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6. Impact of Climate Change on Forest

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Abstract:

The impact of climate change on forest ecosystem is the greatest challenges and creates effects on forest ecosystem in India and all over the world. Forest ecosystems are sensitive to Climate Change; therefore, climate change has significantly affected the growth rate and structure of forests and species distributions. The Influences of climate change are extremely affecting forest ecosystem by varying the growth, mortality and reproduction of trees. Due to continue increasing temperatures changes the life cycle time, phenology, earlier bud burst, leafing and flowering in trees. In this chapter focuses the effect of climate change on forest ecosystems affects both directly and indirectly. Increasing temperature directly affects the rate of photosynthesis and respiration processes, and indirectly affects increases the risk of infestation. The carbon cycle, forest structure, species composition, and alter forest ecosystem function can affect by Climate change disturbance regimes such as fire, species invasions, insect and disease etc. Due to increasing temperature the nutrient availability of soil has been affected by the stimulation of organic matter decomposition and mineralization of soil nutrients.

Keywords:

Climate change, Forest ecosystems, adaptation, disturbance, fire temperature.

6.1 Introduction:

Climate change reveals forest ecosystems are probable to undergo substantial change in structure and composition in the future (IPCC 2014). Due to industrial carbon emissions will have multiple direct or indirect effects on forests through increases in carbon dioxide in the atmosphere. While additional carbon may increase forest growth in the future, changes in temperature and precipitation patterns as a result of rising CO2 levels could alter forest disturbance patterns and forest location.

Forests in some provinces may benefit from climate change, while other provinces will experience increases in drought-induced mortality and potentially greater forest fire activity.

The climate of world is changing, thus changes in the climate are probable to strongly affect forest ecosystems by changing the growth, mortality and reproduction of trees. Ecosystem services supporting, regulating, provisioning and cultural services are currently affected by climate change.

These ecosystem services are the benefits of people derive from the natural processes that sustain ecosystems. At present global climate change displays a general increase in temperatures and levels of atmospheric carbon dioxide as well as changes in precipitation.

The host physiology and defenses, relationships between pests, their environment and other species such as natural enemies, competitors and mutualists are affected when climate changed. Climate variation produces detectable effects on tree and sapling growth in natural forests.

The productivity and integrity of forest ecosystems is linked to the supply of nutrients and climate change can influence nutrient dynamics by altering the rate of litter decomposition. The potential of ecosystems to take up carbon is constrained by the availability of nitrogen and it is a basic element that is fundamental to the growth of plants. Nitrogen limits forest growth under most conditions. Too much nitrogen, however, can have detrimental effects on soil, trees, or indirectly through its impacts on forest composition, growing season length, and the water cycle. The main aim of this chapter is to provide the current and scientific information on impactof climate change on forests and forest ecosystems.

Do We Know the Name Climate Change?

The word "Climate change is to defined as the long-term changes in temperatures and weather patterns". Such changes can be natural, due to changes in the activity of sun or large volcanic eruptions. But since the 1800s, Human activities are the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas.Burning fossil fuels produces greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the heat of sun and raising temperatures.

The main greenhouse gases that are causing climate change include carbon dioxide and methane. These come from using gasoline for driving a car or coal for heating a building, for example. Clearing land and cutting down forests can also release carbon dioxide. Agriculture, oil and gas operations are major sources of methane emissions. The main parts causing greenhouse gases like energy, industry, transport, buildings, agriculture and land use are among.

GENEVA, Aug 9 – Scientists are observing changes in the Earth's climate in every region and across the whole climate system, according to the latest Intergovernmental Panel on Climate Change (IPCC) Report.

Many of the changes observed in the climate are unprecedented in thousands, if not hundreds of thousands of years, and some of the changes already set in motion such as continued sea level rise are irreversible over hundreds to thousands of years. However, strong and sustained reductions in emissions of carbon dioxide (CO2) and other greenhouse gases would limit climate change. But it is not just about temperature.

6.2 Reasons of Climate Change:

There are different main Causes increasingly influencing the climate and the earth's temperature as follows:

- Heat-trapping Greenhouse Gases and the Earth's Climate.
- Greenhouse Gases.
- Reflectivity or Absorption of the Sun's Energy.
- Changes in the Earth's Orbit and Rotation.
- Variations in Solar Activity.
- Changes in the Earth's Reflectivity.
- Volcanic Activity.
- Burning fossil fuels,
- cutting down forests
- farming livestock

We Reduce the Climate Change.

