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A COMPREHENSIVE STUDY ON CLIMATE CHANGE IMPACT ON FOREST AND ADAPTIVE MEASURES

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Abstract

The enormous tropical forests are always in danger of being degraded. Numerous researchers have previously made the effort to identify the cause and provide remedies for sustainable management. However, the most important accelerator of forest degradation now is due to recent, significant changes in climatic conditions. Increased species extinction rates, changes in reproductive timings, lengthened plant growth seasons, altered species habitat distribution, and other effects are some of the key expected effects of these changes on forest ecosystem accounting. India is a tropical country with two of the world's biodiversity hotspots, making it even more important for the nation to participate in research on the effect of climate change. The Western Ghats, Eastern Himalayas, and Eastern Ghats of the nation are the three areas where the majority of this biodiversity is found. In research on the effects of climate change, the Eastern Ghats of India have gotten the least attention. This research came to the conclusion that it is crucial to investigate how climate change is affecting the variety of flowers in India's Eastern Ghats. The Eastern Ghats region's Kolli Hill, where climate research is still in its infancy, is the location of the current study.

Keywords: Forests, Climate, Eastern Ghats, Biodiversity, Sustainable and Himalayas.

1. Introduction

A forest is not just a collection of randomly arranged trees; rather, it is an ecosystem made up of a complex of vegetation and environment that has evolved as a result of interactions between its numerous components [1]. Globally, forest ecosystems are acknowledged as important habitats due to the biological richness they support and the ecological tasks they provide (SCBD 2001). The value of the forest ecosystem to humanity is extremely clear, and international accords like the Convention on Biological Diversity and the United Nations Framework Convention on Climate

Change clearly acknowledge their importance to the functioning of the planet [2]. More than half of all living forms on Earth are found in the tropical forest environment, which occupies less than 10% of the planet's surface [3]. The uniqueness of tropical forest types is the wide variability in tree species variety from location to location [4]. However, the proportional consequences of various forest types vary throughout the globe and are deteriorating at an alarming pace [5]. Deforestation, fragmentation, and overexploitation are frequent causes of degradation in the tropics. Recently, climate change has sped up the pace of ecological deterioration in tropical forests. Compared to moist and wet forest types, dry tropical forests are often more endangered and less protected [6]. The creation of vegetation in the tropics may progressively change depending on temperature, rainfall quantity and distribution, and the length of the dry season [7]. Numerous studies have shown how the recent fluctuations in temperature and rainfall, as well as their imminent effects on the tropical ecology, are indicators of the changing climate. However, the effects of climate change may differ from time to time and location to place. Trees in a forest environment have a long lifespan, making it challenging for them to adjust to sudden climate changes. Therefore, understanding potential local or regional effects of climate change is necessary to adapt to the changes. Since we have a woefully insufficient knowledge of the structure and dynamics of tropical forests, they have started to disappear [8]. A considerable effect on both regional and global biodiversity will result from any changes made to this distinctive and diverse environment [9]. The loss of biodiversity has dramatically grown during the second half of the 20th century and may continue into the future. Climate and the forest ecosystem are intimately related, and the forest ecosystem plays a dual role in preparing for adaptation to climate change as well as mitigating its effects. Forest degradation is responsible for 20% of all carbon emissions, and scientists are working hard to mitigate these emissions via a variety of strategies (Bellassen et al 2008). Unfortunately, even if we cut our emissions, the globe will continue to warm, with a range of 1.8°C to 4°C increase in average global temperature by 2100 [10]. According to the IPCC AR5 assessment, a significant portion of terrestrial species may face an elevated risk of extinction during and after the 21st century as a result of global warming. Changes in species distribution, shifts in reproductive times, and duration of the plant growing season are important factors in the effect of climate change on floral biodiversity worldwide [11]. Studies on the impacts of climate change have significant ramifications for those whose livelihoods rely on it [12]. India has relatively few of these impact studies, mostly focusing on the Western Ghats and Himalayas despite being a nation with a high biodiversity and a forest cover covering more than one fifth of its entire geographical area [13]. However, the potential effects of climate change on the richness of the forest are not expressly included in our current forest management plans. Despite having a rich biodiversity, India's Eastern Ghats are not given as much consideration in climate change effect research as the Western Ghats or the Eastern Himalayas. A nation requires adaptable and objective sustainable adaptation priorities in order to address or manage the current consequences of climate change on the environment and the people who rely on it. Depending on the repercussions, different places and times may have different adaptation priorities. Understanding how species respond to local or regional climate change is thus crucial for prioritising adaptation methods for biodiversity conservation. 86% of the forests in India are tropical, with 37% being wet deciduous and 54% being dry deciduous [14]. These are mostly found in India's Western Ghats and Eastern Ghats. Even though the Eastern Ghats have a healthy quantity of biodiversity, research on the effects of climate change pay less attention to them. Of order to evaluate the influence of climate change on the floral variety in India's Eastern Ghats, this research has taken on the issue. The viability of an existing forest type as a habitat in the Eastern Ghats is explicitly evaluated, together with temporal variations in floral variety and the effects of climate change.

