Biodiversity Status and Climate Change Scenario in Northeast India

P. Saikia, A. Kumar and M.L. Khan

Abstract Conservation of biodiversity and impacts of climate change are perhaps the most critical challenges faced by all sectors of the society. The patterns and processes related to climate change and biodiversity are so complex that corrective measures are often taken with an imperfect scientific knowledge base. This article addresses the biodiversity status and climate change scenario in Northeast India. The normalized difference vegetation index (NDVI) is used to explain the vegetation pattern of Northeast India and majority of area (58 %) are under tropical climatic zone, followed by subtropical (23 %), alpine (10 %), and temperate (9 %) zones. Although the Northeastern India is very susceptible to climate change because of its ecological fragility, the forest cover is reported increasing in the past few years because of the successful implementation of the different plantation and community development schemes. In order to avoid rapid and irreversible change in biodiversity, conservation strategies needed to focus on supporting the species' natural capacity to adapt to climate change.

Keywords Biodiversity · Climate change · Mitigation · NDVI · Northeast India

1 Introduction

Climate change, global warming, and biodiversity depletion are considered as the most critical challenges for sustainable development worldwide. Environmental conditions in combination with other factors play a key role in spatial distribution of biodiversity. Climate change is recognized as a significant manmade global

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environmental challenge, which has enormous impacts on biodiversity patterns in the past and is seen as having significant contemporary impacts (Sahney et al. 2010). It is predicted that it will remain one of the major drivers of biodiversity patterns in the future also (Sala et al. 2000). A thickening layer of carbon dioxide pollution, mostly from power plants and automobiles that traps heat in the lower atmosphere, is considered as the main reason of climate change. It has a direct impact on biodiversity (Chapin et al. 2000) influencing the reduction in species' diversity (Franco et al. 2006) which ultimately affect the ability of biological systems to support human needs (Vitousek et al. 1997). The industrialization, urbanization, and agricultural intensification has led to a significant change in land use and associated land cover (Kumar et al. 2011), which intensified the pressures on habitats and landscapes and biodiversity in general (Stanners and Bordeaux 1995). The steady decline of habitats and landscapes demonstrates the need for protection, which has also been addressed in Convention on Biological Diversity (CBD) in order to identify and monitor ecosystems, habitats, species, communities, genomes, and genes. Global climatic changes also affect agriculture through their direct and indirect effects on crops, soils, livestock, and pests (Pathak et al. 2012).

Forests have been influencing the gas composition in the atmosphere, which in turn influenced temperatures and weather patterns on Earth (Zachos et al. 2001; Sigman and Boyle 2000). The two important measures of climate change are the variation in precipitation and temperature (Sukumar 2000). Changes in rainfall pattern are likely to lead either to severe water scarcity or flooding and on the other hand, rising temperature with increasing number of days having high temperature accelerates the extinction rate of many species and also cause shifts in crop growing seasons, which ultimately affects food security. Plant growth, flowering, animal reproduction, and migration also depend in part on temperature. Changing environments are expected to lead to changes in species distribution (Lynch and Lande 1993) and life cycle events, which have been recorded for many plant species (Parmesan and Yohe 2003). Phenology is being used as an indicator of species sensitivity to climate change (Bharali and Khan 2012). Plants used to respond to climate change in four possible ways: (a) phenotypic plasticity enabling species survival, with alterations in eco-physiological processes in the changed climate, (b) evolutionary adaptation to new climate, (c) emigration to favorable habitats, and (d) extinction (Bawa and Dayanandan 1998; Saxena and Purohit 1993). Global climate change along with continued habitat loss and fragmentation is now being recognized as a major threat to future biodiversity (Bharali and Khan 2012). Ongoing distributional changes may not necessarily allow the species to persist throughout its range. There is strong evidence that plant species are shifting their ranges in altitude and latitude as a response to changing climatic conditions (Parmesan and Yohe 2003). Human-induced climate change impacts biodiversity and on the other hand, biodiversity reduces the impacts of climate change on the environment. Genetic evidence for *Fagus sylvatica* suggests that populations may show some capacity for an in situ adaptive response to climate change (Jump et al. 2006).

