INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 22, No. 6, p. 30-36, 2023
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Spatial variations of current forest structure and composition of mangrove forest in Biliran Island, Philippines

Randy A. Villarin[1], Ruffy M. Rodrigo[*2]

[1.] *School of Agribusiness and Forest Resource Management, Biliran Province State University, Biliran, Philippines*

[2] *Department of Forest Science, Biliran Province State University, Biliran, Philippines*

Article published on June 07, 2023

Key words: Spatial variations, Mangrove forest, Forest structure, Species composition, Philippines

Abstract

Mangrove forests are unique ecosystems that provide numerous ecological services, including carbon sequestration, biodiversity conservation, and coastal protection. However, more information is needed about the structure and composition of the Biliran Island mangrove forest in the Philippines. Basal area or diameter at breast height is a commonly used parameter for biomass estimation; we aimed to investigate the spatial variability of forest structure, including diameter at breast height and basal area and species composition. We found significant variations in forest structure and composition among different localities, likely due to natural and human-made disturbances. These findings provide a valuable baseline for understanding forest dynamics and informing future forest policies toward protecting and conserving essential mangrove ecosystems in the country. Furthermore, our study highlights the importance of understanding the structure and composition of mangrove forests for effective conservation and management. These results can help inform future research on carbon storage and sequestration in mangrove forests as blue carbon, as well as conservation and management strategies for these vital ecosystems.

***Corresponding Author:** Ruffy Rodrigo ✉ rodrigoruffy@gmail.com

Introduction

Forests are critical in the global carbon cycle by serving as important carbon storage sites (Pan *et al.*, 2013). Mangrove forests are highly productive ecosystems that provide sustenance and livelihood opportunities for local communities, regulate coastal erosion, promote tourism and spiritual practices, and provide habitats for diverse species (Primavera, 2000; Spanding *et al.*, 2019). Carbon levels stored in forest biomass vary based on location, species composition, and disturbance history (Chapin *et al.*, 2006), making it crucial to understand the factors that affect forest biomass variation to assess its future capacity as a carbon sink (Pan *et al.*, 2013). Mangroves contribute to coastal ecosystems' richness, diversity, and productivity and can thrive in challenging environmental conditions (Abino *et al.*, 2014). Additionally, they offer essential ecological services, including protection against coastal erosion (Naylor *et al.*, 2002), wave and tsunami dissipation, and protection from cyclonic storms (Alongi, 2002).

Similarly, the capacity of mangrove forests to capture and store carbon dioxide (CO^2) has recently generated considerable global interest, with the term "blue carbon sinks" being coined to describe their importance (see Rosen and Olsson, 2013). In the Philippines, researchers have conducted studies on carbon stock assessment and sequestration potential (see Salmo *et al.*, 2019), payment plans, and policy proposals to facilitate their preservation [e.g., 9], as well as local stakeholder perceptions (see Quevedo *et al.*, 2021). However, due to their proximity to the coast, mangrove forests risk being impacted by development-related activities. Reports indicate that significant portions of mangroves in the region have been cleared for aquaculture ponds (Rosen and Olsson, 2013). Unsustainable human practices and climate change-induced sea-level rise pose a significant threat to mangrove ecosystems, resulting in further loss of forest biomass and contributing to the already alarming concentration of CO^2 in the atmosphere. To accurately estimate forest carbon, it is necessary to consider aboveground biomass, which can be determined by examining forest structure and species composition. These indicators provide valuable insights into the amount and distribution of carbon stored within the forest ecosystem. Forest structure, which is often assessed using metrics such as diameter at breast height and basal area, is a commonly used parameter for biomass estimation (Wirth *et al.*, 2004), while species composition can help identify the types of trees and other vegetation present in the forest. As indicated by diameter, forest structure is typically the strongest indicator of productivity, while the basal area is a reliable proxy for biomass (Slik *et al.*, 2010).

On the other hand, species diversity could also affect aboveground biomass within a stand or community due to ecological processes such as niche complementarity, mass ratio selection, and competitive exclusion effects (Ali & Yan, 2017). Yachi and Loreau (2017) proposed that multilayered stands may increase light availability, thereby promoting niche differentiation and facilitation mechanisms among different species within a community.

