FOREST ECOSYSTEM MANAGEMENT AND CLIMATECHANGE

ABSTRACT:Climate change is one of the world's greatest challenges. Which creates effects on our forest ecosystem. Sensitivity of forest ecosystem and climate significance affects the growth rate and structure of the forest, and italso affects species distribution, growth of tress, theirmortality and reproduction of trees is alsoaffected by climate change. Increase and decrease in temperature leads to change in time phenology due to which earlier burst of bud, leafing and flowering in trees is affected, this review is all about how climate change affects forest ecosystem. All direct and indirect alterations and shifts in the ecosystems are affected by change in climate. Rise in temperature will affect respiration process due to which photosynthesis rate will also change. Disturbance in climate change. Affects carbon cycle, forest structure, composition of species and alteration in forest ecosystem. Disturbance includes; invasion in species, forest fire, insects and disease outbreaks. Disease outbreaks destroy the structure, composition and function of forest ecosystems. Forest fire also disturbs our forest ecosystem by disturbing wildlife, habitat, increase and decrease in nutrient cycling and mortality of individual. Trees frequency, size, seasonality, intensity due to fire multiplication of pests and pathogen is faster. They expand their range and invade into new regions under warmer, wetter, or carbon dioxide enriched conditions. Nutrient availability is affected by an increase in the temperature through change of organic matter decomposition and mineralization of soil nutrients, mainly nitrogen.

Keywords: Carbon sequestration,Climate Change, carbon,Forest Ecosystem, Nitrogen.