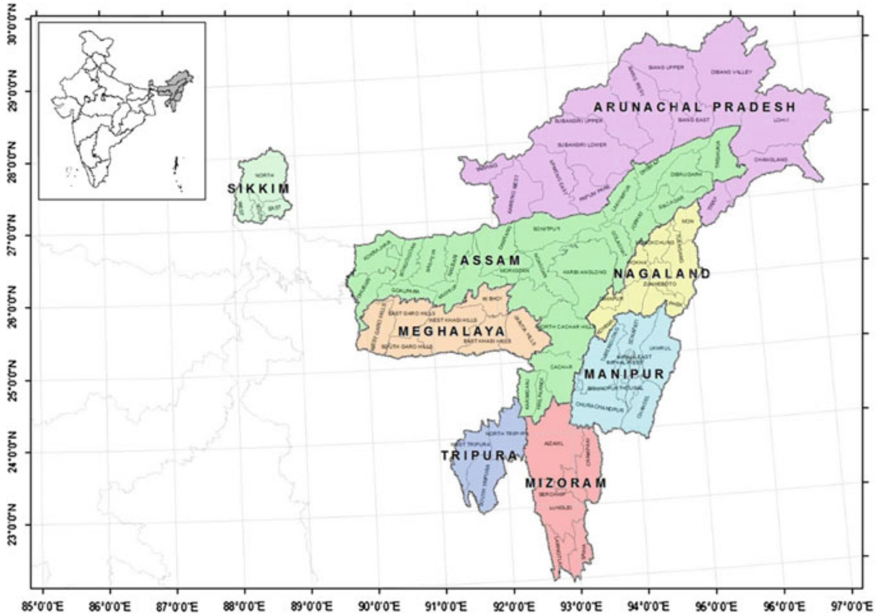

Fig. 1 Map showing the locations of eight Northeastern states of India

The Northeast region of India is consisting of eight states covering a geographic area of 26.2 million hectare (Fig. 1). The Brahmaputra and Barak are the two main river basins of the region. Northeast India has diverse vegetation types encompassing from tropical, subtropical, temperate, sub-montane, montane, subalpine to alpine. The local tribal populations are highly dependent on forest's resources, which provides livelihood to more than 225 tribal groups native to the region. The timber trade, tourism and wildlife resorts, and shifting cultivation in the hills are closely woven with the region's forest wealth. The total forest cover was 54 % of the total area in 1993 (FSI 1995) and increased to 66 % in 2005 (FSI 2008) although doubts have been expressed over official data (Bose 2005). Official reports (FSI 2008) state that forest cover varies from 80.9 % (of the total geographical area) in Arunachal Pradesh to 35 % in Assam, with the other states placed from 76 % in Manipur to 88.6 % in Mizoram. The region is characterized by diverse climatic regimes and is highly dependent on the southwest monsoon. It has two globally recognized biodiversity hotspots and an eco-region renowned for its high species diversity and endemism. According to biodiversity records, Northeast India supports nearly 50 % of the total flowering plants recorded in India, out of which 31.58 % are endemic. It is also recognized as one of the 'centers of origin of cultivated plants.' It is the original locations of over 50 important tropical and subtropical fruits, cereals, and rice (Vavilov 1926; Dhawan 1964; Hore 2005). In addition, out of an estimated 800 species used for food in India, about 300 species occur in Northeast India alone (Rao and Murti 1990). The natural resources of the region are subjected to degradation and loss due to deforestation, unsustainable shifting cultivation practices, fragmentation, and degradation which ultimately impact the biodiversity (Ravindranath et al. 2011). In this article an attempt has been made to address the geoinformatics application in climate change and biodiversity research in Northeast India, a region distinguished globally for its rich biodiversity and variable climatic conditions.