The relationship between species diversity and stand structural complexity will likely drive high aboveground biomass or carbon storage over time (Ali & Yan, 2017). However, species diversity and stand structural complexity can be independent predictors of aboveground biomass, with the structure being a more robust predictor (Yuan *et al.*, 2018). Together, these indicators can be used to estimate forest carbon and to identify areas that may be particularly important for carbon sequestration and storage.

Hence, the main objective of this study is to evaluate the current forest structure, represented by diameter at breast height and basal area and species composition mangrove forest on Biliran Island, Philippines. Specifically, the current study aims to answer the following research questions: (a) Are there any variations in forest structure among the study sites? (b) Is there any similarity in species composition among the study sites? By addressing these research questions, this study seeks to enhance our understanding of the carbon sequestration potential of the mangrove forest and its variability, contributing to the development of effective conservation and management strategies.

Material and methods

Study Area

Biliran Province, located in Region VIII, is a volcanic island comprising eight municipalities (Fig. 1). Due to its susceptibility to natural calamities such as storm surges, flooding, and earthquakes, Biliran Island presents a unique opportunity to explore and establish permanent plots to monitor the productivity of mangrove forests under these natural disturbances, which are more frequent in island locations within the Philippines.

The study was conducted in five essential mangrove forests in Biliran, Biliran, Philippines (Fig. 1). These study sites were selected based on their availability and accessibility to the mangrove forest. Further, the selection of study sites in Biliran Province was based on the existing MOAs, allowing for effective collaboration with local communities in conserving and managing the mangrove forests. The frequent natural disturbances in the area also provided a unique opportunity to monitor the productivity of mangrove forests under such conditions.

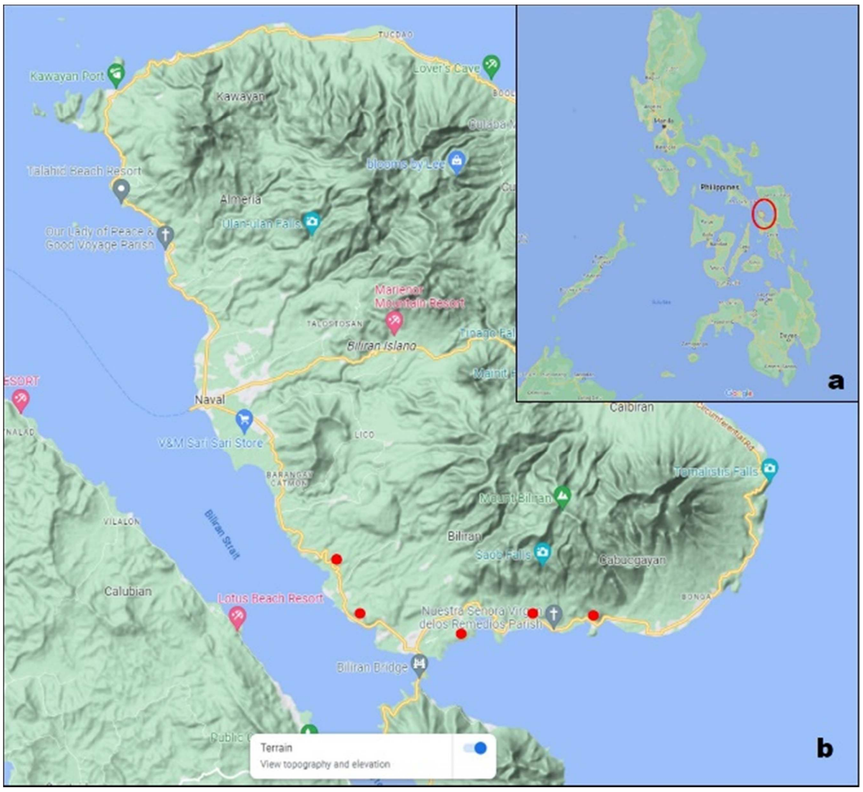

Fig. 1. (a). Displays a map of the Philippines, highlighting the location of Biliran Island (b) Illustrates a detailed map of Biliran Island, pinpointing the five significant study sites where important mangrove forests are located. The red dots in the maps indicate the spatial locations of these study sites. The maps were sourced from Google Maps (Terrain) and provided a valuable visual reference for understanding the study's geographic location.