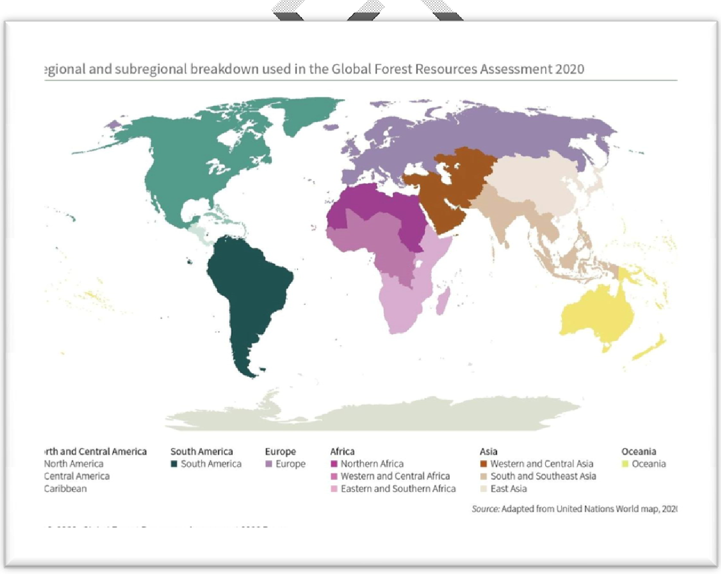
INTRODUCTION

A functional unit or a system comprising soil, tree and other living things is termed as forest ecosystem.About 4.1 billion ha of global land surfaceis covered by forest (Hisano et al. 2018).Forest ecosystemsprovide many eco-services like timber and non-timber products and play a key role in contribution to the world economy (Hui et al.2017).Other than this, the forestprovides many other services which include habitat for wildlife,clean water, carbon storage & climate action (Lindquist et al.2012). The collection and reserving of carbon in thiscarbon cycle is termed carbon sequestration. A major pool of carbon is forest biomass and soil carbon sequestration.About 359 million tons is the total carbon sequestered in forest vegetation (Hobbset al.2016). Carbon cycling and curbing climate change is majorly affected by forest. The world's biggest threat is climate change. Due toclimate changes many activities that are harmful for forest ecosystems like fossil fuel burning,deforestationcarbon dioxide level has been increasedfrom 280 ppm to 379 ppm (Penuelas et al.2013). Human activities contribute mostly to forestloss,fragmentation, and degradation (FAO 2015) and this effect led to loss of forest ecosystem (Var der pals et al. 2016) However, forest ecosystem and climate areinterrelated.The impact of climate change on forest ecosystems primarily focuses on their roles in carbon emissions and sequestration. (Mori et .al2017). Increases in disturbance severity could dramatically impact forest ecosystem structures, species composition, and their capacity to function as carbon sinks. (Cardinale. 2012) And the increase in disturbance is due to Climate change. It can directly impact nutrient cycling by affecting temperature and precipitation. A gradual rise in temperature will impact the regeneration and growth of certain species. Climate changemajorly affects forests and their services flow.Global climate changes consequences that includelong term droughts limited by the availability of nitrogen; a fundamental element essential for plant growth. Nitrogen often limits forest growth under most conditions. However, excessive nitrogen can negatively affect soil and trees, and can also impact forest composition, growing season length, and the water cycle. Increased temperatures can hinder the regeneration of tree species by reducing soil moisture and increasing competition during the seedling stage. Climatic variability and change lead to the degradation of forest resources, resulting in higher carbon dioxide emissions and adversely affecting the forest's ability to provide its ecosystem services. Whereas high co2 emission results in increasing temperature, affecting nutrient availability in the soil through stimulation of organic matter decomposition and mineralization of soil nutrients. We can perform some conservation practices like afforestation (It is defined as and imbalances in water supplies; decreasing carbon sequestering capabilities, soil erosion, loss of soil fertility,desertification, reduction in food production capacity (Isbell et .al 2015). Decrease in precipitation and higher temperature will lead to increase in arid land which is a major threat to biodiversity and survival of certain forests ecosystem (Zuidema et al. 2013) The revival of these harmful impact is costly or irreversible for ecosystems and biodiversity (Peterset al. 2013).Ecosystem is the interaction between living organism and their physical environment within a particular areais defined as ecosystem and whereas on other hand, Biodiversity is defined as the variety and variation of living form under an ecosystem therefore biodiversity and ecosystem are interrelated.Biodiversity and forest ecosystem conservation is increasing concern and demand worldwide to cope with the declining biodiversity and forest ecosystem. **(**Tian et al .2012; Gebeyehu et al. 2019).Conservation of biodiversity and forest ecosystems will also help in managing climatechanges.It also changes the frequency or intensity of natural disturbances in certain forests, especially those caused by fire and insects.These changes will reduce the ability to mitigate harmfuleffects, andwill reduce human wellbeing, particularly for the poorest populations of low-income countries and arid climate regions (Dukes et al .2014). The productivity and health of forest ecosystems are closely connected to nutrient availability, and climate change like precipitation pattern can alter nutrient dynamics by modifying the rate of litter decomposition. The ability of ecosystems to absorb carbon is creating a new forest by planting more and more trees) because trees and soil nutrient availability areinterrelated to each other. The biochemical cycling between the soil and plants is one of the main factors of forest ecosystem functioning. Climate variationaffectsreadiness of nutrients for plant uptake and limits the output andpersistence of Forest ecosystems. Nutrient readiness affects forest ecosystem and net energy production(Juneja et al.2014).Nitrogen can be sourced from biomass broken down by microbes (e.g.: fallen leaves release nitrogen to the soil).Boosting the nitrogen requisition is essential for plant growth, development and builds protein. However, boosting carbon dioxide tier in the atmosphere will lead to global warming, further leading to climate changes. The yield of forest ecosystem appears to be governed by quantity and readiness of nutrients. Temperature boost has direct physical reaction effects on rate photosynthesis, macronutrient dosage in soils and leaves of trees, shrubs and herbs. boost in temperature can lead to reductions in nutrient readiness (Tian et al. 2013).Climate change poses significant threats to forests and the vital services they provide. Expected impacts include prolonged droughts and disruptions in water availability, reduced carbon sequestration capabilities, soil erosion, decreased soil fertility, desertification, diminished food production potential, and increased risks from certain species and ecosystems.

FOREST ECOSYSTEM

Forests are the largest terrestrial ecosystems on Earth, covering over 4.1 billion hectares (Pohjanmieset al. 2013). They offer habitats for most of the planet's species and supply crucial ecosystem resources and services to humans, including food, fiber, timber, clean water, carbon storage, and climate rregulation (an et al. 2022).

Figure 1FAO. 2020. *Global Forest Resources Assessment2020*. Rome.*https://www.fao.org/forest-resources-assessment/fra-2020/maps/en/*



FOREST ECOSYSTEM SERVICES:

Environmental services are the direct and indirect participation that ecosystems make to human well-being. These benefits encompass supplying, managing, cultural, and supporting services, all of which are essential for sustaining other ecosystem functions.(May et al. 2015) Forests are widely recognized as key providers of ecosystem services (Peñuelaset al. 2017). National classifications often identify up to 100 distinctenvironmental services, including food, timber, and fuel production; water conservation and regulation; nutrient retention; carbon sequestration; biodiversity protection; climate regulation; ecotourism; and the preservation of spiritual and traditional values. Biodiversity- ecosystem functioning (BEF) (Chitsazet al .2012) show that biodiversity is related to functionality of ecosystem(Example – primary production , decomposition , nutrient cyclingEtc.) and also provide ecosystem services (e.g. – food production , climate regulation ,pollinationand other**)** **.**Experimental and theoretical work has developed BEF theory with the contribution from experimental manipulation of plant assemblages in grassland ecosystem over the last several decades (Mitričăet al. 2015) .