A. We Can Use the Following Actions for A Healthy Planet:

- Save energy at home. Much of our electricity and heat are powered by coal, oil and gas.
- Change your home's source of energy.
- Walk, bike or take public transport.
- Switch to an electric vehicle.
- Consider your travel.
- Reduce, reuse, repair and recycle.
- Eat more vegetables.
- Throw away less food.

Climate change is bringing multiple different changes in different regions which will all increase with further warming. These include changes to wetness and dryness, to winds, snow and ice, coastal areas and oceans. For example:

- Climate change is intensifying the water cycle. This brings more intense rainfall and associated flooding, as well as more intense drought in many regions.
- Climate change is affecting rainfall patterns. In high latitudes, precipitation is likely to increase, while it is projected to decrease over large parts of the subtropics. Changes to monsoon precipitation are expected, which will vary by region.
- Coastal areas will see continued sea level rise throughout the 21st century, contributing to more frequent and severe coastal flooding in low-lying areas and coastal erosion. Extreme sea level events that previously occurred once in 100 years could happen every year by the end of this century.
- Further warming will amplify permafrost thawing, and the loss of seasonal snow cover, melting of glaciers and ice sheets, and loss of summer Arctic Sea ice.
- Changes to the ocean, including warming, more frequent marine heatwaves, ocean acidification, and reduced oxygen levels have been clearly linked to human influence.

These changes affect both ocean ecosystems and the people that rely on them, and they will continue throughout at least the rest of this century.

- For cities, some aspects of climate change may be amplified, including heat (since urban areas are usually warmer than their surroundings), flooding from heavy precipitation events and sea level rise in coastal cities.

6.3 Human's Activities Are Responsible for Change in Climatic Conditions:

Climate scientists have showed that humans are responsible for virtually all global heating over the last 200 years. Human activities like the ones mentioned above are causing greenhouse gases that are warming the world faster than at any time in at least the last two thousand years. The average temperature of the Earth's surface is now about 1.1°C warmer than it was in the late 1800s (before the industrial revolution) and warmer than at any time in the last 100,000 years. The last decade (2011-2020) was the warmest on record, and each of the last four decades has been warmer than any previous decade since 1850.Many people think climate change mainly means warmer temperatures. But temperature rise is only the beginning of the story. Because the Earth is a system, where everything is connected, changes in one area can influence changes in all others.

The consequences of climate change now include, among others, intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms and declining biodiversity.

6.3.1 People Are Experiencing Climate Change in Diverse Ways:

Climate change can affect our health, ability to grow food, housing, safety and work. Some of us are already more vulnerable to climate impacts, such as people living in small island nations and other developing countries. Conditions like sea-level rise and saltwater intrusion have advanced to the point where whole communities have had to relocate, and protracted droughts are putting people at risk of famine. In the future, the number of people displaced by weather-related events is expected to rise. In a series of UN reports, thousands of scientists and government reviewers agreed that limiting global temperature rise to no more than 1.5°C would help us avoid the worst climate impacts and maintain a livable climate. Yet policies currently in place point to a 3°C temperature rise by the end of the century. The emissions that cause climate change come from every part of the world and affect everyone, but others. The seven biggest emitters alone (China, the United States of America, India, the European Union, Indonesia, the Russian Federation, and Brazil) accounted for about half of all global greenhouse gas emissions in 2020.Everyone must take climate action, but people and countries creating more of the problem have a greater responsibility to act first.

6.3.2 Many Solutions to Over Climate Change:

Many climate change solutions can deliver economic benefits while improving our lives and protecting the environment. We also have global frameworks and agreements to guide progress, such as the sustainable development goals, UN Framework Convention the on Climate Change and the Paris Agreement. Three broad categories of action are cutting emissions, adapting to climate impacts and financing required adjustments.

Switching energy systems from fossil fuels to renewables like solar or wind will reduce the emissions driving climate change. But we have to act now. While a growing number of countries is committing to net zero emissions by 2050, emissions must be cut in half by 2030 to keep warming below 1.5°C. Achieving this means huge declines in the use of coal, oil and gas: over two-thirds of today's proven reserves of fossil fuels need to be kept in the ground by 2050 in order to prevent catastrophic levels of climate change.