Sampling and Data Collection

The study employed a random sampling method, where permanent sampling stations were established within the mangrove areas. A transect line ranging from 100 to 200 meters perpendicular to the shoreline was established at each station. Three transect lines were used within each station, and three plots (10 x 10m) were established systematically along the transect line with a 30-m distance interval (Ogawa *et al.*, 2022; Abino *et al.*, 2014). To identify mangrove tree species, all species were recorded in each plot. Diameter at breast height (dbh) was measured using a 10-m diameter tape, and height (m) was measured using a calibrated pole. All mangrove tree species were identified and classified taxonomically using the field guide manual to Philippines Mangroves (Primavera *et al.*, 2016; Primavera, 1995). This study employed a rigorous sampling method to ensure representative data. The identification and classification of mangrove tree species using a field guide manual by Primavera *et al.* (2016) of the study's results.

Data Analysis

This study employed several statistical analyses to compare the differences among locations. We conducted descriptive statistics for both diameter at breast height (dbh) and basal area, including minimum, maximum, standard deviation, and coefficient of variation to identify differences among locations. We used the same parameters to compare species across all study sites and plotted the basal area per hectare among species to determine differences. Additionally, we performed a simple Analysis of Variance (ANOVA) in R Core Team to verify the significant differences of mean dbh and basal area (as a proxy for productivity) among the locality. We upscaled basal area per plot into basal per hectare by multiplying the expansion factor by 100 (plot size). Finally, we plotted the linear relationship between height and dbh. We performed all analyses using (R Core Team, 2021) and utilized the libraries ggplot2, tidyverse, and dplyr (Wickham, 2016).

Results and discussion

Forest Structure

Our study demonstrates significant differences in diameter at breast height (dbh) among the five localities studied. Specifically, we observed a significant difference between Sangalang and Julita and between Sangalang and Villa Enaje (Table 1; Fig. 2). Burabod had the highest basal area per hectare (m^2 ha^{-1}) among the five localities, followed by Julita, while Busali had the lowest basal area (Fig. Supplementary 2). Moreover, our findings reveal that Julita and Villa Enaje had the highest dbh measurements, whereas Burabod had the lowest.

This could be because Sangalang is pruned to a human-induced disturbance where accessibility to local communities nearby. Hence, Sangalang would have lower dbh due to disturbance than other localities where disturbance is not rampant.

Table 1. Summary of forest structure comparing the five study locations.

Location	nbtrees	nbspec	meandbh	mindbh	maxdbh	sd_dbh	cv_dbh	meanba	minba	maxba	sd_ba	cv_ba
Burabod	10	4	9.1	3.76	17.19	3.39	0.37	0.01	0	0.02	0.01	0.78
Busali	12	4	9.34	3.02	20.05	5.29	0.57	0.01	0	0.03	0.01	1.09
Julita	16	5	9.31	2.13	37.56	6.33	0.68	0.01	0	0.11	0.02	1.78
Sangalang	25	9	6.88	2.39	28.43	4.51	0.66	0.01	0	0.06	0.01	1.82
Villa Enaje	18	7	9.53	2.07	37.56	6.25	0.66	0.01	0	0.11	0.02	1.66

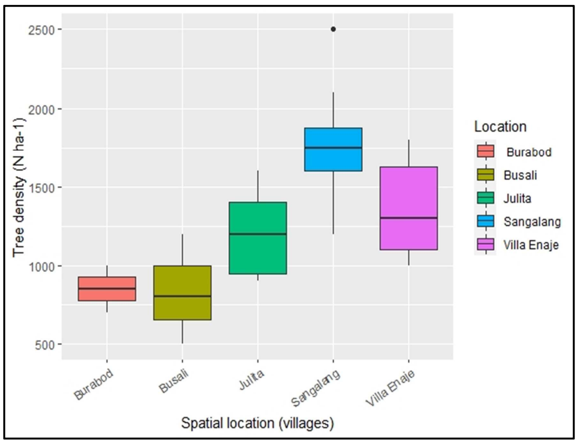

Fig. S1. Tree density (stems per hectare) comparing the five study sites.

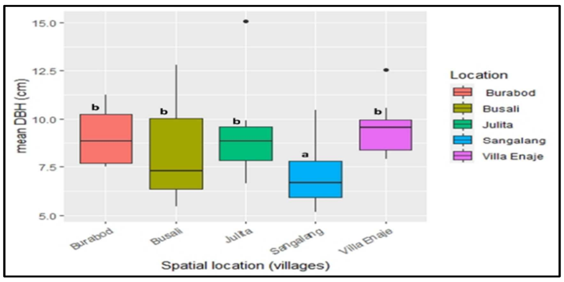

Fig. 2. The spatial variations of DBH among the five study localities were analyzed, and the results showed significant differences between the localities (p-value < 0.05). Different letters were used to indicate statistically significant differences among the localities as determined by simple ANOVA.