NUTRIENT CYCLE AND CLIMATE CHANGES:

Climate crisis is becoming a great warning to the world. It is leading to aboost in global surface temperature at an uncontrolledrate. Increase in temperature, co2 level will affect rainfallpatterns, nitrogen deposition will affect the tree growth and forest dynamics and majorly the accumulation of carbon in forest ecosystem (Damkjaeret al.2013).It is crucial for predicting ecosystem carbon dynamic in forest ecosystem.Carbon sequestrationcan be defined as the process of storing carbon in a carbon pool. Carbon sequestration majorly contributes to limiting climate change. This process helps in controlling climate changes by reducing the amount of carbon dioxide in the atmosphere.Forest ecosystems can either act as carbon sinks, sequestering more carbon, or as carbon sources, releasing more carbon, depending on the net carbon exchange.

The effects of climate crisis on forests have shown both positive and negative impacts. On the positive side, elevated CO2 levels can lead to increased forest growth and improved water use efficiency. Conversely, negative effects include reduced growth, which can arise from a combination of factors such as higher temperatures, altered precipitation patterns, and increased frequency of extreme weather events.

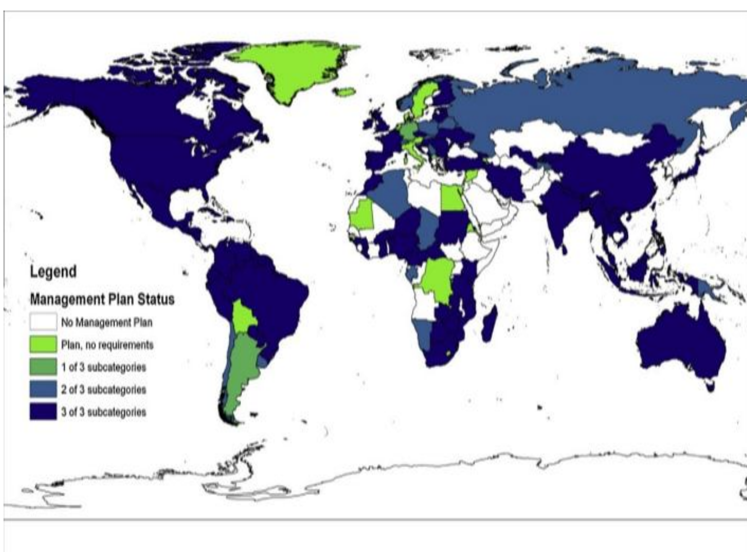


Figure 2Countries with required inclusion of soil and water management, stakeholder inputs and high conservation value forest designation in forest management plans.*(Macdicken et al. 2015)*

IMPACT OF NITROGEN IMPEACHMENTON CARBON SEQUESTRATION BY FOREST ECOSYSTEM:

Figure 3.Carbon sequestration in forest ecosystems, including major carbon pools and fluxes (*Hui et al.2015)*

Over the past 25 years assessments of global carbon (c) budget show that more than 50 % pf the.Human activitiesCo2 emission is stored in oceans and land. For oceans and terrestrial ecosystems, the most recent global estimate of C sinks is2.6±0.5 Pg c yr^{-1} and 2.6 ±0.8 Pg C yr^{-1}respectively (Corinne Le Quéréet al. 2013).The storage of human-caused CO2 emissions mainly happens in forest ecosystems.(Pan et al. 2013). For theprediction of long-term Henceforward global forestsink, it is important to have insight of interaction between environment of the processes that determines the forest C balance. Other than site disruption and forest managementmany filed studies, and models have been approached that suggest increasing atmospheric co2 and climaticwarming. They are the major driver of continental and global carbon sinks.However, the significant disruption of the nitrogen (N) cycle since the early nineteenth century has led to increased atmospheric nitrogen deposition in forests. There is growing evidence that this has also significantly boosted forest carbon sequestration.(Büntgen et al. 2014). While most of the forest ecosystems are nitrogen deficient, increased nitrogen deposits will increase net primary production (NPP) thus stimulating carbon sequestration in trees and it will lead to declining biodiversity.