6.4 Climate Change Can Cause Forest Disturbances:

Climate change can modify a disturbance regime that affects forest ecosystem structure and function. The change in forest structure and function are disrupted when disturbances exceed their natural range of variation. Natural disturbances, such as fires, insect outbreaks and wind throws are an integral part of ecosystem dynamics in forests around the globe. Warming climates pose significant threats to forest ecosystems. It may increase mortality in older forests stressed by low soil moisture. A gradual increase in temperature will alter the regeneration and growth of some species. Regeneration of tree species is affected by low soil moisture and competition with other species during the seedling stage as the temperature increase. Climatic variability and change results degradation of the forest resources to emission of carbon dioxide in the atmosphere and affecting the forest resources and its ability to deliver its ecosystem services.

6.4.1 Fire:

Increases in temperatures create conditions that dramatically elevate the risk and severity of forest fires. Fire effect on forest ecosystem includes disturbance of wild life habitat, acceleration of nutrient cycling, and mortality of individual trees. The frequency, size, intensity, seasonality, and type of fires depend on the amount and frequency of precipitation in addition to forest structure and composition. Fire is a major control of forest carbon balance and reduces the strength of forests carbon sinks. The forest wildfires loss most soil nutrients and it has effect on the available macronutrient concentrations. Climate change is increasing the likelihood of fire ignition and propagation such as, extreme temperatures and plant biomass accumulation, but these are possibly interacting with socio-economic factors. Forest fires directly a loss of habitat, kill plants and animals in forest ecosystem. The potential for prescribed fire to mitigate nitrogen saturation resulting from atmospheric deposition and disturbances that can cause comparable nutrient loss in such a short amount of time.

6.4.2 Invasive Species:

Climate change will have the effect of increasing the extent, frequency, and severity of invasive species, as well as facilitating a shift toward invasion in species that have not historically been invasive. It creates a favorable condition for invasive species to invade the forest ecosystem. The removal of temperature or moisture constraints to dispersal and survival lead to changes in the distributions of species and successfully invade new areas. Species range shifts will also lead to becoming rare and creates ecological space for non-native invasive species to increase in abundance and move in. Invasive species show a greater response to increased carbon dioxide than non-invaders.

Invasive species have strong dispersal abilities and broad environmental tolerances, which will allow them to cope with rapid changes. Invasive plants are recent introductions of non-indigenous or exotic species that are successfully spread into new localized natural habitats to cause economic or environmental harm. Change in weather events increases the disturbance regime, and invasive species generally, thrive in disturbed landscapes with high light availability and fragmented native communities.

6.5 Change Effect on Forest Health:

Forest ecosystem pests and pathogens are likely to increase, either through the direct effect of climate change on their abundance or distribution, or the indirect effect of increased water stress or wind damage which will increase the susceptibility of trees to attack. Climate change alter the disturbance dynamics of native forest insect pests and pathogens, as well as facilitating the establishment and spread of non-indigenous species. Pathogens can take advantage of changing climate; it could have major effects on tree health and survivorship. Forest pathogens may be viral, bacterial or fungal, viral or bacterial infection and transmission rates seem to vary with temperature and moisture in the forest ecosystem. Pathogens like fungal can survive and remain infective over a wide range of temperatures. However, the conditions that favor epidemic growth for most fungal pathogens are constrained to within a band of a few degrees Celsius.

6.5.1 Incident of Pests and Disease:

Climate change increased the extent of greater insect overwinter survival, shortened reproduction cycles and development. Insects and pathogens have been noted to respond to warming in all the expected ways, from changes in phenology and distribution to influencing community dynamics and composition. Incidence of pests and diseases may increase with climate variability and climate change. With long dry spells and more intense rainfall, the resulting decline in water quality will lead to greater risk of waterborne diseases. Invasive forest plants, insects and pathogens can directly cause tree mortality. Increased disturbance in forests was occurred from insects, especially from bark beetles. Trees damaged by insects and pathogens can have substantial socioeconomic effects because of their high physiological sensitivity to climate, short generation times, high mobility, and explosive reproductive potential. Many pests and pathogens will reproduce more quickly, expand their ranges and invade new regions under warmer, wetter, or carbon dioxide enriched conditions. Insect pests are sensitive to a warming climate under greater moisture or temperatures stress their survival and reproductive rate. Climate change cause tree pest and pathogen outbreak that can have negative economic and environmental impacts. A highly virulent pest can lead to significant changes in forest structure and species composition especially decimate populations of susceptible tree species.

