CHAPTER 1
GENERAL INTRODUCTION

1.1 Introduction

The Himalaya, meaning "abode of snow" in Sanskrit, or Hindu Kush Himalayan region, constitutes a monumental and unique expanse, extending over 9 degrees of latitude and 22 degrees of longitude, covering about 2.9% of the Earth's total land area [1,2,3]. The latitudinal and altitudinal changes, along with the geographical conditions towards the Asian monsoon, generate diverse climate types throughout the Himalayan region. The northward flow of moisture-laden Asian monsoon winds over the mountains causes cooling and condensation, resulting in different precipitation patterns across the Himalayan region [1]. Thus, the Himalaya comprises four major biogeographic regions: Paleoarctic, Indo-Chinese, Indo-Malayan and Indian subcontinent, with observable vertical and horizontal vegetation zonation present in this region. Previously, two botanical regions, namely the Western and Eastern Himalaya, were recognized [4,5]. Subsequently, four regions were recognised, with the central region being consistent across classifications; however, the fourth region was classified as Assam by Chatterjee [6] and north-east India by Razi [7]. Singh and Singh [8] included the mountains of northeastern India and Assam within the Eastern Himalaya region. The Himalayan region is typically classified into three regions: (i) Western Himalayan region, (ii) Central Himalayan region and (iii) Eastern Himalayan region [8,9].

The Eastern Himalayan region spans from Koshi Valley in Nepal to northwest Yunnan in China, including Bhutan, Northeast India, West Bengal (Darjeeling hills), southeastern Tibet in China, and northern Myanmar, covering an area of 5,24,190 km^2 [10]. It was comprised of five landscape complexes: Terai Arc Landscape, Bhutan Biological Conservation Complex, Kangchenjunga-Singhalila Complex, Kaziranga-Karbi Anlong Landscape, and North Bank Landscape [10]. The orographic features in Northeast India, located in the Eastern Himalayan region, significantly affect rainfall patterns [10, 11]. Plants grow in specific environments, forming mutualistic relationships with each other and their surroundings. Variations in topographical and climatic conditions have developed this region into a heterogeneous array of vegetation i.e. from tropical seasonal rainforest to dry alpine scrubs [12,13]. The forests of Northeast can be classified under thirteen different types: tropical wet evergreen forests, tropical semi-evergreen forests, moist forests, swamp forests, khair-sissoo forests, subtropical hill forests and savanna, pine forests, East Himalayan wet temperate forests, East Himalayan moist temperate forests, East Himalayan sub-alpine birch-fir forests, birch-rhododendron scrub and dry alpine scrub [13]. The lowland and foothill regions of Arunachal Pradesh and Assam in the Eastern Himalaya are characterized by Assam Valley tropical semi-evergreen forests, which occur at elevations between 50 m and 600 m [14,15]. However, most of the tropical semi-evergreen forests in Assam originate from the degradation of tropical evergreen forests, resulting in a mixture of both forest types in the foothill regions [15].

Assessment of climate changes reveals that the Eastern Himalayan region experiences a warming rate beyond the global average [16]. Alterations in the climatic variables such as precipitation, relative humidity, as well as soil moisture content with temperature fluctuations significantly impact plant growth and distribution by influencing the phenological events. The occurrences of phenophases in plants are controlled by a combination of genetic components and environmental variables [17]. In the preceding decades, several phenological studies have reported that the occurrences of phenological events are cued by different climatic variables like temperature [18,19], precipitation [20,21], and photoperiod [22,23], signifying the sensitivity of plants to variations in climatic variables. The vegetation in the Himalayan region is closely associated with variations in elevation and moisture levels influenced by monsoonal climatic conditions. Several studies indicate that the phenological traits of tropical trees – such as deciduous, semi-deciduous, and evergreen characteristics, are seasonal responses to variations in tree water balance [24,25,26]. Forest patches in the Eastern Himalayan region, specifically Northeast India, frequently exhibit deciduous traits as an adaptive response to unfavourable conditions like high evapotranspiration [13]. However, within the same forest, the occurrence of phenophases as plant responses to the seasonal variations in the climatic variables is not uniform across different species. Therefore, the species-specific occurrences of phenophases in plants allow them to be used as indicators of seasonal cycles in this region [27]. According to Menzel et al. [28] despite phenology being one of the oldest methods of environmental monitoring, its significance as a reflection of changes in the prevailing climatic conditions has gained prominence in recent decades at both regional and global levels. As a result, present phenological studies primarily deals with assessing alterations in the timing of phenological events due to anthropogenic warming as a consequence of climate change [28].