Increased productivity can also enhance carbon sequestration in the soil through greater soil carbon inputs from litterfall (de Vries et al .2011) and reduced decomposition of organic matter. There is substantial evidence that nitrogen availability, and more broadly nutrient availability, is crucial in how forest ecosystems respond to higher CO2 concentrations, elevated temperatures, and altered water availability (Lu etAl. 2014)

DIFFERENT FACTORS EFFECTING CARBON SEQUESTRATION

1) Consequences of CO_2
2) Consequences of temperature
3) Consequences of precipitation
4) Consequences of O_3

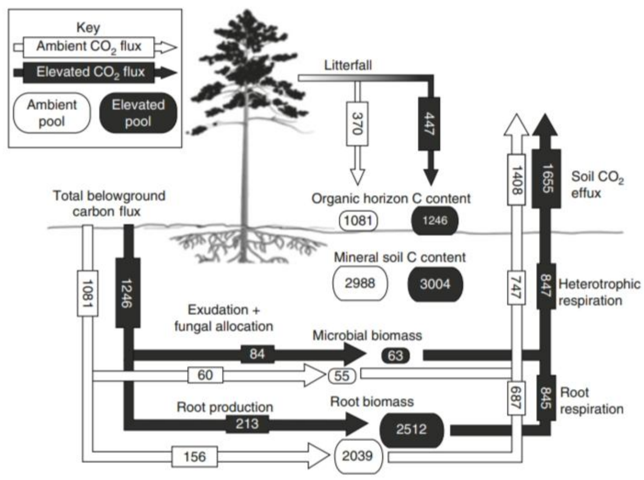
Consequences OF CO2

The effect of increasing atmospheric CO2 levels on carbon sequestration in forest biospherehas been researched for decades. Natural ecosystem and socio-economic systems are impacted by any global change in climate. Since the industrial revolution, many human activities like burning fossil fuelshave led to aboost in the concentration of greenhouse gases in the atmosphere causing temperature rise which is defined as global warming. **(**Fernández-Martínezet al. 2020). Warming has seriously altered justifiable development, and climate crisis has been listed in the top10 ecological problems faced by human beings (Huanget al. 2019). In early years, many researchers used closed chambers, glasshouses and growth chambers to grow tree seedlings or small trees under controlled condition. As glasshouse and growth chambers are artificial mean of growing tree seedlingsit cannot really copy the real-world environment so these practices of growing under controlled condition are criticized by many other researchers because these gave different results as under natural conditions. Glasshouses have an open top chamber which provides natural light and precipitation which may maintain air and soil temperature inside the chambers. Recently, free air Co2 enrichment (FACE) technology made it feasible for trees to artificially provide exposure to higher Co2 levels. This technique involves the treatment of entire forest ecosystems with CO2 enriched air in large scale,unrestricted plots, eliminating the need of enclosed structure (glasshouse,polyhousesetc.) (Drake et al. 2011)

CONSEQUENCES OF TEMPERATURE

9,000 soil profile reveals that carbon sequestration is affected by high annual mean temperature, importantly it is common in coarse - textured soils, this soil has less capacity to stabilize organic matter as compared to fine textured soils with better stabilization properties. This trend is constant across both cool and warm regions and affecting factors like plant yield, rain,aridity,cation exchange capacity and pH.The outputs are represented by an accepted earth system model (ESM).Warming will promote real soil losses, but ESMs may not be able to predict the losses accurately. **(**Hartley et al. 2021). Low soil temperature in cold and wet regionsencourages theemergence of thick organic horizons and peats, resulting in storage of carbon i.e.~500 Pgof C (Z.C.Yu2012).

FIGURE 4. Underground carbon budgets for a warm-temperate forest exposed to elevated atmospheric CO2 at the Duke free-air CO2 enrichment (FACE) site. Ambient CO2 is shown in white, while elevated CO2 is shown in black. Ovals reflect pools and have units of g C $m^{-2;}$ squares within arrows reflect fluxes of C and have units of g C m^{-2} $year^{-1}$(Drake et al. 2011)



