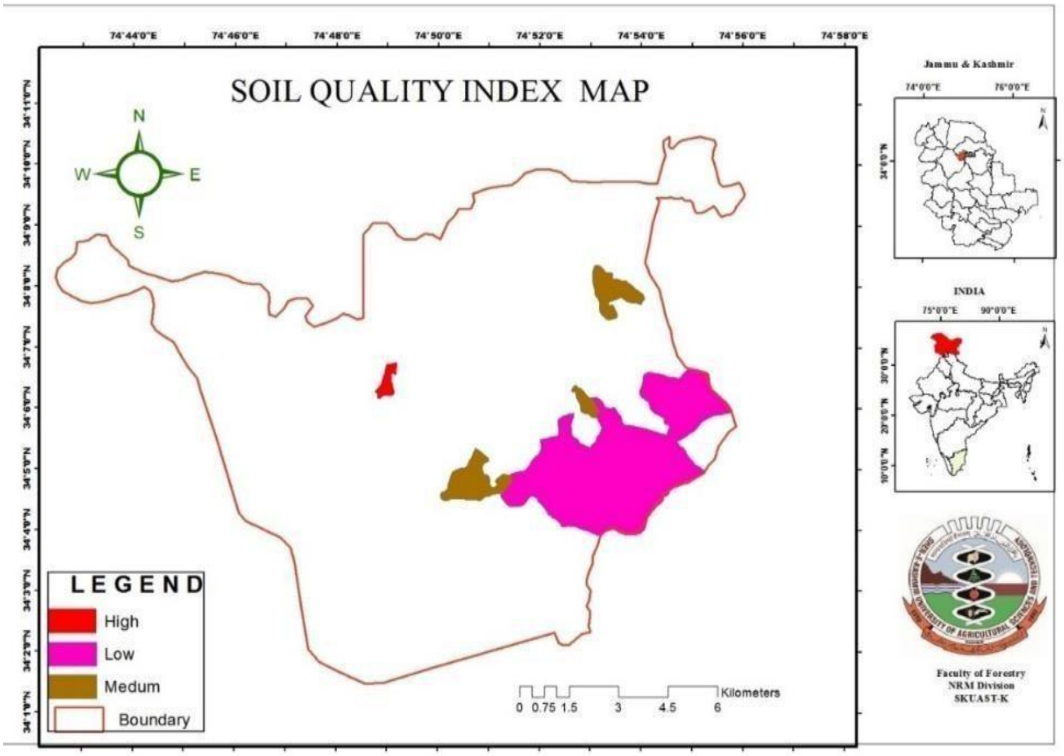


Fig. 4.7: Soil Quality Index Map

Chapter-5

DISCUSSION

The result of the study entitled "**Soil Quality Indices for Assessing the Forest Soil Quality health of Urban Forest Division Srinagar** "are given in the preceding chapter and explored under thefollowing headings:

5.1 Soil Physical Indicators

5.2 Soil Chemical Indicators

5.3 Soil Biological Indicators

5.4 Soil Quality Index

5.1 Soil Physical Indicators

5.1.1 Bulk density

The recorded bulk density in different ranges give valuable insights into the ecological dynamics of these ranges. Basiwan stands out with the highest bulk density of (1.49 gcm^3) which reflects the presence of abundant organic matter, facilitated by continuous litter fall and decomposition, along with the well-developed root systems of the vegetation and the lowest was recorded in Nishat (1.06 gcm^{-3}) and Kralsangri (1.06 gcm^{-3}). The possible reason for lowest bulk density in Nishat and Kralsangri is accumulation of organic matter in these ranges, thus influencing soil structure and particle arrangement. The significant variations among the different indicates heterogeneity in soil properties across the different ranges. The heightened bulk density observed in Basiwan signifies the complex interplay of various ecological factors, including the accumulation of organic matter through continuous litter fall and decomposition (Chandel *et al.* (2017). The intricate root systems of vegetation in Basiwan may play a crucial role. The presence of well-developed roots can create a cohesive structure, reducing pore spaces and leading to higher bulk density values (Sharma *et al.* 2014) This observation aligns with the findings of Chandel *et al.* (2017), further supporting the significance of organic matter and root systems in influencing bulk density. The lowest bulk density recorded in Nishat (1.06 gcm3) and Kralsangri (1.06 gcm3). One possible reason for the low bulk density in Nishat and Kralsangri could be attributed to a lower accumulation of organic matter through litter fall and decomposition compared to Basiwan. Organic matter plays a significant role in influencing bulk density, as it contributes to the formation of soil structure and affects the arrangement of soil particles. Similar findings was reported by Kumar *et al.* (2018).