2 Review of Literature

The scattered information on biodiversity and climate change of Northeast India exists in available literature which needs a systematic compilation. The impact of global warming on biodiversity has emerged as an active area in contemporary conservation biology research and is extremely important for Northeast India, where community dependence on forests is very high (Ravindranath et al. 2006). Earth is facing biodiversity crises with very high rates of biodiversity loss and biodiversity change (Duraiappah et al. 2005). Conservation of biodiversity is one of the key issues in terms of global environmental change and its monitoring is necessity as it is strongly related to human well-being. Roy et al. (2012) used remote sensing and GIS data for identification, assessment, and monitoring biodiversity and they considered it as better and contemporary tool because it ensures uniformity in biodiversity data collection. The need to conservation of biodiversity and natural resources in Northeastern states with special reference to Manipur was addressed by Singh et al. (2009). Recent State of Forest Reports point to continued forest losses in Northeast India, including its protected landscapes (FSI 1995, 2005, 2008). Saikia (2009) studied the forest cover changes in Northeast India using normalized difference vegetation index (NDVI) and explained the behavior of NDVI among different land use and land cover changes with reference to rainfall and temperature.

The use of continuous thematic fraction layers, derived from linear unmixing, provides a good basis for monitoring land cover changes. However, gradual and small changes in habitats and their quality are not easily detected from space by satellite imagery, and therefore, additional information from field surveys is needed (Mücher 2011). Singh (1989) used Landsat data for detecting the changes in the forests of Northeastern region of India and considered it as an effective tool for forest cover mapping. On the other hand, Chakraborty (2009) used moderate resolution imaging spectroradiometer (MODIS) to study the change in forest cover of Barak basin, Northeastern part of India. The climate change vulnerability profiles for Northeast India were studied by Ravindranath et al. (2011) and they reported that majority of the districts are subjected to climate-induced vulnerability at present and in the near future. Another important study was done by Bharali and Khan (2012) on impact of climate change on biodiversity and its mitigation in the state of Arunachal Pradesh, which indicates that climate change not only threatens the biodiversity, but also affects the socioeconomic condition of the indigenous people of the state.

The possible causes of climate change in India with satellite measurements were done by Ganguly (2011) and reported population growth accompanied by uncontrolled urbanization and rapid industrialization as the main causes of high levels of pollution and imbalances in the regional climate. Recent research shows that climate change will be even more pronounced in high-elevation mountain ranges, which are warming faster than adjacent lowlands. Hydrological and ecological changes of this magnitude would result in a loss of unique biodiversity, as well as a loss of many of the environmental goods and services provided by these mountains, especially water supply, basin regulation, and associated hydropower potential (The World Bank 2008). Integrated Model to Assess the Global Environment (IMAGE) is a helpful tool for investigating climate change, loss of biodiversity, water scarcity, accelerated nitrogen cycle, and their causes and inter-linkages in a comprehensive framework (Kram and Stehfest 2011). With respect to the altitudinal spectrum, climate change is affecting mountain ecosystems and biodiversity. Glacial retreat in the eastern Himalayas is occurring at an alarming rate, which are likely to result in substantial impacts on water flows to Northeastern (Assam) valleys. At lower mountain altitudes, changes observed include loss of water regulation, increased likelihood of flash fires, and changes in ecosystem composition and resilience. Moreover, as temperatures increase, there is a substantive risk of recurring glacial overflows caused by ice melting, placing large downstream populations and infrastructure at imminent risk. Warming is also affecting the moorlands, high-altitude ecosystems with unique and abundantly diverse flora and fauna that are also a storage area for water and carbon in the soil (The World Bank 2008).