soils are mixture of organic and mineral material, which is further referred as mineral soil, this soil contains two third of the global soil C stock, the role climatic variables in controlling C storage have been frequently questioned (Doetterl et al. 2015). In the inadequacy of anaerobic environment, decomposers will affect long term persistence of soil organic matter (SOM) in mineral soil (Dungait et al. 2012). The study of soil profile is significant because soil properties are important for C stock judging, role of temperature in determining C storage may be hyperbolize, which limits the potential of release of C from soils as the climate warms. (Dominguez et al. 2019). Whereas physiochemical stabilization mechanisms are considered temperature sensitive. For example, sorption (stabilization) and desorption (destabilization)are argued to be both more and less sensitive reactions, with the relative temperature sensitivities varying with harmony of organic matter surfaces (Wiesmeier et al. 2011). Evidence shows that the decomposition of older and more protected SOM is more sensitive to temperature than rapidly increasing SOM, showing that destabilization reactions are highly temperature reactive (Conant et al. 2020). Thus, it is controversial to identify that at which extent of temperature C storage controls in mineral soils, and it is not known whether the C stored in mineral soils with large capacities stabilizes more carbon or less vulnerable to climate warming than the C stored in soils with more limited stabilization capacities.

CONSEQUENCES OF PRECIPITATION

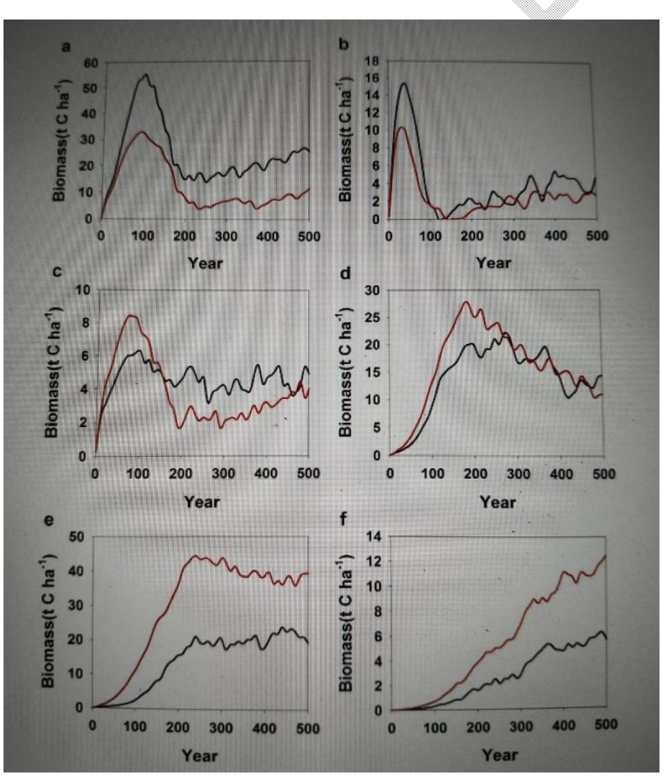
15 % of the universalground cover,in which 14.4% of global population is supported represents transitional section between arid and semi humid regions (Jia et al. 2024). Low soil water storage capacity, sparse vegetation cover, and smashable ecosystems, these regions exhibit sensitivity to climate change and human activities (Gonget al. 2024). Over the past century, Semi-arid regions have undergonenoticeable warming which accounts 44% of the universal average annual surface warmingtrend (Wanget al. 2014). The increase in universal warming, serious drought poses important threats to the carbon sequestration capacity and biodiversity in terrestrial ecosystems within semi-arid areas (Huanget al.2012), this projection indicates the threat will increase warming in future (Pal et al. 2023) Semi-arid regions, as current scientific hotspots in global climate change (Knowles et al. 2020), have significant carbon stocks from SOC due to a range of reasons. Therefore, to propose feasible strategies and protect this fragile ecological environment accordingly requires understanding of the characteristics of semi-arid regions and how they will respond under climate change. Abstract Global warming is thought to intensify hydrological processes within terrestrial ecosystems. This resulted in a broad increase in total global PRE and heightened occurrence rates of extreme PRE, especially over semi-arid regions (Ahlström et al. 2015). PRE limits the physiological processes of vegetation (Ameer et al., 2023) and grassland-dominated semi-arid ecosystems show a high sensitivity in photosynthesis carbon uptake to varying PRE strength (Chenet al. 2021). The longevity and amount of PRE affect land surface ecological processes, such as plant physiology development or soil moisture condition which indirectly modify the carbon flux strength and direction (Jayara et al., 2023). Vegetation growth can be promoted by an increase in PRE in water limited terrestrial ecosystems. This is only possible when there is a highconnection between PRE and vegetation (Zhang et al. 2024). Many studies demonstrated PRE as enhancer of carbon absorption in ecosystem (Zhan et al. 2023), Furthermore, in most of semi-arid region's groundwater is deep and relatively disengage from soil moisture. Therefore, resulting in boost in facile soil water content (SWC) which primarily depends on vertical drainage during PRE eevents (ao et al. 2017). Near surface and root zone) (Liu et al. 2024). Enhancement in photosynthesis, boost in carbon absorption in vegetation, carry in microbial activity and organic matter decomposition in the soil is done by adequate SWC levels (Liu et al. 2019), soil respiration generates carbon

