Analysis of Positive and Negative Impacts of Increasing Carbon Dioxide on Forest Ecosystem

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Abstract. Nowadays, the concentration of carbon dioxide is increasing rapidly, also leading to severer global warming. The increase of carbon dioxide affects the forest ecosystem from many aspects, which also brings significant influence to human life. As a consequence, it turns out to be an important topic to analyse the impacts of increasing carbon dioxide to the forest ecosystem, no matter positive or negative. For individual plants, carbon dioxide is beneficial in some ways because of the elevation in photosynthesis and water use efficiency, but its respiration process has been depressed, resulting varies in NPP. By contrast, for a longer period of time, the raise in carbon dioxide concentration can harm the ecosystem from the declination in tree diversity and even the decrease of forest areas. The analysis also focusses on some improvements to be made and suggestions for further researches.

Keywords: Carbon Dioxide; Forest Ecosystem; Photosynthesis.

1. Introduction

Since industrial evolution, engines have been developed in a rapid speed, resulting in the upward trend of the amount of carbon dioxide emission, which continually intensified global warming as one of the main greenhouse gases. The concentration of carbon dioxide reached 419.13ppm in 2021(NOAA, 2021), far more than the 369.52ppm in 2000, indicating that its influences on our ecosystems turned out to be more profound. Since the forest ecosystem is the most important ecosystem in the world, the change in its structure and functions will impose serious effect on human survival and development. People are eager to clarify how deep the forest ecosystem has been influenced to predict its future scientifically. Although the growing period of forest is so long that the adaptations to the increasing of carbon dioxide take too long time (Zhou Guangsheng, 2003), scientists successfully discovered proofs to determine the impacts on the trees themselves like photosynthesis and respiration process and water use efficiency as well as the impacts on the whole ecosystem like the migration and extinction of types of trees and wood quality through long-time observation and simulated experiments. This passage analyses the impacts of increasing carbon dioxide on forest ecosystem and proposes outlook for future researches.

2. The Impact on Photosynthesis Process

Carbon dioxide is the basis for Calvin Cycle in the photosynthetic activity of plants in forest ecosystem. It is proved that the optimum concentration of CO_2 for plant photosynthesis is about 0.1% (Pingping Chen, 2002). The increasing of carbon dioxide can facilitate photosynthesis, elevating biomass and yield, since more glucose is produced during the process. For example, schima superba growing under 500 $\mu L\ L^{-1}$ carbon dioxide possesses the net photosynthesis rate 95% higher than growing under 350 $\mu L\ L^{-1}$(Dazhi Wen, 1997). While some plants' photosynthesis rate can be raised sharply in a short time, they may decline after a period time, for photosynthetic acclimation. It is also worth mentioning the influence of temperature on photosynthesis, whose decrease will cause declination in photosynthetic rate. Yet, the global warming caused by greenhouse gases like carbon dioxide maintained warm temperature to some extent.

3. The Impact on Respiration Process and NPP

At a certain temperature, because of the partial pressure of the product of respiration --carbon dioxide-- is increased, the respiration intensity is inhibited with the increase in carbon dioxide concentration. It is also because the partial pressure of oxygen decreases inside the cell due to the shrink of guard cells and the closure of stomates. Although the decrease in respiration results in less energy support for the plants to live, the growth of plants gets guaranteed as the photosynthesis is stronger than respiration under abundant carbon dioxide. When the photosynthesis rate excesses the respiration rate, the Net Primary Productivity (NPP) of the forest will be increased. Rustard analyzed statistics from 20 experiments on boreal and temperate ecosystems under warmed conditions, discovering that the global warming has significantly increased plant productivity in aboveground parts by 19%.(Rustad L E. 2001). However, Tian 's research on the Amazon rainforest region in the past 100 years showed that global warming reduced the net primary productivity of the forest ecosystem (Tian H Q, 1998), since the plants can fix more CO_2 while they can also consume more carbon by autotrophic respiration. In conclusion, The impacts of global warming on forest ecosystems are inconsistent in different latitudes. The net primary productivity in low latitudes is generally decreased, while the net primary productivity in middle and high latitudes is generally increased or unchanged.