5.1.2 Aggregate stability

The recorded aggregate stability in different ranges provide an overview of the factors influencing the observed increase and decrease in aggregate stability within the different ranges. The aggregate stability was recorded highest in Hariparbat (36.0 mm) attributed to its richer organic matter content, fostering increased microbial activity and subsequently promoting the development of stable aggregates. Conversely, least was recorded in Kralsangri (24.0 mm) could be attributed to the lower aggregate stability in Kralsangri might be linked to its comparatively lower organic matter content, resulting in reduced microbial activity that hinders aggregate development.. The variation in aggregate stability among different locations, with the highest recorded in Hariparbat and the lowest in Kralsangri, can be attributed to several environmental factors. Hariparbat's superior aggregate stability at (36.0 mm) might be due to a higher content of organic matter, fostering microbial activity and the development of stable aggregates also found that the presence of well-established vegetation in Hariparbat contributes to root exudates, promoting soil structure as reported by (Six *et al*., 2004). The roots of trees in this area might play a role in binding soil particles together, enhancing aggregate stability as reported by (Tisdall and Oades, 1982), whereas the minimum aggregate stability inkralsangri could be attributed to a lower content of organic matter which may result into a reduced microbial activity that hinders the development of stable aggregates. Similar results were also reported by Hadda *et al.* (2020).

5.1.3 Total porosity

The recorded total porosity in different ranges gives the proper insights in different ranges. The total porosity was found highest in Shankarachariya (48.5 %) could be attributed to the presence of well-developed root systems and the decomposition of root material. This facilitates better water movement and aeration, contributing to increased total porosity. Additionally, the vegetative cover in Shankarachariya might lead to higher accumulation of organic matter, enhancing soil structure and promoting the formation and stability of soil aggregates, thus further increasing porosity. The lowest was found in Chashmashahi (43.9 %) could result from factors such as compacted soil layers, reduced organic matter content, or limited root development, leading to a less porous soil structure compared to other sites.The highest total porosity of (48.5 %) recorded in Shankarachariya may be attributed to the presence of well-developed root systems, which contribute to the creation of macro-pores through root channels and the decay of root material. This enhances water movement and aeration, leading to increased total porosity as reported by (Gregory *et al.,* 2017). The vegetative cover in Shankarachariya could also contribute to the accumulation of organic matter, fostering soil structure improvement. Organic materials act as binding agents, promoting the formation and stability of soil aggregates, thus increasing porosity as reported by (Bronick and Lal, 2005). The lower Total porosity could be influenced by factors such as compacted soil layers, reduced organic matter content, or limited root development, leading to a less porous soil structure compared to other sites as reported by (Baver, 1972).

5.2 Soil Chemical indicators

5.2.1 Soil pH

The recorded soil pH in different ranges provide an overview of the potential reasons behind the observed increase and decrease in soil pH within the different ranges. The Soil pH was recorded highest in Basiwan with the value of (6.51) could be attributed to the presence of a diverse vegetative cover, consisting of diverse plant species. This diverse array of plant species is likely releasing alkaline organic compounds during their decomposition, thus leading to an elevation in soil pH levels. Conversely, the lowest soil pH was recorded in Hariparbat with the value of (6.22), might be attributed to human-induced factors and farming methods, including the application of acidic fertilizers or the effects of urban development, all of which can contribute to gradual soil acidification over the years. The presence of diverse plant species can contribute to the release of basic organic compounds during decomposition. there by elevating the soil pH, the similar findings were reported by (Gillman and Sumpter, 1986). The other possible reason could be the differences in water quality, including the pH of precipitation or irrigation water, can influence soil pH. The other possible reason would be that the range Basiwan might receive water with a natural alkaline pH, contributing to the observed higher soil pH, as reported by (Havlin *et al.*, 2014). The lower pH in range Hariparbhat might be due to the influence of human activities and agricultural practices, including the use of acidic fertilizers or the impact of urbanization that leads to soil acidification over time, the similar findings were reported by (Schlesinger, 2009).

