Restoring Mangroves in China: A Dual Approach to Climate Mitigation and Community Empowerment

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Course Information

This paper was originally written for Dr. Audrey Pearson's GEOG 215 course: *The Biosphere.* Instructor contact: audrey_pearson@sfu.ca. The assignment asked students to research a topic related to the biosphere, formulate a research question, and present their findings in an essay that highlights a positive environmental news story on any topic. The paper uses APA citation style.

Abstract

Mangroves play an important role in mitigating climate change by sequestering carbon, protecting coastlines, and supporting biodiversity. This paper explores the effectiveness of mangrove restoration in China as a nature-based solution for climate resilience and climate justice. It examines carbon sequestration potential of mangrove ecosystems, comparing afforestation and reforestation methods, and highlights the socioeconomic implications of restoration projects. While China made significant progress in mangrove restoration, equitable community involvement remains a challenge. Case studies, such as the Zhanjiang Mangrove National Nature Reserve, demonstrate that community-based management enhances restoration success. By integrating ecological and social factors, mangrove restoration can contribute to global climate goals while ensuring benefits for vulnerable coastal communities.

Article

Negative news about climate change is constant, highlighting the consequences of fossil fuel consumption, deforestation, and urbanization, which drive greenhouse gas emissions, and extreme weather events (European Commission, 2024). To combat these effects, scientists are exploring wetland restoration as a nature-based solution, with a growing emphasis on climate justice to ensure equitable benefits for vulnerable communities (U.S. Environmental Protection Agency, 2018a). Wetlands can store 20% of atmospheric carbon, exceeding marine and forest ecosystems (Ida, 2023). Among them, mangrove forests are particularly effective, sequestering 12 billion metric tons of carbon globally while providing coastal protection and biodiversity support (Correa, 2023). These salt-tolerant coastal wetlands thrive in tropical and subtropical regions and play a crucial role in climate change mitigation through their effective carbon storage mechanisms (U.S. Environmental Protection Agency, 2018b).

Compared to peatlands and freshwater marshes, mangroves can store carbon both above ground in their biomass and below ground in their soils, making them highly effective carbon sinks (Bai et al., 2021). To clarify, biomass refers to the organic matter derived from plants and animal remains that serve as an energy source. It can be used by burning it directly or processing it into fuels like biofuels (U.S. Energy Information Administration, 2023). While peatlands store twice as much carbon, and freshwater marshes contribute to inland carbon sequestration, mangroves thrive in coastal environments, offering additional benefits like storm protection and critical habitats for diverse species. Beyond their ecological role, mangroves provide social and economic benefits, making them essential for climate justice efforts (Kopansky, 2019; The Pew Charitable Trusts, 2021). Therefore, conserving diverse wetlands are essential for maximizing these climate benefits.

China is the focus for this paper because it is one of the world's largest greenhouse gas emitters, where industrial activity and energy consumption significantly contribute to climate change (Sugar et al., 2012). Despite this, China has made notable efforts to mitigate climate change through mangrove restoration (Thura et al., 2022). Between 1973 to 2000, China’s mangrove forests declined by 60%, making it one of the most depleted globally due to overfishing and aquaculture (Ouyang et al., 2024). In response, the Chinese government has implemented various restoration projects as a nature-based solution (Thura et al., 2022). However, ensuring that restoration efforts are both effective and equitable remains a challenge. These projects must balance ecological goals with community involvement, ensuring that marginalized groups who depend on mangrove forests are included in decision-making and benefit from conservation efforts. Therefore, this paper explores how mangrove forests in China mitigate climate change and promote climate justice through carbon sequestration, restoration efforts, and equitable conservation strategies.

Background

Mangrove forests are classified as blue-carbon ecosystems, as they sequester large amounts of atmospheric carbon in their soils (Ratul et al., 2022). On Xiamen Island, these forests support high biodiversity, offering essential habitats for benthic organisms and bird species (Thura et al., 2022). Their diverse species play a crucial role in carbon storage, with each contributing differently to the ecosystem's overall biomass (Bai et al., 2021).

In southern China, mangroves are found along the coastline, with the majority located in Guangdong (41.0%), Guangxi (38.0%), and Hainan (17.8%) provinces (Liu et al., 2014). However, the significant decrease in mangrove forests from deforestation highlights the urgent need for restoration (Wang et al., 2020). This decline in mangroves not only threatens biodiversity but also impacts local communities who rely on these ecosystems for fisheries, coastal protection, and materials for construction (The Pew Charitable Trusts, 2021). The loss of mangroves decreases fish stocks, reduces natural barriers to storms, and weakens local economics by limiting resources and income opportunities (Luo et al., 2022; Thura et al., 2022). Thus, their role in carbon sequestration can help mitigate the detrimental effects from climate change (Bai et al., 202; Correa, 2023). Restoration practices, such as reforestation and afforestation, are critical to reversing the damage caused by anthropogenic activities. By implementing these practices, the Chinese government has shown that mangrove forests can once again thrive, ensuring biodiversity and climate resilience (Song et al., 2023; Thura et al., 2022).

