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Tropical Tree Associations in the Anthropocene

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Abstract

In the Anthropocene, tropical tree associations are undergoing unprecedented changes driven by deforestation, climate change, and other human activities. To move from description to a deeper understanding, it is essential to focus on the functional roles of tree species and their contributions to ecosystem services. This knowledge is crucial for developing strategies that preserve tropical forest ecosystems and mitigate the impacts of the Anthropocene on biodiversity and human well-being.

Key Words: *Anthropocene, Africa, Sudan, ecosystem services*

Introduction

Tropical forests are among the most diverse ecosystems on the planet, characterized by complex tree associations that define their structure and ecological function. In the Anthropocene, the current epoch dominated by human activity, these tree associations are undergoing significant changes due to deforestation, climate change, invasive species, and habitat fragmentation. Moving beyond simple descriptions of these associations to a deeper understanding of how human influences are reshaping them is critical for the preservation of biodiversity and ecosystem services.

Describing Tree Associations in Tropical Forests:

Tree associations in tropical forests refer to the specific relationships between tree species, which determine forest structure and influence ecosystem processes. These associations vary across vertical layers (stratification) and horizontal gradients (heterogeneity) based on light availability, soil nutrients, moisture levels, and species interactions.

Vertical Stratification of Tree Associations

Tropical forests exhibit a multi-layered vertical structure, with different tree species occupying distinct ecological niches at varying heights:

Emergent Layer: Tall trees, such as *Ceiba pentandra* (Kapok) and *Shorea robusta*, rise above the canopy and thrive in full sunlight. These trees are typically scattered, with deep roots that provide stability in strong winds.

Ceiba pentandra L.

Shorea robusta

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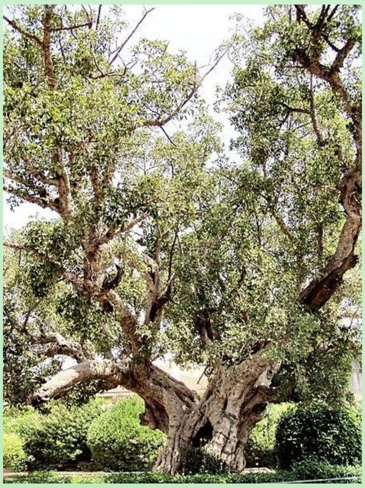
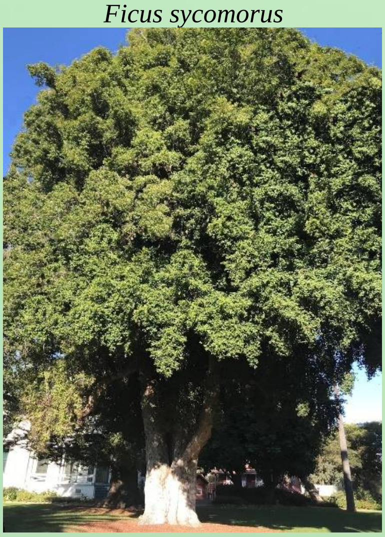
Canopy Layer: The dense, continuous canopy, formed by species like *Dipterocarpus* spp. and *Ficus* spp., regulates light penetration and moisture availability for the lower layers. This is the most biologically active layer, supporting a wide variety of animals and plant interactions.



Ficus sycomorus

Dipterocarpus alatus



Eugenia spp.

Inga edulis

Understory and Shrub Layers: Below the canopy, shade-tolerant species like *Eugenia* spp. and *Inga* spp. thrive in low-light conditions. These species play crucial roles in seedling regeneration and contribute to forest resilience after disturbances.

Figure 1. Vertical Stratification of Tropical Forests:

Layer	Dominant Species	Height (m)
Emergent	*Ceiba pentandra, Shorea robusta*	50-70
Canopy	*Dipterocarpus, Ficus* spp.	30-50
Understory & Shrubs	*Inga* spp., *Eugenia* spp.	5-20

Horizontal Heterogeneity and Niche Partitioning

Tree species distribution varies across tropical forests due to differences in soil quality, moisture, and topography. This horizontal heterogeneity allows species to coexist by occupying unique ecological niches.

Pioneer Species: Light-demanding pioneer species, such as *Cecropia* spp., rapidly colonize forest gaps created by natural disturbances (e.g., tree falls) or human activities (e.g., logging). These species play a key role in early forest succession.

Shade-Tolerant Species: Species that grow more slowly in shaded conditions, such as *Swietenia macrophylla* (mahogany), dominate mature forest interiors, where they contribute to long-term forest stability and biodiversity.

Cecropia spp.

Swietenia macrophylla

Keystone Species
Certain species, known as keystone species, have disproportionate effects on forest ecosystems. *Ficus* spp., for instance, provide a critical year-round food source for frugivorous animals, which in turn facilitate seed dispersal, maintaining the diversity and structure of tropical forests (Shanahan et al., 2001).