3 Application of Geoinformatics in Biodiversity and Climate Change Research

The rate of species extinction will overtake the rate of biodiversity inventorization and characterization (Chapin et al. 2000). Maximum inaccessible areas of the natural habitats have been yet to be inventorized as most of the biodiversity documentations in our country are concentrated in the areas accessible to the researchers which led to a gap in the biodiversity exploration. Traditional identification and monitoring of biodiversity has many lacunae, some of them serious enough to question the authenticity of the results (Roy et al. 2012). Field sampling provides detailed information but it is quite expensive and time-consuming process. Strategic ground sampling, expert knowledge, and interpretation of remote sensing data can form a reliable, repeatable, and cost-effective analytical framework for accurately assessing the rate of biodiversity change. Remote sensing is well recognized for the integral role it plays in assessment and monitoring of biodiversity and climate-related indicators. Although field surveys provide higher levels of accuracy, remote sensing techniques make it possible to increase the speed and frequency (Arockiaraj et al. 2015). The recent advancement in the fields of remote sensing and geographic information system has enabled accurate and uniform documentation of biodiversity helping in identifying the gap in biodiversity exploration (Roy et al. 2012). Using remote sensing and GIS, vegetation-type mapping, habitat mapping, ecological niche modeling, spatial disturbance regimes and biological richness mapping, etc. can be done which are of special importance in the field of biodiversity research. Researches focusing on remote sensing data maximize the opportunities for ensuring long-term preservation of endangered species, better understanding of how fauna make use of maximum space occupied by vegetation, and to predict the future impacts of climate change and land management on species distributions. Satellite remote sensing has been proved to be the most cost-effective means of mapping and monitoring environmental changes in terms of vegetation and other ecological issues (Deka et al. 2013). Biodiversity monitoring by remote sensing enables us to scale up the understanding and knowledge on biodiversity. Remote sensing brings tremendous possibilities to estimate the climatic and anthropogenic impacts on biodiversity and moreover, to predict its temporal change in the future through ecosystem modeling (Suzuki et al. 2010). Remote sensing will provide us plenty of biodiversity-related information as ecosystem types, their distribution patterns, and information about habitat structure for organisms. Biodiversity can be assessed and interpreted at each level of ecological organization using various approaches at several spatial and temporal scales (Noss and Cooperrider 1994). Monitoring the extent and quality of biodiversity is also required in a more comprehensive fashion across the countryside, ranging from regional to global scales (Mücher 2011). He suggested that operational remote sensing enables land cover characterization at various scales but the classification accuracies are still insufficient at continental and global scales for monitoring purposes.

Climate is one of the most important factors controlling the growth, abundance, survival, and distribution of species as well as regulating natural ecosystems (Faisal 2008). Climate change will affect all natural ecosystems, but the impacts will be more prominent on the already stressed ecosystems of the Northeastern region (ICIMOD 2010). It poses a major challenge to conservation efforts worldwide from habitat shifts (Parmesan 2006) to the threat of new invasive species (Hellmann et al. 2008). Changes in climate have potential direct and indirect affects on individuals, populations, species, ecosystems, and the geographic location of ecological systems which ultimately cause extinction of wildlife, change in phenology, and hatching and immigration of species, disrupted plant communities, species, and ecosystems (Trisurat et al. 2011). Variety of remotely sensed data is being used to monitor and quantify numerous climate change indicators at different scales (temperature/Land Surface Temperature, precipitation, water content in atmosphere, vegetation cover, changing phonology/crop growing patterns, aerosol concentration, etc.). A series of satellite and airborne sensors have been developed to collect thermal behavior of land data from the earth surface, such as HCMM, Landsat TM/ETM+, AVHRR, MODIS, ASTER, and TIMS (Quattrochi and Luvall 1999; Weng et al. 2004). LST modulates the air temperature of the lower layer of urban atmosphere, and is a primary factor in determining surface radiation and energy exchange, the internal climate of buildings, and human comfort in the cities (Voogt and Oke 2003). Important elements such as land cover and land use processes, the global current and historical carbon cycle, the global nitrogen cycle, management of nutrients in agricultural systems, and climate variability including interaction with land use are addressed by Kram and Stehfest (2011) in the integrated modeling of global environmental change.

The normalized difference vegetation index ($NDVI = (\rho_{NIR} - \rho_{RED})/(\rho_{NIR} + \rho_{RED})$) is the most commonly used vegetation index. It quantifies the contrast between red surface reflectance (ρ_{RED}), which decreases with increasing chlorophyll content, and near-infrared surface reflectance (ρ_{NIR}), which increases with growing leaf area index and crown coverage. Atmospheric noise in the NDVI caused by clouds, dust, and aerosols is generally considered negatively biased. This is because additive path radiance causes an increase in red reflectance, while lower atmospheric transmission reduces near-infrared reflectance (Guyot et al. 1989). NDVI has been widely used across diverse biomes as a proxy for rainfall (Barbosa et al. 2006), as a substitute for vegetation growth and health (Schmidt and Karnieli 2000) and in ecological studies (Pettorelli et al. 2005).