Socioeconomic and Environmental Justice in Mangrove Restoration

Restoring mangroves is not just an environmental solution, but also a climate justice issue. Coastal communities like fishers and Indigenous groups are disproportionately affected by mangrove deforestation, facing a loss of livelihood, increased flooding risks and destruction (Dominicis et al., 2023; The Pew Charitable Trusts, 2021). While China has initiated large-scale restoration projects, there is limited evidence of significant community engagement in decision-making. In particular, the Zhanjiang Mangrove National Reserve (ZMNNR) is one of the few reserves that have community involvement, while many other projects follow top-down governmental approaches (Dai et al., 2024; Huang, 2022). Workers from the reserve emphasize that collaborating with local communities is essential for sustainability in China's largest mangrove reserve, which is home to 2.44 million people and 39 villages (Huang, 2022). To ensure climate justice, mangrove restoration must incorporate local knowledge, provide alternative livelihoods, such as sustainable fisheries and ecotourism, and prevent the displacement of vulnerable communities (Dai et al., 2024; Luo, 2022).

The ZMNNR has implemented a Community-Based Co-Management (CBCM) model to involve local communities, including a village committee and a township government in mangrove restoration and management (Huang, 2022; Luo, 2022). They agreed to co-manage aquaculture ponds, while ensuring mangrove growth. Residents actively participated in planting mangroves, maintenance and establishing mangrove education centers to educate people on mangrove protection laws. Collaboration with the local community has improved the overall protection and management of the mangrove ecosystem by improving fish farming, incorporating ecotourism and promoting sustainable aquaculture (Luo, 2022). Overall, involving local communities in ZMNNR has been a key factor in successfully restoring and protecting mangroves, demonstrating the effectiveness of community engagement in achieving ecological and socio-ecological goals.

Biodiversity of Mangrove Forests

Mangrove forests emerge as powerful resources in the fight against climate change by increasing biomass and carbon storage (Correa, 2023). Bai et al. (2021) found that on Hainan Island, the rich biodiversity of mangrove forests greatly enhances biomass production and carbon storage in both soil and above-ground biomass. Taller mangroves contribute to biomass accumulation over time, enhancing carbon sequestration. Their research shows that biomass increases exponentially with stem diameter and decreases with tree density, indicating that larger, less dense forests play a more effective role in carbon sequestration efforts. High nitrogen soil content, annual precipitation, and biodiversity interact to create optimal conditions for mangrove productivity, increasing biomass growth and carbon storage (Bai et al., 2021). This underscores how species diversity complements restoration strategies, which will be explored further in the next section.

Biodiversity enhances productivity through mechanisms like niche complementarity, where different species efficiently utilize resources such as light, water, and nitrogen, resulting in higher biomass production. Forrester and Bauhus (2016) and Turnbull et al. (2013, as cited in Bai et al., 2021) explain that dominant species contribute to overall community biomass through a process known as the selection effect. In Wenchang, mangrove forests with rich biodiversity stored the most carbon, averaging 537 Mg C/ha—significantly higher than the global average for mangroves, which is 386 Mg C/ha (Bai et al., 2021). This underlines how biodiversity directly affects their carbon sequestration capacity by allowing diverse mangrove species to contribute to biomass production at varying rates (Bai et al., 2021; Ratul et al., 2022). Prioritizing diverse mangrove species in restoration efforts not only maximizes carbon storage but also provides a nature-based solution for global climate change mitigation (Thura et al., 2022).

Difference in Mangrove Species

Various plantation methods are used to restore mangrove forests, with their effectiveness varying based on environmental conditions and species. In Xiamen, Ratul et al. (2022) demonstrated that a monospecific plantation of *Kandelia obovata* achieved 61% higher carbon sequestration over a 10-year period compared to mixed plantations of *K. obovata* and *Sterculia apetala*. This higher rate is attributed to *K. obovata's* species-specific traits, such as rapid growth and high branch biomass, which facilitate fast carbon accumulation in younger plantations (Ratul et al., 2022). However, mixed-species plantations showed greater long-term carbon storage, driven by complementarity effects that improve resource use efficiency and ecosystem resilience. For example, Li et al. (2024) found that carbon sequestration in mixed plantations showed an effect size of 33.2%, which is significantly higher than the 9.4% in monospecific plantations, with benefits becoming noticeable after 7 to 20 years after restoration.

Global trends further support the long-term effectiveness of mixed-species plantations in storing carbon, driven by biodiversity-based mechanisms and the stabilization of complementarity effects (Bai et al., 2021). The short-term benefits in monospecific systems, like those seen with *K. obovata*, may reflect the influence of plantation age and environmental factors such as sediment chemistry, and hydrology, requiring further research (Li et al., 2024). This comparison in plantation methods highlights the importance of adapting restoration approaches to site-specific conditions and long-term goals for effective carbon sequestration.