5.2.2 Total Nitrogen

The recorded Total Nitrogen in different ranges provide an overview of the potential reasons behind the observed increase and decrease in Total Nitrogen within the different ranges. The Total nitrogen was recorded highest in Nishat (512.6 kg/ha^{-1}) which may result from accelerated decomposition rates, promoting the release of nitrogen into the soil, especially with contributions from organic matter and nitrogen-rich compounds found in forest tree residues. Conversely least was recorded in Basiwan (451.9 kg/ha^{-1}) which may be due to the leaching and denitrification in this range. The soil in Nishat range may experience faster decomposition, releasing more nitrogen into the soil, compared to Basiwan where decomposition rates might be slower. Forest tree residues contribute organic matter and nitrogen-rich compounds during decomposition enhance soil nitrogen content similar findings were reported by (Sainju *et al.,* 2002) and (Davidson *et al.,* 2000). The geological composition of soil present in Hariparbat range may contain minerals that release nitrogen during weathering. Parent material can significantly influence the nutrient composition of soils as reported by (Brady and Weil, 2008).The lowest content of total nitrogen recorded in Basiwan range might be due to the agricultural practices or land use which may contribute to nitrogen leaching or denitrification thereby reducing total nitrogen levels similar findings were reported by (Robertson and Vitousek, 2009) ; (Garcha, 2016) ; (Maqbool *et.al.* 2017) and (Chandel *et al.* 2017).

5.2.3 Available Phosphorous

The highest available phosphorous was recorded in Chashmashahi range (20.5 kg/ha^{-1}) could be linked to the distinctive geological formations shaping the soil's mineral composition, consequently resulting in increased phosphorus concentrations. Conversely, the least was recorded in Basiwan range (15.3 kg/ha^{-1}) may be attributed to potentially containing fewer phosphorus-rich minerals. The elevated phosphorous levels in Chashmashahi may be to the geological formations which may influence the mineral composition of the soil, leading to higher phosphorous concentrations as reported by (Jones *et al.,* 2018). Additionally, weathering processes over time may contribute to the release of phosphorous into the soil as reported by (Smith, 2019). A positive correlation between geological factors and phosphorous levels in soil as reported by (Brown *et al.,* 2017). The lower phosphorous levels recorded in Basiwan range may stem from different geological and environmental conditions. The region's geological formations might contain fewer phosphorous-rich minerals, leading to a lower baseline concentration in the soil as reported by(Smith, 2019).

5.2.4 Available Potassium

The available potassium was found highest in Nishat (243 kg/ha^{-1}) could be attributed to the geological formations might contain potassium-rich minerals and rocks, naturally contributing to higher potassium concentrations in the soil. Conversely, the lowest was found in Chashmashahi (221 kg/ha^{-1}) could be due to geological formations containing fewer potassium-rich minerals. The highest potassium levels in Nishat may be due to the geological composition of the region can play a pivotal role, as certain minerals and rocks are rich in potassium, contributing to higher soil concentrations as reported by (Gupta *et al*., 2018). Additionally, the agricultural practices, including the use of potassium-rich fertilizers, may contribute to the observed higher levels in the Nishat range the similar finding was reported by(Kováčik *et al*., 2019). The lower potassium levels recorded in the Chashmashahi range may be attributed to distinct geological and environmental conditions. The geological formations in this region might contain fewer potassium-rich minerals, leading to a lower baseline concentration in the soil as reported by (Gupta *et al*., 2018). Climate and weather patterns can also influence potassium leaching and availability, potentially contributing to lower levels in Chashmashahi range as reported by (Tang *et al*., 2017).

5.2.5 Cation Exchange Capacity

The Cation Exchange Capacity (CEC) was recorded highest in Chashmashahi (20.8 cmol (+) kg^{-1}) might be due to the presence of clay minerals and organic matter is likely to enhance Cation Exchange Capacity (CEC), enabling the soil to retain and exchange essential nutrients more effectively. Organic matter, as a crucial component, contributes significantly to Cation Exchange Capacity (CEC) enhancement by providing binding sites for cations.

Conversely the lowest was recorded in Nishat (17.1 cmol (+) kg^{-1}) may be attributed to the dominance of geological formations containing minerals with inherently lower Cation Exchange Capacity (CEC) values, such as sandy soils with less clay content. The elevated Cation Exchange Capacity (CEC) in Chashmashahi is indicative of the soil's ability to retain and exchange essential nutrients. The presence of clay minerals and organic matter, plays a crucial role in enhancing Cation ExchangeCapacity (CEC) as reported by (Karlen *et al.*, 2017). A positive correlation between soil organic matter content and Cation Exchange Capacity (CEC), underscoring the importance of organic material in influencing soil cation exchange properties as reported by (Six *et al.,* 2004). The lower Cation Exchange Capacity (CEC) was observed in Nishat may be associated with different soil characteristics and land-use practices. The geological formations in this range might be dominated by minerals with lower Cation Exchange Capacity (CEC) values, such as sandy soils with less clay content as reported by (Nelson and Sommers, 1996). Sandy soils generally exhibit lower Cation Exchange Capacity (CEC) due to their reduced capacity to holdonto cations.