6.5.2 Effects of Climate Change on Forest Processes:

Trees require light, heat carbon dioxide and water nutrient to grow through the process of photosynthesis. Increasing temperature, atmospheric carbon dioxide concentrations are altering photosynthesis rates and growth. Naturally plants have their own mechanism to tolerate a certain level of increased temperature.

Soil decomposition rate of organic matter will increase as temperature increase and then nutrient mineralization and availability for plants uptake become increased. Thus, the interaction and different combination effect of rise carbon dioxide concentration and temperature is determined by soil properties, water, mineral and nutrient availability.

The availability of forest resources will determine whether a tree will grow well or not, altering the balance between growth and mortality and therefore determining forest productivity. Increase temperature, precipitation, and carbon dioxide alter carbon balance over longer time and affect nutrient cycling directly or indirectly through its impacts on forest composition, growing season length, and the water cycle.

6.6 Changes in Nutrient Availability:

Increasing temperature is likely to affect nutrient availability in the soil through the stimulation of organic matter decomposition and mineralization of soil nutrients. There are important links between trees and soil nutrient availability.

The cycling of nutrients between the soil and plants is one of the main factors of forest ecosystem functioning. Climate change affect availability of nutrients for plant uptake and limit the productivity, survival of forest ecosystems. Nutrient availability affects forest ecosystem and net primary productivity. On the forest floor organic matter that broken down by microbes such as down fallen leaves release nitrogen to the soil.

Increasing the nitrogen demand is essential for plant the growth, development and builds protein however, increasing carbon dioxide levels in the atmosphere more microbes are becoming nitrogen limited and releasing less nutrients to the trees. The productivity of forest ecosystem appears to be controlled by quantity and availability of nutrient. Warming temperature has direct physiological effects on rate photosynthesis, macronutrient concentration in soils and leaves of tree, shrubs and herbs. Increase in temperature can lead to reductions in nutrient availability.

6.6.1 Climate Change, Forests and Mitigation:

Forests are a large source of both emissions of carbon due to deforestation and harvesting (e.g., DeFries et al. 2002, Houghton 2003, Houghton et al. 2012) and sequestration of carbon through forest regrowth (e.g., Kauppi et al. 2006, Pan et al. 2011). As noted in Figure 6.1, the net effect of both these processes has resulted in forests being a net sink over the last 100–120 years. But this work has not focused on explaining how the sink could have arisen (Ciais et al.2012). Mendel Sohn and Sohngen (2019) develop an economic analysis of historical carbon from forest land management and change, and their results suggest that forest management, in addition to carbon fertilization, played an important role in the emergence of the large carbon sink in forests over the last century.

A. Impacts on Forests:

Forests may be affected by climate change at both local and regional scales. The impacts can vary even within a single forest. There are three key impacts described in this chapter.

B. Natural Disturbances:

Climate change will influence a number of natural turbulences like insect outbreaks, invasive species, wildfires, and storms that threaten forest health. Some disturbances, like a wildfire, take place quickly. Changes in animal or plant populations will happen over decades to centuries. Some of their effects may be temporary, allowing a forest to recover. climate impacts on some forests may advantage from certain. For example, warmer temperatures can lead to more tree and plant growth in regions where cold weather limits the growing season. However, in other forests, warmer temperatures may allow invasive species to thrive. Warmer weather can also encourage insect survival and growth. Over the past decade, climate change has led to an increase in bark beetle damage to mountain pines in parts of the West. Disturbances can also interact with one another to increase risks to forests. For example, drought can weaken trees and make a forest more vulnerable to wildfire or insect outbreaks. Similarly, wildfires can make a forest more vulnerable to pests. Climate impacts can also interact with other stressors, like land development, that decrease a forest's ability to adapt.

C. Reduced Carbon Storage:

Climate change is expected to affect forest's ability including carbon storage, clean air, water supply, recreation, and wildlife habitat. One of the most important ecosystem services forests provide is absorbing carbon dioxide from the atmosphere and storing it in roots, soil, aboveground tree growth, and the forest floor. Climate change can affect carbon storage in numerous ways. For example, it may bring more frequent and intense rainfall to some regions. Heavy precipitation and flooding can erode forest soils and cause stored carbon to be released back into the atmosphere. Damage to forests from more wildfires, insects, and disease outbreaks can also release stored carbon.