Restoration Methods

Mangrove afforestation and reforestation serve as restoration methods to improve carbon retention and atmospheric carbon reduction (Song et al., 2023; Thura et al., 2022). Afforestation involves restoring mangroves to previously uninhabited areas, whereas reforestation restores mangroves in recent deforestation areas (Song et al., 2023). Over 15 years, restoration efforts on Xiamen Island have resulted in an exponential increase in soil organic carbon storage, with an average of 59.44 Mg CO_2 through afforestation (Thura et al., 2022). In comparison, Song et al. (2023) found that mangrove reforestation outperformed afforestation by accumulating even higher rates of carbon by 60%. Within 5 years, there was double the amount of carbon sediments in the reforestation field sites than in afforestation sites, with a carbon density of 220.7 Mg/C ha. After 40 years, the carbon density in sediments had increased even more in the reforestation sites. These impressive results demonstrate the effectiveness of this solution in climate change mitigation efforts.

Converting human-altered land back to mangrove wetlands enhances carbon sequestration in the soil. For example, Hou et al. (2024) found that restoring aquaculture ponds to mangrove habitats significantly increased carbon sequestration in soil aggregates. The restored mangroves contained larger soil aggregates with the highest carbon concentration compared to aquaculture ponds. Additionally, fungal network symbiosis was more extensive in these sites than in manually restored sites. These findings demonstrate the ecological benefits of mangrove restoration for climate change mitigation (Hou et al., 2024). However, Ouyang et al. (2024) found that converting tidal flats to mangroves is avoided, as these habitats are crucial for shorebirds, which spend over 70% of their total foraging time there, and for migratory birds that rely on them as habitats. Therefore, it is recommended that China prioritize mangrove restoration in areas like former aquaculture sites, where mangroves were previously removed.

Importance of Mangrove Forests

Mangrove forests are our heroes in climate change by protecting us from severe weather events such as tsunamis and storms by using their seawalls. These forests have successfully protected the coastline of the Pearl River Delta in China from strong typhoons (Hato, 2017, as cited in Dominicis et al., 2023). Without mangroves, 15 million people would face severe flooding annually, as these ecosystems help reduce the impact of intense waves. The mangroves' seawall protects coastal infrastructure and 120 million people who are projected to live near the Pearl River Delta by maintaining the shoreline and absorbing up to 1.5 million gallons of excess flood water (Dominicis et al., 2023; The Pew Charitable Trusts, 2021). As a result, their protection of coastlines leads to cost savings for municipalities and infrastructure maintenance. Additionally, mangrove forests support the biodiversity of terrestrial and marine species by providing a diverse coastal habitat, food, and nurseries, contributing to their productivity (The Pew Charitable Trusts, 2021).

Continuing to invest in these restoration projects will increase these protective and biodiversity benefits while mitigating climate change.

Global Climate Justice and China's Role

China’s mangrove restoration efforts contribute to global climate justice, but not every community benefits equally (Paulson Institute, 2020). Compared to other countries, Un Environment Programme (2023) reported that Indonesia has successfully restored 120 hectares of mangroves and sustainability managed 300 hectares of aquaculture ponds. These efforts have benefited 70,000 people by enhancing their resilience to climate change. Additionally, the elimination of artificial fertilizers has improved shrimp survival rates, allowing local fishers to harvest more shrimp and increase their income to support their families (UN Environment Programme, 2023). While restoration aligns with China’s climate commitments, wealthier urban populations may see greater benefits than rural coastal communities. This is due to wealthier communities having more access to ecotourism and sustainable aquaculture, while rural coastal communities struggle with poor management and limited public engagement, restricting their benefits from these initiatives (Paulson Institute, 2020). Incorporating CBCM into mangrove protection efforts can enhance local involvement, ensuring they benefit from both ecological preservation and economic opportunities (Luo, 2022).

As China is one of the world’s major greenhouse gas emitters, they must balance their industrial growth with restoration initiatives that prioritize climate justice with environmental goals (Sugar et al., 2012). Ultimately, mangrove restoration is not just a national issue, but part of a greater global movement toward environmental sustainability and equity (Huang, 2022). Thus, addressing both ecological and social aspects in restoration will be needed to ensure long-term success to mitigate climate change impacts.

Conclusion

Mangrove forests play a vital role in mitigating climate change by combining biodiversity-driven carbon storage mechanisms with effective restoration practices. They support aquatic life, stabilize productive ecosystems, and store some of the highest carbon concentrations on Earth. Additionally, they protect our coastlines against severe weather events, which enhances coastal resilience.

Reforestation and afforestation efforts further increase carbon sequestration, providing long-term benefits for over 40 years. By examining both carbon storage benefits and community impacts of mangrove restoration, it is evident that mangroves can be used for climate mitigation and climate justice, making communities more resilient against environmental threats.

The success of mangrove restoration projects emphasizes the critical need for continued stewardship and the implementation of natural-based solutions. By restoring and protecting mangroves, we can enhance coastal resilience, mitigate climate change, and safeguard biodiversity. Therefore, prioritizing long-term restoration initiatives, having community involvement and integrating scientific research into restoration strategies are required steps toward ensuring a sustainable and climate-resilient future.

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