4 Vegetation Assessment in Northeast India Using NDVI

In the present study, the IRS P6 (RESOURCESAT-1) AWiFS product is utilized to quantify NDVI of the region during 2010. The IRS P6 AWiFS-based NDVI of the Northeast India exhibits that the majority of area (55 %) having higher NDVI (≥7.0) largely located in eastern Himalayas (Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura) and Meghalaya followed by 33 % (NDVI 0.4–0.7) located in the adjoining areas of eastern Himalayas (including Assam). In contrast, only 8 % area is under low positive NDVI (0.1–0.4) mainly located in Assam (Figs. 2a and 3a).

The Cartosat-I digital elevation model (DEM) of Northeast India exhibits that the majority of the total area (48 %) exist in 0–500 m elevation spatially found mainly in Assam, Tripura, western Meghalaya, south Arunachal Pradesh, and western Mizoram, followed by 500–1000 m (17 %) and 1000–1500 m (12 %), whereas only 8.5 % area is above 3000 m elevation spatially found only in northern Arunachal Pradesh and northern Sikkim (Figs. 2b and 3b). Different climatic zones were classified on the basis of elevation, i.e., tropical (0–800 m), subtropical (800–1800 m), temperate (1800–2800 m), and alpine (>2800 m) zones. The NDVI distribution of Northeastern India in four different climatic zones exhibited that