4. Water Use Efficiency(WUE)

The increase of carbon dioxide leads to decreased stomatal conductance and density, the transpiration process is weakened, so that the water loss of plants is reduced, which means the WUE is increased. This is because high concentration of carbon dioxide activates Rubisco and speeds up carboxylation reactions as substrate, as well as declining the loss brought by light respiration. When the concentration of carbon dioxide doubles, the transpiration will decrease by 34%, and the biomass will increase by 30%, inferring that the WUE will increase by 70-100% (Kimball B A, 1983) According to Xiang's experiment, the apparent photosynthetic rate of Medicado Sativa increased by 18.7% under carbon dioxide concentration of 700 μ mol mol^{-1} than the concentration of 350 μ mol mol^{-1}, and the stomatal conductance decreased by 2% while the transpiration rate decreased by 2.7%, but its water use efficiency increased by 30.1%, which is very significant (Xiang Bin, 1996).

Evatraspiration(ET), the rate of water loss over a single land area, decreasing with the increase in WUE, is affected by temperature to a large extent. It is estimated that the double of carbon dioxide can rise the temperature by 1.5-4.5℃(Jiang Gaoming, 1995). According to the ET model established by Penman-Monteith, if the temperature rises by 3.6℃, ET will increase by 24%. If take the dew point pressure, wind speed and other meteorological factors into consideration, ET will increase by 9%. However, if also take the stomatal resistence into consideration, ET will only increase by 2% (Rosenberg, 1990), indicating that the decrease of ET caused by increasing carbon dioxide will be compensated by rising temperatures.

5. Interspatial Migration of Forest Ecosystems

Studies of the effects of climate warming on the distribution of forest species mainly include two types of methods: the first type is vegetation-climate classification, commonly used include Holdridge life zone system, BIOME model and MAPSS model; The second one is forest growth and succession simulation, whose commonly used models include BKPF forest gap model, Zelig model, etc.(Wang Ye, 2006).

Since the increase of carbon dioxide concentration causes the rise in world temperature, 40% of the boreal forest will disappear, whose pioneer trees will move at the speed of 1.0-1.5km/a (Harrington J., 1989). Due to the rise in temperatures, drought, and forest fires, the forest near equator will shrink while evergreen broad-leaf forest will expand. Additionally, the area of tropical rainforest

will expand to subtropical and temperate zones, and the rainforest may become savana with the declination of rainfall. Hirota et al. discovered based on the predicted result of the model ClimateVegetationNatural that as the climate continues to warm up, about 20% - 85 % of South America's forests will disappear, while forests of roughly 150-300 km wide in the latitudinal direction will be converted to savanna. (Hirota M., 2010).

In latitude, many species have moved towards higher places, like trees expanding to pass the tundra lines. During 1990 to 2000, unclosed and closed forest lines of Larixsibirica in the polar Ural Mountains moved up, respectively, 26m and 35m (Shiyatov S G, 2007). Since the summer temperature increased by 1℃ in the 20th century, the alpine timberline of Scandinavian Mountains have moved up 150-165m(Kullman L., 2001). As a consequence, the diversity of trees in forest ecosystems faces great challenges.

6. Improvements and Future Researches

In order to drive the condition of forest ecosystems to a better direction, it is better for us to plant more trees that can maintain normal or higher photosynthesis level under high concentration of carbon dioxide, like Rhizophora stylosa. Additionally, high carbon dioxide concentration can help mangrove resist drought because of reduction in stomatal density (Jacotot A., 2018). In the future, more researches are needed for tall trees under comprehensive factors instead of shrubs. More long term observations on the carbon cycles of trees in different locations and climates are also required. In order to develop more effective forestry management, the pest control under high carbon dioxide concentration have to be considered.

7. Conclusion

The increase of carbon dioxide concentration harms the forest ecosystem in long-term development, but improvements on tree types to be planted can only be temporary. To solve the problem basically, it is necessary to change production method and develop renewable energy sources to cut carbon dioxide emission, which can mitigate global warming can benefit human from several aspects.

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