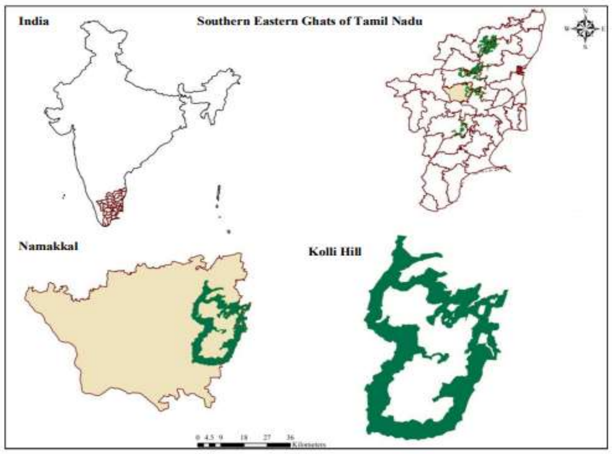

Figure.1. Study Area Map – KH

The research area, Kolli Hill (KH), is located in India's Eastern Ghats between the latitudes of 11°10' and 11°30'N and the longitudes of 78°15' and 78°30'E. (Figure.1.). 503 km2 is the overall area, and the altitudes range from 200 m in the foothills to 1415 m at the plateau. KH is a part of the Namakkal district and is divided between the Namakkal and Rasipuram taluks. There are 5 forest ranges, 14 revenue villages, and 14 reserve woods. The epic Ramayana and the prehistoric Tamil literature are two ancient Indian works that have a connection to the history of the KH [15]. The inhabitants of KH still firmly believe in the folklore connected to it. The average temperature is between 17 and 33 °C, while the average rainfall is between 800 and 1600 mm. The four seasons—winter (January–February), summer (March–May), southwest monsoon (June–September), and northeast monsoon (October–December)—are when rainfall occurs most often in KH. In the sequence of geological succession, KH is indicated by the earliest crystalline rocks of Archaean age, the immediate era of metamorphic rocks of Magnetite quartize, the tertiary period Laterite and Bauxite, and the recent period colluvium and soils. KH is an oval-shaped physiographic feature comprising six primary landforms, including an escarpment, ridge and valley, valley fill, linear ridge bazada, and composite slope[22]. A significant chunk of this hill is surrounded by a composite slope. 20% of the KH area falls into the moderately steep to severe slope category, while 53% of the area is classified as such. Entisols, inceptisols, and alfisols are the main soil types represented in KH. Each soil type has a variety of soil textures, from sandy-loam to sandy clay loam. In contrast to inceptisol, which has high levels of phosphorus and potassium, entisol has high levels of soil organic matter and nitrogen. While entisol levels in the available micronutrients were high. KH has five classifications based on the depth of the soil: very shallow, shallow, moderately deep, deep, and very deep. KH has a significant potential for surface water during the southwest monsoon. The Olaiyar, Arappli Iswar, Aiyar, Sama Odai, Vaattar, and Vachchikai perennial streams are only a few of the hill's six water sources. There are nine sub-watersheds in KH in addition to the four main watersheds (Swetha Nadhi, Yercaud, Valayapatti, and Ayyar). The largest one is Ayyar, which has a 208.7 km2 area. According to the 2011 census data, there are 40,479 people living on the hill overall, 20,862 of them are men and 19,617 of whom are women. A significant portion (95.5%) of its population is made up of Malayalis, a tribe. Although accessibility to education and tourism has increased throughout time, the people's primary source of income remains agriculture. Paddy and millets were the principal crops grown in this region traditionally, but cash crops like pineapple and tapioca are now more often grown there. The whole composite slopes of the KH are covered in several kinds of woods [23]. In its high altitudes (above 900 ma.s.l.), KH falls within the tropical dry deciduous forest type semi evergreen (Lateritic semi evergreen forest-2/E4) forest types. The majority of the southern thorn forest types (southern thorn forest - 6A/C1) and deciduous forest types (Southern dry mixed deciduous forest - 5A/C3) are dispersed up to an elevation of 900 ma.s.l (Figure.2.). The plateau is home to Ariyur sholai, one of the 14 protected forests, and a small piece of Puliyansholai. The restricted woods in the Ariyur sholai, Karavallikombai, Jambuttu, Nayakkankombai, and Selur extension include the majority of the evergreen forest type [24]. The Puliyan sholai protected forest is home to a semi-evergreen forest type. In contrast, the 11 designated forests in the KH are made mostly of deciduous forest types. Southern thorn species are found in 13 protected forests.