D. Impacts on Water Resources:

Another key ecosystem service that forests provide is water for drinking, irrigation, recreation, and other uses. Forest watersheds also moderate extreme weather impacts, such as flooding from heavy rainfall, on downstream communities and ecosystems. Droughts, wildfires, rising temperatures, and reduced snowfall and snowpack due to climate change can all limit a watershed's ability to provide these services. For example, more frequent or severe droughts could reduce streamflow in some forests. Less streamflow means less water may be available for people to use. Reduced streamflow can also affect some plants and animals, such as fish that migrate to certain streams to reproduce.

6.7 How to Overcome the Climate Change's Impacts on Forests:

Actively managing forest ecosystem to improve forest structure, function, diversify tree species, and increase resilience to climate change. Community awareness programs on effective forest conservation, reforestation and afforestation can be used an effective tool to cope with the increasing effect of climate change on forest ecosystem. Increasing alternative livelihood and using forest resource in sustainable way. Information and tools need to be available to make decisions in solving climate change effect on forest ecosystem.

In order to tackle climate change challenges on forest ecosystem, it is important to provide capacities and support to the forest sector. There is also a need for alternative practices to reduce subsequent vulnerability of forests ecosystem, such as planting genetically tolerant trees identified through breeding programs. Most of the Literatures discussed only the effect of climate change on forest and related ecosystem rather than discussing the solution for so, it's important to put the solution and action to solve the problem rather than writing only the effects and constraints.

We can reduce the impacts of climate change on forests areas in many ways including the following.

- **Adopt climate-smart forestry practices.** Forest owners and managers can use strategic forest management options, such as removing wildfire fuel, thinning trees, or managing controlled burns, to address the specific climate change vulnerabilities facing that area. Urban forest managers can also take steps to maximize their ecological benefits.
- **Reduce wildfire risk.** Be aware of where and when weather conditions may increase the risk of wildfire, and take steps to reduce the likelihood of causing a wildfire. For example, keep campfires small and put them out completely before leaving an area.
- **Protect forest watersheds.** Explore EPA's Healthy Watersheds Program to learn about watersheds in your area and how to protect them.
- **Prevent spread of invasive species.** Help prevent invasive species from entering forest land. Clean clothing and shoes before entering and leaving a forest and stay on marked trails.
- Control pests. Forest owners and managers can use integrated pest management practices to help control pest outbreaks while reducing pesticide use.

6.8 Conclusion:

Climate change is one of the world's greatest challenges. At present global climate change shows a general increase in temperatures and levels of atmospheric carbon dioxide as well as changes in precipitation. It creates effects on forest ecosystem. Climate change affect ecosystem service comprises both goods, process and it poses major new challenges to forest ecosystem. Forest ecosystems are sensitive to climate; thus, climate change has significant effects on species distributions, the growth rate and structure of forests.

In this chapter the changes in climate are likely to strongly affect forest ecosystems by altering the growth, mortality and reproduction of trees. Forest ecosystems are sensitive and subjected to climate change produce detectable effects on tree and sapling growth in natural forests. Climate change particularly facilitates drought, fire and insect disturbance; thus, changes increase carbon dioxide concentration, reduce the strength of carbon sinks and may turn carbon sink into source. Forest fires directly a loss of habitat, kill plants and animals in forest ecosystem. Climate change can create a favorable condition for invasive species to invade the plant ecosystem. Invasive plants are recent introductions of nonnative, exotic, or non-indigenous species that are successfully established or naturalized and spread into new localized natural habitats to cause economic or environmental harm. Effect on forest health and forest properties with larger changes in temperature and precipitation will affect forest ecosystem more strongly.

Forest ecosystem pests and pathogens are likely to increase either through the direct effect of climate change on their abundance or distribution or the indirect effect of increased water stress or wind damage which will increase the susceptibility of trees to attack.

Different literature suggests that global forest ecosystem disturbance such as invasive species; insects and pathogens in particular are likely to increase in a warming world. Increasing temperature is likely to affect nutrient availability in the soil through the stimulation of organic matter decomposition and mineralization of soil nutrients.

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