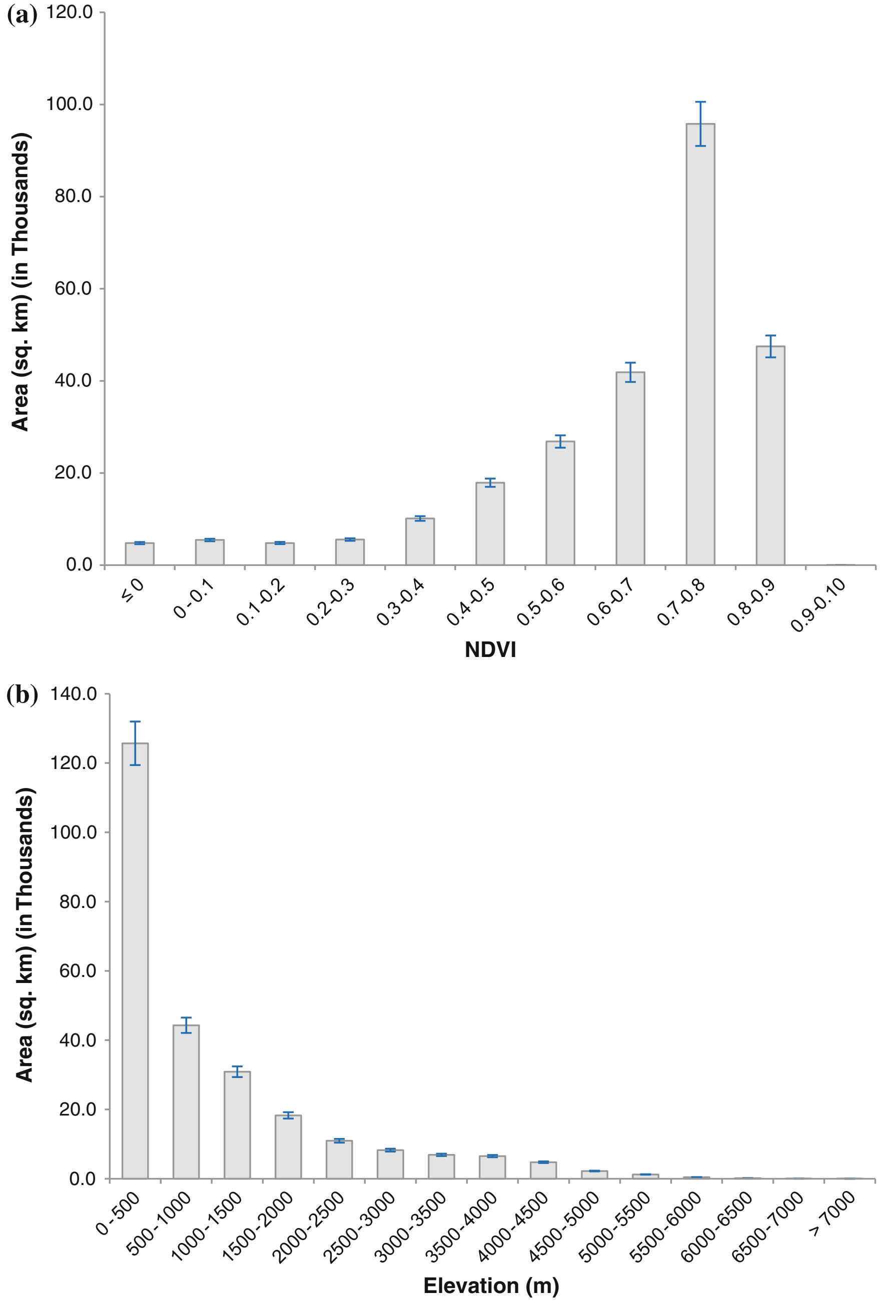

Fig. 2 **a** NDVI distribution and **b** Elevation zones of Northeast India

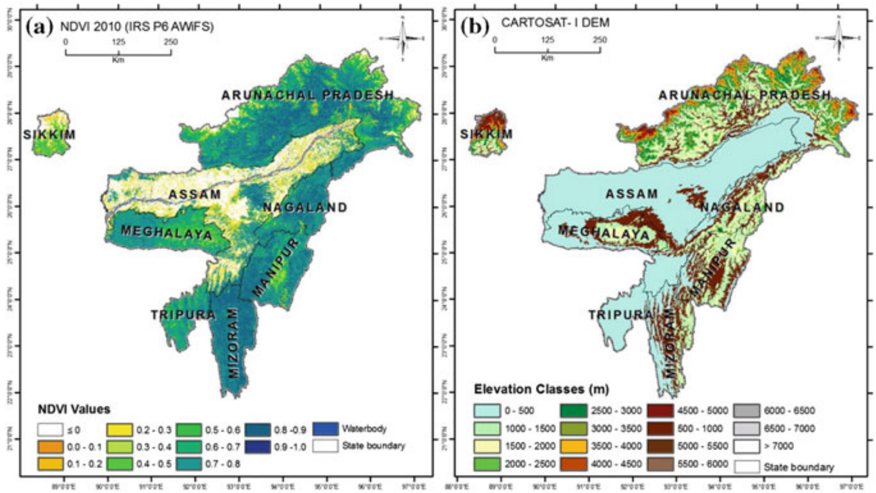

Fig. 3 Spatial distribution of (**a**) NDVI and (**b**) Cartosat-I Digital Elevation Model (DEM) of Northeast India

majority of area (58 %) are under tropical climatic zone, followed by subtropical (23 %), alpine (10 %), and temperate (9 %) zones. NDVI distribution in different climatic zones is shown in Fig. 4.

5 Challenges to Conserve Biodiversity and Climate Change Mitigation of Northeast Region

The exceptional biodiversity in Northeastern region is mainly due to the multiple biogeographic origins and its location at the juncture of two continental plates. It is in an ecotone represented by flora and fauna of both Asian continental shelf and the Indian plate having the Gondwana origin (Roy et al. 2012). The climatic variability associated with the vast, complex, and steep topography is another reason which offers variety of biodiversity in diverse habitats of the region. The region is subject to tremendous threat of landslide, flood, earthquake, as well as human disturbances including roads, agricultural development, forestry activities, deforestation, and energy development which may lead to the loss of biodiversity of different endangered and endemic species of flora and fauna. The threats to biodiversity arising from climate change are likely to be very acute in Northeast region because of ecological fragility, economic marginality, and richness of threatened and endemic species. The vulnerability is very high mainly for ecologically delicate species like lichens, orchids, and insectivorous plants which occupy highly specific and narrow niches.