5.3 Soil Biological indicator

5.3.1 Soil organic carbon

The higher Soil Organic Carbon (SOC) levels observed in Hariparbat compared to Shankarachariya indicate variations in organic matter content within the soil profiles of different ranges. The Soil Organic Carbon was recorded highest in Hariparbat (8.73g/kg) could be attributed to the incorporation of cover crops and natural vegetation cover can significantly enhance organic carbon inputs into the soil, fostering soil organic carbon accumulation over time. Conversely, the lowest were recorded in Shankarachariya (7.90g/kg) range may be linked to human-induced activities such as deforestation and intensive agricultural practices. These activities can lead to the depletion of organic matter in the soil due to inadequate organic matter incorporation, ultimately resulting in declining SOC levels over time. The elevated Soil Organic Carbon (SOC) levels in Hariparbat suggest that a soil profile may be rich in organic matter. The incorporation of cover crops, may enhance organic carbon inputs into the soil as reported by (Lal, 2004). Additionally, natural factors such as vegetation cover and microbial activity play pivotal roles in organic matter accumulation as reported by (Six *et al.,* 2006). The positive correlation between vegetation cover and SOC levels. The lower SOC levels observed in Shankarachariya range may be associated with different anthropogenic activities such as deforestation, intensive agriculture, or inadequate organic matter incorporation that contributes to a decline in Soil Organic Carbon (SOC) levels over time as reported by (West and Post, 2002).

5.3.2 Microbial biomass carbon

The significantly higher microbial biomass carbon (MBC) observed in Hariparbat compared to Shankarachariya indicates notable differences in soil microbial activity between the two ranges. The microbial biomass carbon was found highest in Hariparbat (188µgkg^{-1}) could be attributed to enhance nutrient availability in the soil, thereby supporting diverse microbial growth. Moreover, the presence of diverse vegetation cover in Hariparbat provides a conducive environment for microbial development, possibly through increased root exudates stimulating microbial biomass. Conversely the least value was recorded in Shankarachariya (7.90µgkg^{-1}) This could be due to the anthropogenic activities such as deforestation and the reduced vegetation cover and organic matter incorporation could lead to diminished nutrient availability for microbial communities, thereby hindering microbial growth in the soil. The significantly higher MBC in Hariparbat suggests a soil environment conducive to microbial activity. The elevated microbial biomass may be attributed to several factors. The region's land-use practices, including potential organic farming, cover cropping, or the incorporation of organic amendments, can enhance nutrient availability and support microbial growth as reported by (Li *et al.,* 2019). Moreover, the presence of diverse vegetation cover in Hariparbat may contribute to increased root exudates, fostering microbial biomass development as reported by (Bossio and Scow, 1998). The positive correlation between Soil Organic Carbon (SOC) and microbial biomass is well-documented as reported by(Six *et al.*, 2002). The lower MBC levels observed in Shankarachariya may signify limitations in microbial activity. Land-use practices, such as deforestation, intensive agriculture, or the application of chemical fertilizers, can impact microbial biomass negatively as reported by (Li *et al.*, 2019). Reduced vegetation cover and organic matter incorporation may lead to a decline in nutrient availability for microbial communities.

5.4 Computation overall integrated soil quality index (SQI) of urban forestry Division Srinagar

SQI affected by different blocks was followed by the trend Hariparbat> Shankarachariya>Chashmashahi> Kralsangri> Nishat.

Hariparbat obtained SQI i.e., 1.00 which was significantly highest than Shankarachariya, Chashmashahi, Kralsangri and Nishat. The computation of the Soil Quality Index (SQI) serves as a comprehensive approach to evaluate and compare the overall soil health of different blocks within the Urban Forestry Division in Srinagar.

The obtained SQI values reveal a distinct trend, with Hariparbat exhibiting the highest SQI (1.00), followed by Shankarachariya, Chashmashahi, Kralsangri and Nishat, each with progressively lower SQI values. Among the three variables in PC1, MBC was chosen for Multi-Dimensional Scaling (MDS) because of its higher correlation sum (3.39). The other variables in PC1 i.e., aggregate stability (2.29) and Total Nitrogen (2.08). In PC1, MBC emerged as the variable with the highest factor loading (3.39), signifying its significant influence on overall soil quality. MBC is often considered a key indicator of microbial activity, reflecting the vitality of the soil microbial community. Similar finding was reported by (Bossio and Scow, 1998). The selection of MBC for Multi-

Dimensional Scaling (MDS) analysis aligns with its pivotal role in soil health assessment.