Species Composition

Our investigation of species composition in the study locations revealed that *Avicennia alba* (Avicenniaceae) was the most abundant species out of twelve species recorded (see Table 2). Among the recorded species, *Avicennia marina*, *Excoecaria agallocha*, and *Sonneratia alba* had the largest trees based *on diameter measurements, whereas* Scyphiphora hydrophyllaceae had the smallest. Furthermore, our study found that *Rhizophora apiculata* had the maximum dbh measurements among all species studied (Table 2). Regarding tree density, Sangalang had the highest value and number of species, while Burabod had the lowest (Fig. S1, Fig. S3) and number of species (Fig. S3). Our investigations show that *Avicennia marina*, *Avicennia alba*, *Ceriops decandra*, and *Rhizophora apiculata* are among the most common mangrove species in the study sites. This could be explained by their ability to tolerate a wide range of salinity levels, making them well-adapted to the fluctuating saltwater conditions in these ecosystems (Odum and Johannes, 1975). These species also have specialized root systems that allow them to absorb oxygen through their roots, enabling them to survive in waterlogged soils (Srikanth *et al.*, 2016). Our results are comparable to the study conducted in mangrove areas in the Philippines.

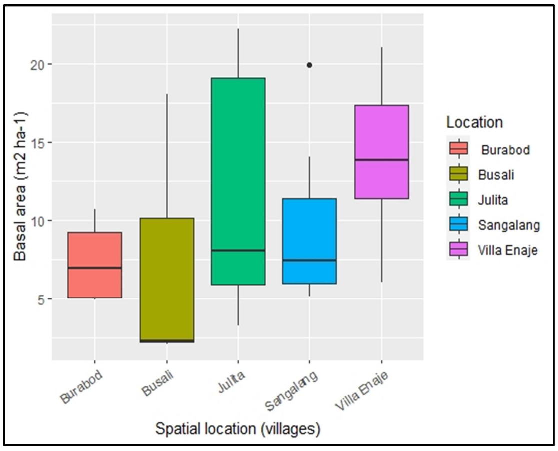

Fig. S2. Basal area per hectare comparing the five study sites.

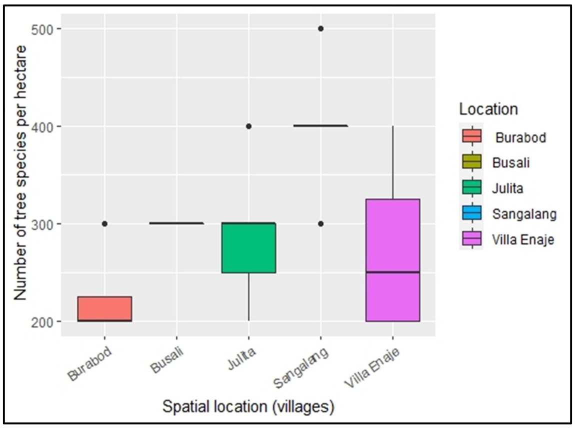

Fig. S3. Number of tree species per hectare comparing the five study sites.

Table 2. Summary of species composition measured in all study localities. (-) Represented by only one species. NA- refers to species with only one dbh.

Species	Family	nbtrees	meandbh	mindbh	maxdbh	sd_dbh	cv_dbh	meanba	minba	maxba	sd_ba	cv_ba
Avicennia alba	Avicenniaceae	23	7.26	2.48	28.43	5.34	0.74	0.01	0	0.06	0.01	1.87
Avicennia marina	Avicenniaceae	14	13.19	3.95	33.84	6.52	0.49	0.02	0	0.09	0.02	1.09
Avicennia rumphiana	Avicenniaceae	9	8.25	3.12	28.27	7.34	0.89	0.01	0	0.06	0.02	2.07
Bruguiera cylindrica	Rhizophoraceae	2	8.85	5.95	10.35	2.51	0.28	0.01	0	0.01	0	0.49
Ceriops decandra	Rhizophoraceae	19	6.21	2.48	11.55	2.18	0.35	0	0	0.01	0	0.69
Excoecaria agallocha	Euphorbiaceae	4	14.82	10.03	23.71	6.2	0.42	0.02	0.01	0.04	0.02	0.86
Rhizophora apiculata	Rhizophoraceae	21	7.15	2.07	37.56	3.62	0.51	0.01	0	0.11	0.01	1.81
Rhizophora mucronata	Rhizophoraceae	2	9.26	5.41	13.11	5.45	0.59	0.01	0	0.01	0.01	1
Rhizophora stylosa	Rhizophoraceae	9	7.5	6.05	9.71	1.4	0.19	0	0	0.01	0	0.38
Scyphiphora Hydrophyllaceae	Rubiaceae	3	5.85	3.85	9.01	2.77	0.47	0	0	0.01	0	0.93
Sonneratia alba	Sonneratiaceae	14	12.58	3.12	37.56	7.99	0.64	0.02	0	0.11	0.02	1.28
Xylocarpus granatum	Meliaceae	1	4.52	4.52	4.52	NA	NA	0	0	0	NA	NA