Table 1. Examples of Keystone Tree Species

Species	Ecological Role	Region
Ficus spp.	Year-round fruit production, supports frugivores	Global tropics
Dipteryx panamensis	Provides habitat and food for animals	Central America
Swietenia macrophylla	Canopy stabilizer, supports biodiversity	Amazon, Central America

Understanding Anthropocene Impacts on Tree Associations

In the Anthropocene, human activities are altering tree associations in tropical forests through deforestation, habitat fragmentation, climate change, and the introduction of invasive species. These changes threaten the intricate balance of species interactions and disrupt ecosystem services, such as carbon storage, water regulation, and biodiversity maintenance.

Deforestation and Habitat Fragmentation

Deforestation, driven by agricultural expansion, logging, and urban development, has led to large-scale habitat loss in tropical forests. Fragmentation isolates populations, alters microclimatic conditions, and changes the dynamics of tree associations.
Edge Effects: Forest fragmentation creates new forest edges, which are exposed to higher temperatures, light levels, and wind. These conditions favor fast-growing pioneer species like *Cecropia* spp., often at the expense of slower-growing, shade-tolerant species such as *Swietenia macrophylla* (Laurance et al., 2011).
Biodiversity Loss*:* Fragmentation reduces genetic diversity in tree populations by limiting seed dispersal and increasing inbreeding. Keystone species, which rely on large, continuous habitats, are especially vulnerable in fragmented landscapes.

Figure 2. Effects of Fragmentation on Tree Associations

Impact	Affected Species	Consequences
Edge Effects	*Swietenia macrophylla*	Decline in shaded habitats
Pioneer Species Expansion	*Cecropia* spp.	Dominance in fragmented forests
Reduced Genetic Diversity	*Dipteryx panamensis*	Loss of genetic variability

Climate Change and Tree Mortality
Climate change is affecting tropical tree associations by altering temperature and precipitation patterns, increasing the frequency of extreme weather events, and intensifying droughts. These changes lead to species range shifts, increased tree mortality, and altered forest dynamics.

Species Range Shifts: Some tree species, such as *Cedrela odorata* (Spanish cedar), are migrating to higher altitudes or latitudes in response to rising temperatures. This disrupts local tree associations and affects the entire ecosystem, from nutrient cycling to species interactions (Feeley et al., 2012).
Increased Mortality: Drought-sensitive species are experiencing higher mortality rates in regions like the Amazon, where extended dry seasons and increased temperatures are stressing even mature, well-established trees. These changes may result in a shift toward more drought-resistant species and reduced overall forest biomass (Phillips et al., 2009).

Invasive Species
Invasive species, introduced by human activities, are altering tree associations by outcompeting native species, disrupting forest dynamics, and reducing biodiversity.
Example: *Lantana camara*: This invasive plant has spread across tropical regions, particularly in Asia and Africa, where it forms dense thickets that prevent native tree regeneration and change the composition of tree associations (Sharma et al., 2005).


Lantana camara


Chromolaena odorata


Dipteryx panamensis

Table 2: Invasive Species Impacting Tropical Forests

Invasive Species	Region	Impact on Tree Associations
Lantana camara	Southeast Asia	Suppresses native tree regeneration
Chromolaena odorata	West Africa	Reduces biodiversity, alters forest structure

Moving Toward Understanding: Functional Traits and Ecosystem Services
To move beyond descriptive accounts of tree associations, it is crucial to focus on the functional traits of tree species—such as wood density, growth rates, and reproductive strategies—that influence their contributions to ecosystem services, including carbon storage, water regulation, and nutrient cycling.

Carbon Sequestration
Tropical forests are vital carbon sinks, sequestering around 1.5 billion metric tons of carbon dioxide annually. Tree species with dense wood, such as *Dipteryx panamensis*, store more carbon than fast-growing, light-demanding species like *Cecropia* spp. Understanding how different tree associations contribute to carbon storage is essential for mitigating climate change impacts (Pan et al., 2011).

Table 3: Carbon Sequestration Potential of Key Tropical Tree Species:

Species	**Wood Density (g/cm³)**	**Growth Rate**	**Carbon Storage Potential**
Dipteryx panamensis	High	Slow	High
Cecropia spp**.**	Low	Fast	Low
Swietenia macrophylla	Medium	Moderate	High

Hydrological Services
Tropical forests play a crucial role in regulating water cycles, influencing regional rainfall patterns and maintaining water availability. Large canopy trees with high transpiration rates, such as *Ficus* spp., help mitigate the impacts of drought by promoting cloud formation and precipitation. Changes in tree associations due to deforestation or climate change can disrupt these hydrological services, leading to more severe droughts and altered rainfall patterns.

Conclusion:

In the Anthropocene, tropical tree associations are undergoing unprecedented changes driven by deforestation, climate change, and other human activities. To move from description to a deeper understanding, it is essential to focus on the functional roles of tree species and their contributions to ecosystem services. This knowledge is crucial for developing strategies that preserve tropical forest ecosystems and mitigate the impacts of the Anthropocene on biodiversity and human well-being.

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