The dynamic interactions between vegetation and soil, facilitated by leaf litter and windfalls, as well as nutrients intake, are the foundation of terrestrial ecosystems. The physicochemical properties of soil such as texture, pH, CEC, etc. are resultants of actions and interactions of various soil-forming factors, such as parent materials, prevailing climatic conditions, living organisms, topography, and time, leading to their variability across both temporal and spatial dimensions [29,30,31]. In the Himalayan region, soil characteristics exhibit considerable variation over short distances in relation to vegetation [31,32]. According to Lukina et al. [33], the arboreal plants in forest-covered areas determine the windfall mosaic structure, which significantly influences the soil. This is because the nutrient contents of leaves, pre-senescence nutrient mobilization, and deciduous traits of trees are species-specific [34,35,36]. Tanner et al. [37] noted that the addition of leaf litter and plant debris modifies the physical properties – particle aggregation and reduction in bulk density of soil, attributed to the fibrous nature of organic matter. According to Kaur et al. [38], soil pH along with the organic matter content have an impact on the availability of nutrients in the soil. Similarly, a study conducted by Antil and Singh [39] showed that enhancement of soil with organic matter increases its availability of available nitrogen (N), phosphorus (P), and potassium (K) in the soil. Several studies [40,41,42] also reported seasonal variations in the nutrient contents of soil. The seasonality of phenological patterns in plants growth, leaf maturation, senescence, and litter decomposition significantly influence the soil nutrient availability; thus, soil can be considered as the extension of plants' phenotypes [33,43]. However, the degradation rate and nutrient bioavailability from various above-ground parts such as bark and timber, as well as below-ground biomass, including root systems, are also regulated by their intensive properties [33,36]. Therefore, the physicochemical properties of forest soil are directly associated with the quantity and phytochemical content of vegetation debris or litter that is returned to the soil [31,37,38]. Thus, the vegetation type of the area significantly affects the soil organic carbon and nutrient availability, induced by seasonal variation in litterfall and windfalls.

The repercussions of changes in the prevailing climatic conditions on biological communities is one of the most studied topics in the present century [44]. The seasonal occurrences of phenophases or phenological events of plants such as leaf initiation, flowering, and fruiting, are crucial for sustaining diverse ecological functions and socioeconomic services at multiple levels [45]. The Himalayan region experiences the consequences of climate change through shifts in the timing of phenophases such as early flowering and fruiting [3]. Correlation analysis is a regularly employed method to determine the presence of any positive or negative associations between the phenophases and climatic variables. However, correlation does not establish the cause-and-effect relationship between the selected variables. Therefore, to determine how phenophases respond to changes in climatic variables and the aftermath of what happens when these phenophases change, plant phenology models are integral tools for studying the "phenology-climate" connections relationships [45]. As a result, many phenological models such as statistical, mechanistic and theoretical models have been developed to understand phenological trends and predict them for future climate scenarios [46]. Phenological studies frequently demonstrate geographical changes in a species' response to temperature, indicating the site-specific characteristics of the phenophases [27,46,47,48,49]. Consequently, the phenological models are generally site and/or species-specific, limiting their broader applicability. Research on the phenology of trees in the foothill region of Eastern Himalaya is sporadic, resulting in deficiency of data. Thus, a detailed study of the vegetation is conducted in this region to comprehend the seasonal characteristics of the forest, the edaphic properties and various statistical models that link phenophases with climatic variables.

1.2 Objectives

1.2.1 The aim of the study

The study aimed to evaluate and document the diversity of plants (angiosperms), identify non-native plants, record the phenological events of dominant and characteristic trees, analyze variations in the soil physicochemical properties, and evaluate different statistical models that elucidate the plant-climate relationship in the Eastern Himalayan foothills.

1.2.2 Specific objectives

The study focuses on the vegetation of Sonai Rupai Wildlife Sanctuary of Assam, situated in the foothill of the Eastern Himalayas, with the specified objectives:

I. Study on vegetation composition and identification of non-native species.
II. To assess the impacts of meteorological parameters on the phenophases of plants through extensive field visits.
III. Study of variations of soil properties with respect to vegetation.
IV. To examine the impact of weather parameters on different phenophases of plants using statistical models.

1.3 Hypotheses

The hypotheses of the research are as follows:

I. There is no correlation between the phenophases and climate variables.
II. Phenophases occur in a uniform distribution without showing any seasonal peaks.
III. The physicochemical properties of soil from forest and scrub patches do not vary significantly.
IV. The physicochemical properties of soil do not exhibit seasonal variations.

1.4 Significance of the study

The findings from the present study could be useful in different ways:

I. Understanding the diversity and evenness of the plant species in the wildlife sanctuary of the foothill region. It will enable the identification of the non-native plants within the protected area, which may cause invasion and alter the vegetation composition in the future.
II. Examining the phenological aspect of the dominant and characteristic trees in the area will help to determination assessmentthe overall response of the forest to climatic variations due to the Southeast monsoon.
III. This study will elucidate the impact of seasonal variations in climatic variables and vegetation cover on the physicochemical properties of soil.
IV. Exploring and evaluating the efficacy of various regression models for different phenophases may serve as valuable tools for comprehending and monitoring the impact of changes in climatic variables and their subsequent repercussions on various ecological services.

1.5 References

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