Height-Diameter Relationship

Mangrove forests provide essential ecological services, such as protecting coastal areas from erosion and supporting diverse marine and terrestrial fauna (Jusoff and Taha, 2008; Walters *et al.*, 2008). Understanding the relationships between the height and diameter of mangrove trees is crucial for estimating forest biomass and productivity and informing management and conservation strategies. Here, we present a simple regression analysis of mangrove trees' height and diameter relationship across different species, sites, and environmental conditions. We collected data on tree height and diameter for a total of 121 individuals belonging to five common mangrove species (*Avicennia alba*, *Avicennia marina, Rhizophora apiculata*, *Sonneratia alba*, and *Ceriops decandra*) in five sites along the coast of Biliran Island (Table 2). We used linear models to assess the height-diameter relationship's shape and strength and explore potential differences between sites.

Our results showed a clear positive relationship between tree height and diameter, with a tendency toward a power-law relationship (Fig. 3), except for the Busali locality. The relationship was generally more robust in Sangalang, although it showed the lowest mean dbh but higher tree density than the other localities. We found some variations in the shape and slope of the relationship across sites; this may be reflecting differences in soil characteristics, salinity, and disturbance impact. Further, our findings provide valuable insights into the height-diameter relationship of mangrove trees and highlight the importance of considering species-specific and site-specific factors when estimating forest biomass and productivity. However, further research is needed to investigate the underlying mechanisms and ecological implications of the observed patterns and to extend the analysis to other mangrove species and other sites on the island.

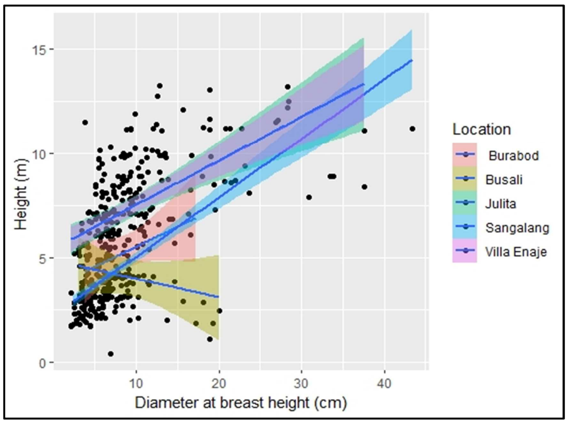

Fig. 3. The height-diameter relationship of all 121 individual mangrove species among the five study localities.

Conclusion and recommendations

Further, our study underscores the importance of understanding the structure and composition of mangrove forests for effective conservation and management strategies. Given the potential impacts of climate anomalies, such as typhoons, on mangrove ecosystems, we strongly recommend further research to explore the influence of climate and other natural disturbances on the structure and composition of these forests. In light of our findings, we urge policymakers and other stakeholders to take concrete steps towards protecting and conserving mangrove ecosystems, such as establishing more protected areas and implementing stricter policies to conserve and protect the vital mangrove forest in Biliran Island, Philippines. We can only ensure the long-term sustainability of these critical ecosystems and the services they provide to humans and wildlife through collective action.

Management Implications

Mangrove forests provide important ecological services, such as coastal protection, blue carbon sink characteristics, and biodiversity conservation. Biliran Island is a unique place in the Philippines where several fishermen depend not only on food for natural disturbances. However, these forests are increasingly threatened by both natural and man-made disturbances, which could lead to reduced productivity, loss of carbon sinks, decreased biodiversity protection, and weakened defense mechanisms against typhoons and flash floods (Upadhyay, 2020).