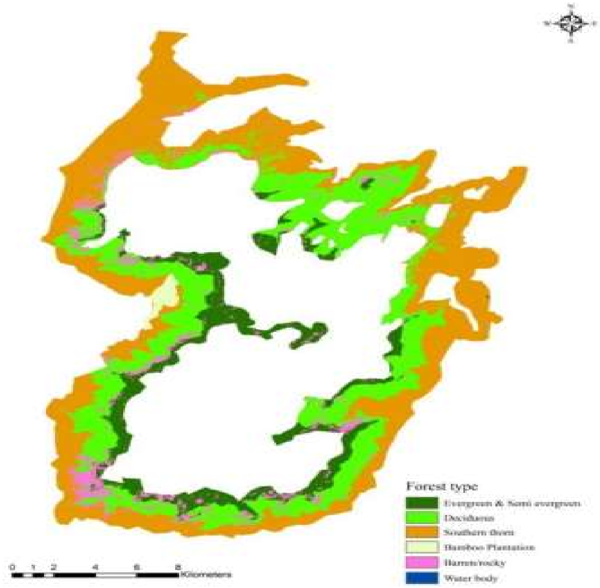

Figure.2. Vegetation Type in KH

KH was designated as the region for India's Green India mission plan to combat climate change in the policy note from the Environment and Forests Department for the 2012–2013 academic year. KH is one among the Southern Eastern Ghats' biodiversity-rich regions.

2. Literature Survey

The forest is a unique ecosystem that includes a variety of animals with various habitats, and any changes to this system would have a big influence on both regional and global biodiversity. The rapid loss of tropical forest variety is one of the most significant environmental and economic issues facing the planet today. More over half of all species are found in tropical forests, which occupy just 7% of the world's geographical area [16]. The variety of tree species is a key component of tropical forest biodiversity. Unfortunately, the tropical forest began rapidly vanishing from the landscape before its structure and dynamics were understood. In order to assess the available resources and issues relating to a forest ecosystem, it is crucial to comprehend diversity and its distribution pattern. The majority of research on floristic variety focuses on floristic inventories; examples are Davis and Richards' study in British Guyana's rainforest and the enumeration of tree diversity in Brazil's Para terra firma forest. Risser & Rice investigation in the Upland forest of Oklahoma, Whittaker & Niering random plot study in the Santa Catalina Mountains, Arizona, Forman & Hahn's investigation into species diversity in the semi-evergreen forest of a Caribbean island, Gentry's permanent plot study in the Upper Amazonian forest on the Brazil-Venezuela border, Knight's 1975 investigation into the species composition and population structure of the Barro Colorado islands in Panama, studies on the diversity and structure of a semi-evergreen forest in Argentina, a quantitative ecological inventory by [17] in the lowland Amazonian tropical moist forest, and In addition to the inventory, there are several more investigations, such as phenological evaluation, spatiotemporal comparison [20], disturbance intensity on regeneration, and diversity monitoring. Tropical forests make up over 84% of India's total forest cover (637293 Km2), or 19.39% of the country's entire geographic area (State Forest Report, 1999). The importance of the forest ecosystem to the inhabitants, communities, and governments of the subcontinent has been recognised throughout Indian history. Indian woods have undergone three major phases: pre-colonial (1000 BCE–1800 AD), colonial (1860–1947), and post-independence (1947-1980). According to the FSI (2013), 21.23% of India's land area is covered by forests, which are found in the Eastern and Western Himalayas, the Western Ghats, and the Eastern Ghats. The great biodiversity of peninsular India was studied by Wight & Walker-Arnot (1834) and Hooker (1874), particularly in the dry evergreen tree species of the coastal areas. Early studies of forest vegetation in the 19th century were mostly conducted by Champion (1921), Troup (1921), and Bor (1940), The Indian forest may be divided into 16 different forest types, according to Champion and Seth (1968). Several significant research on floral inventories have been conducted in India. While others focused on studying the spatiotemporal changes in species richness, other ecologists focused on long-term monitoring using permanent plots. In addition to this, scientists have begun evaluating the severity of the disturbance and the state of the forest's regeneration. Any discrete occurrence that changes the ecosystem, the community, the demographic structure, or the physical environment is considered a disturbance [25]. The Eastern Ghats, in contrast to the Himalayas and the Western Ghats, are a fragmented chain of hills that stretch from Orissa to Tamil Nadu and are encircled by a large number of villages. The first study on the floral composition of several Eastern Ghats forest types was conducted by [20]. Eastern Ghats have received less attention when compared to research on variety in the Western Ghats and the Himalayas. The approach used for each floristic research, however, differed from location to location and throughout time. Over the years, several sample techniques of various numbers, sizes, and shapes have been utilised in floristic diversity research. Plots, line transects, k-tree or fixed tree counts, and ad-hoc sampling are the approaches that are most often utilised, according to the majority of the literature. In addition to this approach, stratified random plots, in which samples are proportionally dispersed in the homogeneous vegetation layers that are obtained from the satellite photos, were also employed. However, some studies are wholly dependent on the survey team's choices, and this kind of floristic survey is referred to as an ad-hoc technique. The preservation of forests and biodiversity prompted the use of remote sensing applications in the phytosociological investigations in addition to the conventional sample techniques. Before the development of remote sensing in 1930, forest managers only depended on ground floristic surveys and observation. As a result, it's easier to comprehend the specifics of a forest's type, cover density, species mix, and degree of change. This has been used by several scientists in different elements of diversity research, such as to determine the age of a forest. Other studies have focused on changes in forest cover through time. Tropical deforestation was a significant issue in the 19th century since colonial rulers relied on the forest environment for lumber and other forest products. Government policies, particularly in developing nations, supported deforestation for rural development throughout the 1960s and 1980s due to fast population increase. Mayers came to the conclusion that one of the primary causes of tropical deforestation is shifting farming in 1984. However, it wasn't until the middle of the 20th century that tropical deforestation became a worldwide problem. Emerging climatic variability hastens the deterioration of tropical forests in addition to the current risks to their ecology. There is now a wide-ranging and quickly expanding global consensus on climate change. The IPCC is only one of the many scientists who have presented the necessary proof of the fact of climate change and its effects on numerous sectors. Temperature increases, changes in rainfall patterns, and extreme weather are all indications of climate change. Since the preindustrial period, anthropogenic greenhouse gas emissions have risen, mostly due to economic and population expansion, and are presently at an all-time high. As a result, the atmosphere now holds unparalleled levels of carbon dioxide, methane, and nitrous oxide for at least the last 800,000 years. Their impacts have been seen across the whole climate system, together with those of other human factors, and they are very likely to have been the main factor in the observed warming since the middle of the 20th century (IPCC AR5). The main changes this century have been seen to be are an increase in atmospheric carbon dioxide concentrations, an increase in land and ocean temperatures, changes in precipitation, and an increase in sea level. This has had a significant influence on a variety of biota characteristics. The expected rates of change for the 21st century, however, are higher than those for the 20th. Different ecosystems, particularly the forest environment and its biodiversity, have been severely impacted by this radical transformation. According to IPCC TAR (2001), future climate change may have a significant negative influence on forest ecosystems. Most ecosystems and landscapes will be affected by changes in species composition, productivity, and biodiversity even with a temperature rise of 1-2 °C. The scientific community has created two mechanisms termed mitigation and adaptation to address these effects. The former will focus on reducing emissions, while the latter will focus on adjusting to changes or repercussions. The scientific community has recently come to understand the importance of forest ecosystems in preventing climate change via carbon sequestration and putting adaptation first to protect biodiversity. Due to the multiple functions that the forest ecosystem serves, forestry has been a major topic of discussion in international climate change policy discussions since the 13th COP of the UNFCCC, which was convened in Bali in 2007. Forests may often thrive in a wide range of climate regimes, from humid tropics to dry boreal locations. The soil's moisture content and available temperature are the key determinants of how quickly plants change. A forest ecosystem's climatic conditions may have varying amounts of impact on the plants there (Figure.3.).