In PC2, total potassium and available phosphorous both are higher factor loading, both thevariables were highly correlated. Available potassium was chosen from PC2. PC2 highlighted the interrelation between Total Potassium and Available Phosphorous, indicating their joint impact on soil quality. The choice of Available Potassium from PC2 for SQI calculation acknowledges its crucial role in plant nutrient availability and soil fertility. Similar findings was reported by (Li *et al.*, 2019).

In PC3 (Cation Exchange Capacity) CEC and total porosity show higher factor high loading. CEC was chosen from PC3. In PC3, Cation Exchange Capacity (CEC) and Total Porosity exhibited higher factor loadings, emphasizing their importance in influencing soil quality. CEC is a key parameter influencing nutrient retention and availability in the soil. Similar finding was reported by (Karlen *et al.,* 2017). The selection of CEC from PC3 for SQI calculation underscores its role in sustaining soil health.

In PC4, only Cation Exchange Capacity (CEC) showed higher factor loading was retained for SQI. The selected soil attributes viz, MBC, total potassium, Cation Exchange Capacity (CEC) indicate the important role being played in them in enhancing the sustainability under the blocks. In PC4, where only Cation Exchange Capacity (CEC) displayed a higher factor loading, it was retained as a significant variable for SQI. Cation Exchange Capacity (CEC) pivotal role in nutrient exchange and overall soil fertility reinforces its selection as a representative attribute for assessing soil quality.

Chapter-6

SUMMARY AND CONCLUSION

The result of the study entitled **"Soil Quality Indices or Assessing the Forest Soil Quality Health of Urban Forest Division Srinagar"** are discussed in this chapter and explored under thefollowing headings:

6.1 Soil Physical indicators.

6.2 Soil Chemical indicators.

6.3 Soil Biological indicators.

6.4 Soil Quality indices

6.1 Soil Physical indicators.

Bulk density exhibited a range from 1.06 gcm^{-3} to 1.49 gcm^{-3}, with Basiwan recording the highest and Nishat, kralsangri the lowest. Notably, Hariparbat and Shankarachariya displayed similar bulk densities, distinguishing them from Chashmashahi.

Soil aggregate stability ranged from 24.03 mm to 36.05 mm, with Hariparbat demonstrating the highest stability followed by Shankarachariya and Nishat. Conversely, Kralsangri exhibited the least stability.

Soil total porosity, variations from 43.85% to 45.15% were observed, with Shankarachariya having the highest porosity and Chashmashahi the lowest. While Hariparbat, Basiwan and Chashmashahi shared similar total porosity values, Shankarachariya, Kralsangri and Nishat exhibited distinct levels. These findings highlight the diverse soil conditions within the forest blocks, emphasizing the importance of tailored conservation and management strategies for optimal forest soil health in the Urban Forest Division Srinagar.

6.2 Soil Chemical Indicators

The evaluation of forest soil health based on chemical indicators, including soil pH, nitrogen, phosphorous, potassium and cation exchange capacity (CEC), revealed substantial variations across different blocks in the Urban Forest Division Srinagar.

Soil pH ranged from 6.22 to 6.51, with Basiwan exhibiting the highest pH and Hariparbat the lowest. Chashmashahi, Kralsangri and Shankarachariya shared similar pH values, differing from Basiwan, Nishat and Hariparbat.

Total nitrogen content varied from 451.9 kg/ha to 512.6 kg/ha, with Nishat having the highest and Basiwan the lowest. Hariparbat, Nishat and Shankarachariya, showed comparable nitrogen levels, distinct from Basiwan,Kralsangri and Chashmashahi.

Available phosphorous ranged from 15.25 kg/ha to 20.5 kg/ha, with Chashmashahi recording the highestand Basiwan the lowest.

Available potassium, variations from 220.86 kg/ha to 243 kg/ha were observed, with Nishat having the highest and Chashmashahi the lowest.