This research emphasizes the potential impact of disturbances on the structure and composition of mangrove forests, highlighting the need for sustainable forest management and conservation. Priority should be given to implementing reforestation activities and enhancing the capacity of local communities in mangrove forest management to ensure the long-term sustainability of these vital ecosystems and the services they provide.

References

Abino AC, Castillo JAA, Lee YJ. 2014. Assessment of species diversity, biomass, and carbon sequestration potential of a natural mangrove stand in Samar, the Philippines. Forest Science and Technology **10,** 2-8.

Ali A, Yan ER. 2017. Functional identity of overstorey tree height and understorey conservative traits drive aboveground biomass in a subtropical forest. Ecological Indicators **83,**158-168.

Alongi DM. 2002. Present state and future of the world's mangrove forests. Environmental Conservation **29,** 331-349.

Jusoff K, Taha D. 2008. Managing sustainable mangrove forests in Peninsular Malaysia. Journal of Sustainable Development **1,** 88-96.

Naylor LA, Viles HA, Carter NEA. 2002. Biogeomorphology revisited: looking towards the future. Geomorphology **47,** 3-14.

Odum WE, Johannes RE. 1975. The response of mangroves to man-induced environmental stress. Oceanography Series **12,** 52-62.

Ogawa Y, Sadaba RB, Kanzaki M. 2022. Stand structure, biomass, and net primary productivity of planted and natural mangrove forests in Batan Bay Estuary, Philippines. Tropics **31,** 1-9.

Pan Y, Birdsey RA, Phillips OL, Jackson RB. 2013. The structure, distribution, and biomass of the world's forests. Annual Review of Ecology, Evolution, and Systematics **44,** 593-622.

Primavera JH, Dela Cruz M, Montilijao C, Consunji H, Dela Paz M, Rollon RN, Maranan K, Samson MS, Blanco A. 2016. Preliminary assessment of post-Haiyan mangrove damage and short-term recovery in Eastern Samar, central Philippines. Marine Pollution Bulletin **109,** 744-750.

Primavera JH. 1995. Mangroves and brackishwater pond culture in the Philippines. Hydrobiologia **295,** 303-309.

Primavera JH. 2000. Development and conservation of Philippine mangroves: institutional issues. Ecological Economics **35,** 91-106.

Quevedo JMD, Uchiyama Y, Kohsaka R. 2021. Local perceptions of blue carbon ecosystem infrastructures in Panay Island, Philippines. Coastal Engineering Journal **63,** 227-247.

Salmo III SG, Malapit V, GarciamcA, Pagkalinawan HM. 2019. Establishing rates of carbon sequestration in mangroves from an earthquake uplift event. Biology Letters **15,** 20180799.

Slik JWF, Aiba SI, Brearley FQ, Cannon CH, Forshed O, Kitayama K, Nagamasu H, Nilus R, Payne J, Paoli G, Poulsen AD. 2010. Environmental correlates of tree biomass, basal area, wood specific gravity, and stem density gradients in Borneo's tropical forests. Global Ecology and Biogeography **19,** 50-60.

Srikanth S, Lum SKY, Chen Z. 2016. Mangrove root: adaptations and ecological importance. Trees **30,** 451-465.

Upadhyay RK. 2020. Markers for global climate change and its impact on social, biological and ecological systems: a review. American Journal of Climate Change **9,** 159.

Walters BB, Rönnbäck P, Kovacs JM, Crona B, Hussain SA, Badola R, Primavera JH, Barbier E, Dahdouh-Guebas F. 2008. Ethnobiology, socio-economics, and management of mangrove forests: A review. Aquatic Botany **89,** 220-236.

Wirth C, Schumacher J, Schulze ED. 2004. Generic biomass functions for Norway spruce in Central Europe-a meta-analysis approach toward prediction and uncertainty estimation. Tree Physiology **24,** 121-139.

Yachi S, Loreau M. 2007. Does complementary resource use enhance ecosystem functioning. A model of light competition in plant communities. Ecology Letters **10,** 54-62.

Yuan Z, Wang S, Ali A, Gazol A, Ruiz-Benito P, Wang X, Lin F, Ye J, Haz Z, Loreau M. 2018. Aboveground carbon storage is driven by functional trait composition and stand structural attributes rather than biodiversity in temperate mixed forests recovering from disturbances. Annals of Forest Science **75,** 1-13.