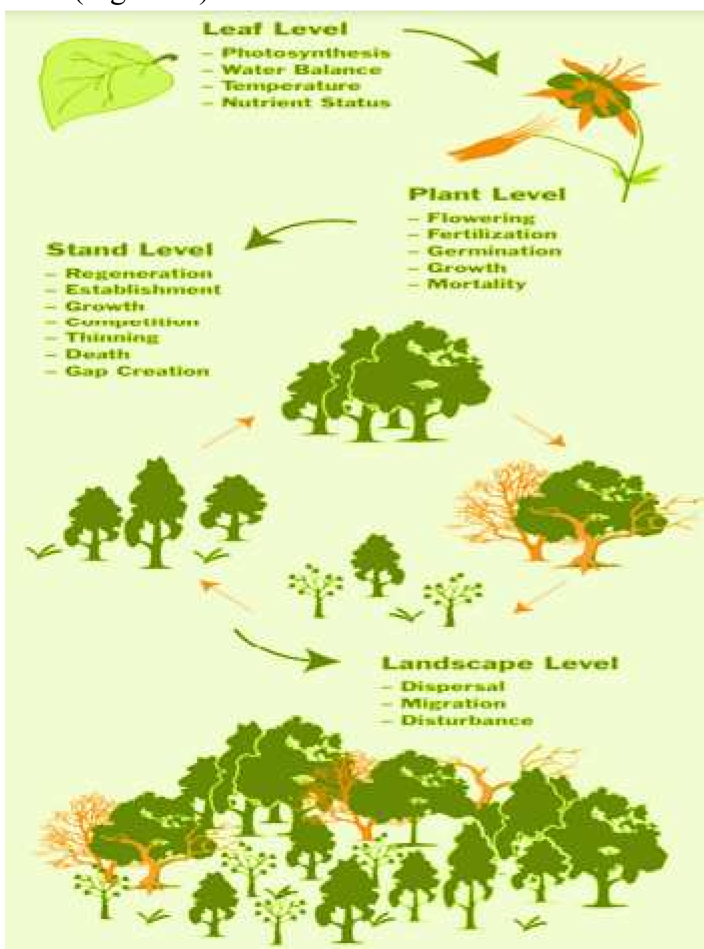

Figure.3. Climate influence on various levels in a forest ecosystem

The broad analysis of the literature revealed that the studies' ability to evaluate the observational changes in connection to climate change has been hampered by a paucity of temporal floristic data. Although many studies evaluate trends in climate parameters, obtaining locality-specific climate data is still difficult when researching the effects of climate change on the forest ecosystem. In many areas of the globe, models are often used to analyse how climate change affects the distribution of forests, but in our nation, these evaluations are only made on a regional basis, with a small number of impact models, and with a primary emphasis on the Himalayas and Western Ghats. Additionally, there is a dearth of comprehensive assessments of the forest ecosystem's vulnerability and capacity for adaptation, and no other locations have used site-specific prioritisation of adaptation techniques.