Cation exchange capacity varied from 17.10 cmol (+) kg^{-1} to 20.82 cmol (+) kg^{-1}, with Chashmashahi exhibiting the highest and Nishat the lowest. Kralsangri, Hariparbat and Basiwan shared similar CEC values, differing from Nishat. These findings underscore the diverse chemical characteristics of soil in different blocks, emphasizing the need for targeted soil management strategies to enhance forest sustainability in the Urban Forest Division Srinagar.

6.3 Soil Biological Indicators

The analysis of soil organic carbon and microbial biomass carbon in different blocks of the Urban Forest Division Srinagar, as presented in Table 4.3, revealed noteworthy variations. Soil organic carbon exhibited a range from 7.90% to 8.93%, with Hariparbat recording the highest content, followed by Nishat, Chashmashahi, Kralsangri and Shankarachariya with sequentially decreasing values.

Microbial biomass carbon displayed variations from 173 µg/kg to 188 µg/kg, with Hariparbat having the highest microbial biomass carbon, followed by Shankarachariya, Kralsangri, Nishat and Basiwan with decreasing values. These findings underscore the distinct microbial and organic carbon dynamics within the forest blocks, highlighting the importance of understanding these components for comprehensive assessments of soil health and ecological sustainability in the Urban Forest Division Srinagar.

6.4 Soil Quality index (SQI)

The scree plot, depicting the relationship between Eigen value and Principal Components (PC), reveals a decline in Eigen values with an increase in PC number, demonstrating that the first four PCs capture the majority of the variance, explaining 73.5 percent collectively. As PC number increases from PC1 to PC4, Eigen values decrease from 2.623 to 1.075 and the explained variance decreases from 26.22 to 10.74 percent. Varimax rotation applied to these four retained PCs enhances the relationship between interdependent variables by distributing their variances. PC1, with an Eigen value of 2.623, explains approximately 26.22 percent of the variance, highlighting positive factor loadings for microbial biomass carbon (MBC) available phosphorus (AS) and total nitrogen (TN). PC2, explaining 23.8 percent variance with an Eigen value of 2.309, includes positive loading factors for available potassium and phosphorus. PC3, explaining 13.50 percent variance with an Eigen value of 1.351, encompasses cation exchange capacity and total porosity. PC4, with an Eigen value of 1.075, explains 10.74 percent variance and involves cation exchange capacity exclusively. Communalities underscore the relative importance of each soil attribute in contributing to all extracted PCs, emphasizing their collective role in enhancing overall soil quality.

The generation of soil quality index maps for the Urban Forest Division in Srinagar involved the assessment of various physical indicators. Bulk density exhibited variations among different blocks, with Basiwan having the highest and Chashmashahi the lowest. Aggregate stability was highest in Hariparbat and lowest in Kralsangri. Total porosity showed variations across blocks, with Shankarachariya exhibiting the highest and Chashmashahi the lowest. pH levels were highest in Basiwan and lowest in Hariparbat. Total nitrogen content was highest in Hariparbat and lowest in Basiwan, while available phosphorous was highest in Chashmashahi and lowest in Basiwan. Available potassium levels were highest in Nishat and lowest in Chashmashahi and Cation Exchange Capacity (CEC) was highest in Chashmashahi and lowest in Nishat. Additionally, soil organic carbon and microbial biomass carbon were found to be highest in Hariparbat, Nishat and Chashmashahi, emphasizing the spatial variability of these crucial soil quality indicators across different forest blocks in the Urban Forest Division Srinagar. The comprehensive evaluation of these parameters contributes valuable insights for effective soil management and conservation strategies tailored to the specific needs of each block within the urban forest area.

CONCLUSIONS

- This study make credible assessment of forest soil quality in Urban Forest Division Srinagar for identifying causative parameters and prioritizing forest areas by assessing the current soil quality index to facilitate adaptation and planning.
- The ultimate purpose of assessing soil quality is to protect and improve long-term forest productivity, water quality and habitats of all organisms including human being.
- These indices would be useful in ascertaining the fragility of soil and for understanding how improved management might strengthen its resilience in Urban Forest division Srinagar.

- Assessing soil quality is advantageous for its holistic way to judge the management induced changes. This capacity of the soil to function can be assessed by physical, chemical, and/or biological properties, which is termed as soil quality indicators.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner **Dr. Shdhakara N. R.** Scientist ICAR-CITH, Srinagar during Viva-Voce examination on **06-05-2024** have been incorporated in the manuscript entitled **“Soil Quality Indices for Assessing the Forest Soil Health of Urban Forest Division, Srinagar”** submitted by **Mr. Ubaid Munawar Mir (Regd. No. MSF/2021/141).**

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