dioxide pulses which are commonly noticed in rewetting of seasonally dry soil after PRE in semi-arid regions (Wanget al. 2023). Therefore, controlling ecosystem processes and land atmosphere interactionsis controlled by PRE.

CONSEQUENCES OF O_3

Ozone can have many effects on forest ecosystems. Increased human activities increases tropospheric ozone abundance. Itis widespread like apollutant in regional air which leads to decrease in rate of photosynthesis and decrease in growth of plant (Prajapati et al., 2012). The probability of O3 becoming more abundant in future is very high resulting in limiting terrestrial carbon sequestration across broader portionsof earth. The impact of O3 on the forest carbon cycling is estimated by using coupled climate biogeochemical cycling model. They are parameterized by using the physiological responses observed during seedling and saplings. The few ecosystem-scale forest O3 experiments that have been conducted (Ainsworth et al., 2012) have revealed that small plants responses cannot always be extrapolated to larger scale. It shows that when level of co2 increases physiological response of O3 can be modified by environmental and biological interaction. As if the understanding of these interactions is comparatively poor for O3 and ecosystem scale. Therefore, there is a criticalneed for research on the impact of O3 on forest carbon cycling remains constant. As for our knowledge of the interactive effects of Co2 and O3 on the forest, carbon cycling is poorly developed. The Aspen face experiment was framed to understand how ecosystem works. In developing forests there is a competition among species and genotypes to interact with CO2 and O3 to influence carbon cycling. (Diaz-de-ouijano et al, 2012) The focal species for this experiment was trembling aspen, trembling aspen is north Americas most widespread tree species and O3 exposure is a common component of north Americasforest. Aspen was planted in mixed species(aspen- birch, aspen-maple) or either in mixed genotype (five clones varying in sensitivity to Co2 and O3) communities, representing common forest type in the northcentral united states

Figure 5. Successional responses to O3 by individual species within the simulated forest. Sensitive species: Liriodendron tulipifera (a) and Acer rubrum (b). Intermediate species: Acer saccharum (c) and Quercusvelutina (d). Tolerant species: Quercusalba (e) and Fagusgrandifolia (f). Dark and red line denote without and with O3 stress, respectively.(Wang et al. 2016)



In this experiment, these all forests were exposed to factorialcombination of increased Co2 and O3 for 11 years and advanced from open grow seedling < 0.25 m in height to closed canopy stands that were >8 m tall. Our first objective of doing this aspen, FACE experiment was to quantify the effects of increased CO2 and O3 on ecosystem C content. At the first phase of experiment in 1997 we presumed that ecosystem C content can be extended by increased Co2 and lowered by elevated O3. According to our limited knowledge, we further presumed that Co2 and O3 would show no such interaction such that two gases would have on ecosystem C content.

CONCLUSION

In this review global average C-N feedback of forest ecosystem are shown, where gradual gathering of tree wood, with long revenue times, lies between 5 to 25 Kg N^{-1} which is totally dependent on forest type. N deposition leads to lower growth responses, but inauspicious impacts occur below 20-30 kg N ha^{-1} yr^{-1}.This will boost the nitrogen loads associated with other environmental problems, including higher nitrogen leaching and decline in biodiversity.The values latervary from 10 and 20 Kg N ha^{-1} for broadleaved forests and for coniferous forest it is 5-15 Kg N ha^{-1}.(Vries et al. 2014). Physical and chemical features of the geosphereare influenced by forest carbon cyclethus it is considered as large and important. Ecological models till now predict carbon cycle at big scale had only contemplate the outcome of nitrogen but it does not take others into account such as phosphorus or pH of the soil, which is related to the availability of nutrients. New ideas and modelling are done to evaluate the importance of forest biosphere–climate interaction for future climate change.Rather than model projection, attention to understanding processes.

Prediction of better constraints for the estimation of upcoming changes in forest biosphere and climatewill be done by upgradedcorrelation between facts and models. **(**Hui et al. 2015)

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