3. Comparison of Temporal Floristic Diversity

For a very long time, the temporal shift in the make-up and organisation of a forest community has been a major issue in vegetative ecology. Since trees are essential to the variety of tropical forest ecosystems, the majority of floristic research in tropical forests focus on the species diversity of trees. The goal of the current research was to determine how the four main forest types on Kolli Hill's floristic diversity (tree species) through time. To clearly understand the changes, the comparative findings are described in terms of each kind of forest. The research area's evergreen forests (EF) are mostly found in 6 protected forests. The 25 research quadrates, totaling 2700 hectares, were placed inside these 6 designated forests. The floristic diversity of this forest type across time was compared, revealing that whereas in the same region in the current research, a total of 50 ha-1 tree species belonging to 30 ha-1 families were counted, in the year 2000, a total of 53 ha-1 tree species totaling 30 ha-1 families were enumerated. The Western Ghats' tropical evergreen forest of Varagalaiar, where studies by Ayyappan & Parthasarathy were conducted, has a mean species richness of 65ha-1. Chandrasehkara & Ramakrishnan recorded a species richness of 30 ha-1 in the Nelliampathy forest. According to Campbell's study, the Varzea forest has 20 species per hectare. Therefore, it is evident that the KH's EF type is a species-rich group. In addition, a quantitative comparison of floristic diversity using a number of criteria, including frequency, abundance, frequency/abundance ratio, density, basal area, IVI, species diversity, and richness, was conducted. The findings are detailed in the sections that follow. The number of samples in which a given species may exist was shown by the frequency distribution of the evergreen forest type in KH. Memecylon umbellattum, Memecylon edule, and Syzygium cumini continued to be the most prevalent species in the research region between 2000 and 2014, according to a comparison of the frequency of evergreen tree species. Neolitsea scrobiculata frequency decreased considerably in 2014, despite this. Figure 4 depicts the 15 tree species that are most common in this kind of forest.

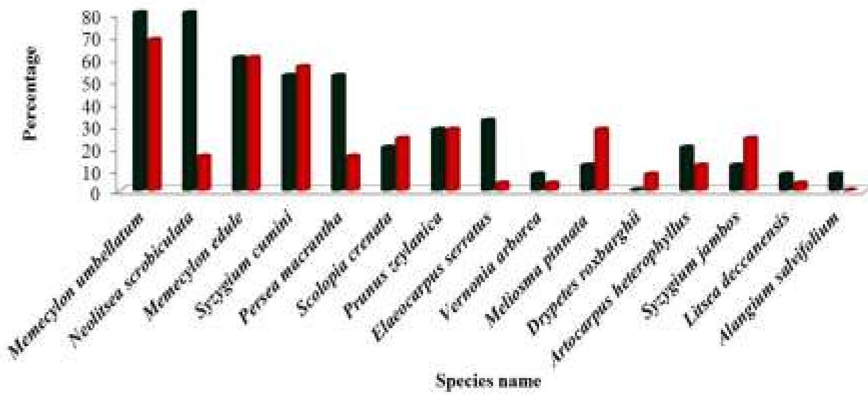

Figure.4. Frequency comparison of dominant tree species in EF

The amount of people in a particular region or sample is represented by an abundance calculation. In the evergreen forest type in 2000, Memecylon umbellattum, Memecylon edule, Scolopia crenata, and Vernonia arborea were the most prevalent tree species. But the current floristic survey revealed that these tree species' abundance had significantly decreased (Figure.5.).