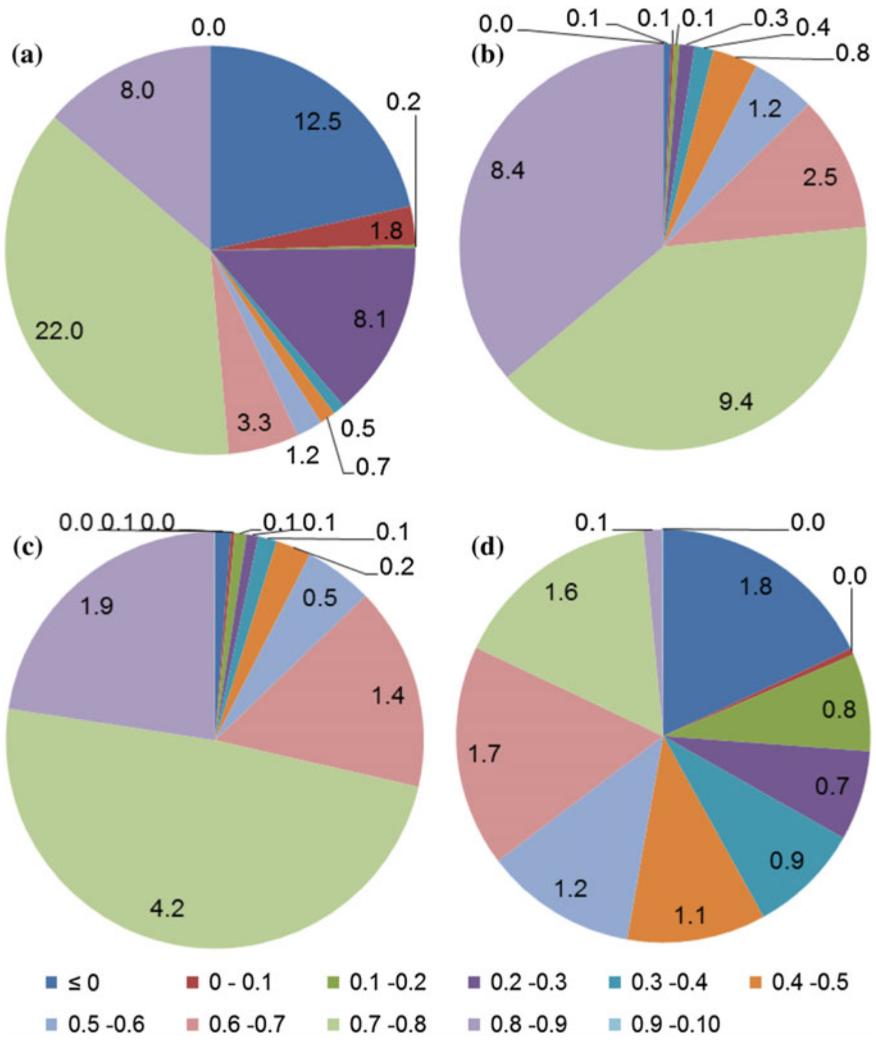

Fig. 4 NDVI distribution in different elevation-based climatic zones **a** tropical, **b** subtropical, **c** temperate and **d** climatic zones in Northeast India

A number of adaptations for conservation of biodiversity have been proposed by several workers, which include assisted colonization (Hoegh-Guldberg et al. 2008), use of invasive species to restore ecosystem services (Hershner and Havens 2008), creation and expansion of protected areas, corridors, and networks (Hannah et al. 2007), and efficient use of resources. Provision of affordable energy; keeping air pollution and climate change under control; management of water systems in support of agriculture, industry, and human settlements; increasing agricultural production; protecting soil, groundwater, and surface water quality; and slowing down and eventually halting further loss of biodiversity are considered as the key elements of sustainable development (Kram and Stehfest 2011).

6 Future Research Prospect

1. There is a need for further research on climate change impact assessment using multiple models as well as multiple approaches for the development of vulnerability profile of the region.
2. Application of geoinformatics in the field of biodiversity requires some new approaches like identification of potential risk zones and habitats to take proper precautions for appropriate conservation measures.
3. The climate change assessment using geoinformatics must consider their consequences with ecosystem structure and functioning so that it could provide more valuable information toward its adaptation and mitigation.
4. A qualitative as well as quantitative approach to assess the impacts of climate change on human health.

7 Conclusion

Biodiversity is intrinsically linked to climate and large-scale changes impacts on the habitats of species within ecosystem. Climatic changes are likely to intense the problems of future food security by exerting pressure on biodiversity. A number of rare and endemic species of flora and fauna found in Northeast India may soon be extinct due to climate change unless conservation efforts are accelerated. For avoiding rapid and irreversible change in biodiversity, conservation strategies needed to focus on supporting the species' natural capacity to adapt to climate change.

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