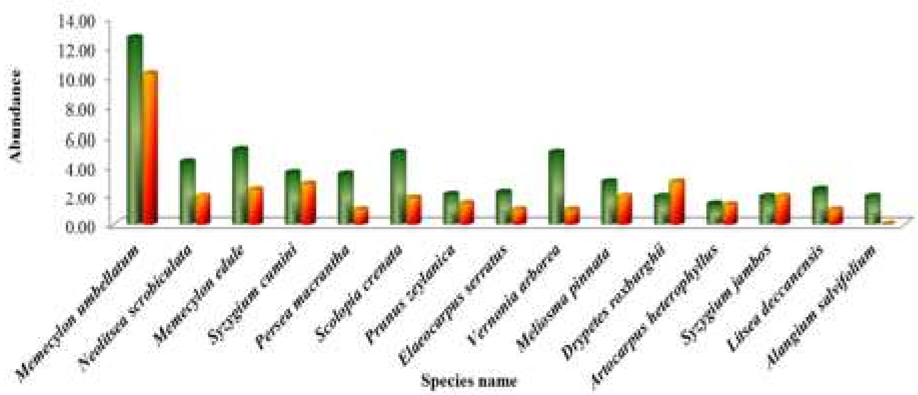

Figure.5. Abundance comparison of dominant tree species in EF

The abundance/frequency ratio paints a picture of the studied area's species distribution pattern. Only 1.8% of the tree species had a random distribution pattern in 2000, compared to 98.2% of tree species that did. In contrast, tree species with random distribution climbed to 12% in 2014 while species with infectious distribution patterns decreased to 88%. In the current investigation, the following tree species showed random distribution: Syzygium cumini, Memecylon edule, Prunus ceylanica, Vitex altissima, and Pongamia glabra. The tropical dry deciduous forest of India's Malyagiri hill ranges in the Eastern Ghats likewise had a similar pattern of tree distribution to that seen in the north-eastern subtropical forests of that country. Memecylon umbellatum, Neolitsea scrobiculata, Memecylon edule, and Syzygium cumini were the most dense tree species of the evergreen forest type in 2000, but their density decreased in 2014, according to the study's temporal comparison of species density (Figure.6.). This forest type had a total tree density of 642 ha-1 in 2000; by 2014, it had dropped to 516 ha-1. Memecylon umbellatum made a significant contribution to the overall species density between the years 2000 and 2014.

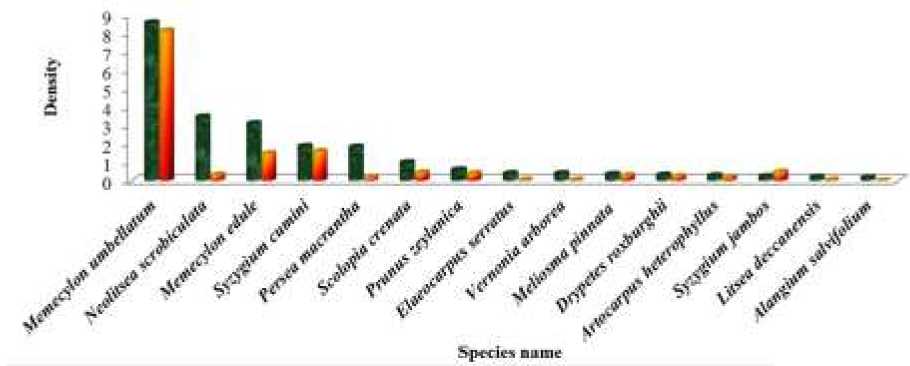

Figure .6. Density comparison of dominant tree species in EF

In the research region's evergreen forest type, the total basal area of all trees was 40.94 m2 ha-1 in 2000, but it had decreased to 38.39 m2 ha-1 by 2014. In this forest type in 2000, Memecylon umbellate, Persea macrantha, Syzygium cumini, and Neolitsea scrobiculata had the greatest basal area values. While Neolitsea scrobiculata, Persea macrantha, and Memecylon umbellatum had a decrease in basal area in 2014.

4. **Temporal Climate Variability Analysis**

Ecologists are well aware that weather and climate have an impact on a species' performance, which impacts both the quantity and distribution of species within an ecosystem. It was shown in the current research that the species distribution and composition drastically altered in KH. As a result, this research investigated the present climatic variability as well as the temporal changes in the climate variable in the study region. Uncertainty around rainfall is one of the components of climatic variance that significantly affects the nation's ecological, economic, and aesthetic variety. The average annual rainfall for KH was determined to be 1477.74 mm from the 41 years of data that were reviewed, with a standard deviation of 604.819 mm. The mean annual rainfall exhibited a declining trend in the data (Figure 7.), but the Mann-Kendall test's tg value indicated it was insignificant at the 0.05 level.

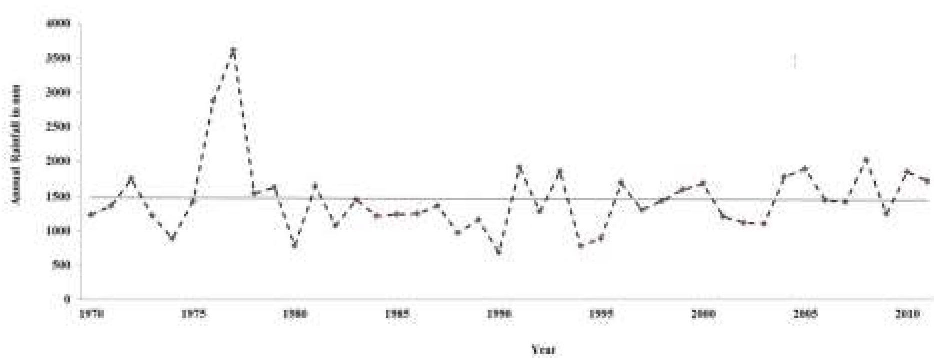

Figure.7. Annual rainfall trend in KH

The examination of monthly and seasonal rainfall conducted for this research showed that the KH saw its peak rainfall in September (17% of the total annual rainfall), and its lowest rainfall in February (0.53%). The usual monthly rainfall during the last four decades revealed a tendency toward less rain in September, June, and July. The Mann-Kendall tau coefficient corroborated the rainfall's considerable declining trend in September and its rising tendency in November. The southwest monsoon (48.15%) and north-east monsoon (36.24%) both contributed significantly to the seasonal rainfall in the study region. The contributions from the winter and summer monsoons were 1.15% and 14.46%, respectively.

5. Results and Discussion

The research shows that climatic factors working along with human interferences, natural disasters like forest fires, and faster decline of forest variety have happened. The forest ecosystem has a dual role in preparing for adaptation to climate change and mitigating its effects. Less attention has been placed on adaptation due to the synergy between climate change and tropical forests, which is primarily focused on climate change mitigation. Because of this rapid climate change, forest ecosystems are predicted to have significant consequences. This backdrop made it evident that India's tropical location and abundant biodiversity drove its active participation in research of the impacts of climate change. Although this biodiversity is mostly found in India's three primary landscapes (the Western Ghats, the Eastern Ghats, and the Himalayas), the Eastern Himalayas and the Western Ghats have received the majority of attention. As a result, this research has taken on the problem of evaluating the effects of climate change on the forest ecosystem of southern India's Eastern Ghats, which are predestined to be a topography rich in biodiversity. The movement of farmers to the higher hill transformed 3786.116 hectares of reserved land into agricultural land, according to a change detection matrix. There have been noticeable alterations in the floristic composition of the conserved woodland. The floristic survey's temporal comparison of the four main forest types in KH reveals that the species richness, frequency, density, and abundance of each forest type have all altered quantitatively through time. Despite the implementation of good conservation strategies, inter- and intra-species migrations were remarkably observed during the field observation, which suggested that climate factors like rainfall and temperature played a major role in the transit of species from lower elevation to higher elevation. The examination of KH's climatic variability revealed fluctuations in rainfall during the south-west and north-east monsoons as well as a notable rise in the annual mean temperature. The KH saw 63.81 mm less rainfall during the south-west monsoon than in the previous, which impeded plant development at the end of the senescence period and prevented the regrowth of the forest environment. In addition, the unpredictable north-east monsoon did not help the forest ecology maintain soil moisture for the coming summer. Thirdly, in addition to the lack of monsoon rains, the increased temperatures experienced throughout the summer may also contribute to the stress. These climatic factors have a significant impact on species' transition from semi-evergreen and deciduous forest types to evergreen forest types. On their upward migration, deciduous plants including Holoptelea integrifolia, Albizia lebbeck, and Albizia odoratissima reached the evergreen forest region. The evergreen species Myristica dactyloides has also transitioned from the SEF to the EF type. Wrightia tinctoria, Albizia amara, and Moringa oleifera are among the plants that have been relocated from the thorn forest to the dry deciduous region, which is filled with many species like Lantana camara and Pterolobium indicum. This migratory pattern demonstrates unequivocally that factors such as temperature and rainfall are increasingly driving species movement. For the existing habitat suitability distribution of each forest type in KH, the logistic output from the MaxEnt model has a high success rate. AUC scores of 0.896 and 0.924 for the training and test sets of data, respectively, showed that the model predicted outcomes with a high degree of accuracy. According to the model's predictions, the distribution of each forest type now found in KH that is suitable for habitats such as EF and SEF may alter over time (2050 as well as 2070). According to the model simulation for the TN type habitat suitability, the research region's foothills, which make up the majority of the existing appropriate habitat, account for around 32.49% (9000 ha) of the total forest area. The forecast showed a rise of 66.06% of the entire area (18300 ha) in 2050, and it may reach 79.78% (22100 ha) of the total forest area in 2070. (Figure.8.). AUC training values of 0.89 and test values of 0.85 indicated a more accurate model. The distribution of TF type in the research region is most strongly influenced by temperature yearly range and annual mean temperature, according to the Jackknife variable contribution plot (Figure.9).

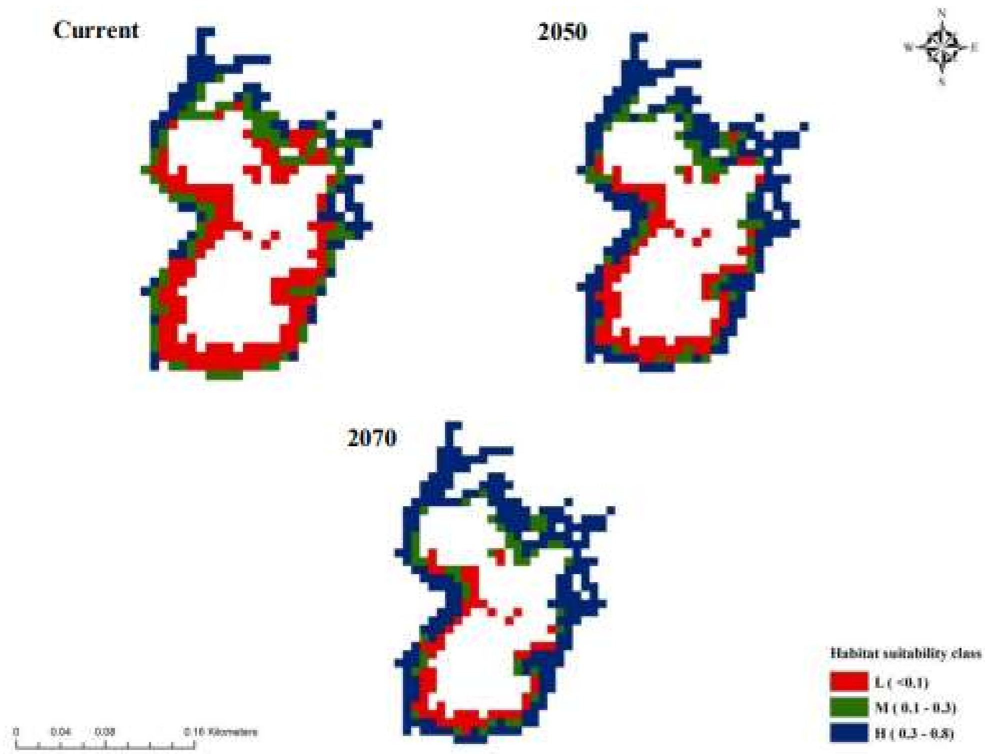

Figure.8. Habitat suitability distribution of TF type in KH

Figure.9.Variable contribution of TF type distribution

According to modelling of habitat appropriateness for each forest type in the research region, the current habitat areas that are suitable for each forest type may vary in the future. If the environment for EF, SEF, and DF becomes less suitable, TF may expand. It is clear from the current research that alterations in the bioclimatic envelop may cause changes in the forest composition of the studied region. As a result, it's important to order adaptation techniques for the current forest types according to the degree of vulnerability they must contend with. Therefore, this research prioritised appropriate adaptation measures and further evaluated each forest type's susceptibility.

Although the ecological appropriateness of DF has decreased, this forest type has showed an upward altitudinal movement in the habitat area. While TF types may be able to increase their acceptable habitat area as a result of future climate change. As a result, the expansion of TF and decrease in EF show that tree species of the EF and SEF kinds are slowly losing the capacity to live in their native environment. It was clear from this impact model forecast that the forest composition in KH may alter depending on changes in the available bioclimatic envelop. The model-driven habitat suitability was used as the exposure, various anthropogenic activities and floristic diversity parameters as sensitivity indicators, ecosystem health and indigenous knowledge as the adaptive capacity, and index-based vulnerability assessment to understand the status of the KH in the present and future climate scenarios. The SEF and EF types that were present in the research area were shown to be the most sensitive to climate change based on a comparison of all four forest types in the KH. As a result, it was crucial to order the adaptation options for the current forest types according to the severity of their susceptibility. The outcomes of a thorough consultation meeting highlighted the need for adequate soil and water conservation amendments for the EF and SEF types as a highly priority adaptation option along with site-specific afforestation programmes. For the thorn forest type in the foothill area, rehabilitation through soil conservation and soil amendments is highly warranted with seamless participation of the community, NGOs, and other stockholders, including government agencies. In the case of DF type, soil and water conservation with species specific afforestation techniques.

6. Conclusion

According to modelling of habitat appropriateness for each forest type in the research region, the current habitat areas that are suitable for each forest type may vary in the future. If the environment for EF, SEF, and DF becomes less suitable, TF may expand. It is clear from the current research that alterations in the bioclimatic envelop may cause changes in the forest composition of the studied region. As a result, it's important to order adaptation techniques for the current forest types according to the degree of vulnerability they must contend with. Therefore, this research prioritised appropriate adaptation measures and further evaluated each forest type's susceptibility.

The current research's temporal comparison revealed that each forest type's composition had changed considerably over time, and these changes may have been influenced by the observed climatic variability in the study region. Additionally, a species movement from lower elevations to higher altitudes was observed. The floristic diversity of KH will be different from what it is presently if these changes continue into the future. Changes in the floristic composition, density, and type of forest in KH were hastened by the observed temperature and rainfall variability. The forecast from the climate change impact model also showed the severity of the effects on each kind of forest in the research region. The most susceptible forest types in the research region in 2050 and 2070 under the mild climate change scenario will be EF and SEF forests, according to climate change-induced species distribution modelling using MaxEnt. Variations in yearly rainfall and temperature had a greater impact on this forest type's habitat appropriateness. The present 2700 ha (9.7%) of EF and 1500 ha (5.4%) of SEF types adequate habitat area may decline or may not be suitable for the two forest types to exist in 2070 when compared to the current model projection. This circumstance calls for sufficient effort to preserve the current ecology while minimising harm to its uniqueness. The KH vulnerability analysis of four forest types showed that the EF and SEF types were very sensitive to both the present and future climatic conditions. Particularly in the future, because to the potential growth of habitat-suitable circumstances, DF and TF kinds are less susceptible. Through a consultative dialogue, appropriate adaptation solutions were chosen based on the vulnerability of the different forest types. The results showed that a site-specific afforestation programme together with the proper soil and water conservation amendments were needed for the EF and SEF types. Including the community in conservation initiatives will undoubtedly have a positive impact. Priorities for adaptation were determined for each kind of forest, which would serve as the framework for KH's sustainable management of its forest resources.

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