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Review Article

Assessment of Carbon Sequestration and Reflective Properties of High-Albedo C3 and C4 Plant Species: A Laboratory Approach

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Abstract

This study explores the dual potential of high-albedo C3 and C4 plant species to mitigate regional climate change through carbon sequestration and reflective properties. C3 and C4 plants differ in their photosynthetic pathways, carbon sequestration capacities, and albedo characteristics, influencing their impact on local and global climates. The research assesses selected high-albedo tropical plant and grass species, aiming to identify optimal plant characteristics for carbon capture while reflecting sunlight to reduce surface heat absorption. Laboratory methods were employed to measure chlorophyll content, a key indicator of carbon sequestration, and albedo using spectrophotometry and radiometry. The results revealed significant variability in chlorophyll content, with Mango (17.705 mg/L), Bamboo (16.550 mg/L), and Napier Grass (16.079 mg/L) exhibiting the highest levels, indicating their strong carbon sequestration potential. Reflectance measurements showed that Mango, Bamboo, and Napier Grass also had the highest albedo values (~0.795), suggesting their potential to reflect solar radiation and contribute to localized cooling. Papyrus Reeds demonstrated the lowest reflectance (0.636) and chlorophyll content, indicating limited potential in both carbon sequestration and solar reflectance. A regression analysis confirmed a significant relationship between reflectance and chlorophyll content, suggesting that high-albedo plants with efficient carbon sequestration are key for climate change mitigation. The findings highlight the importance of selecting plant species with high photosynthetic efficiency and reflectance for reforestation and agroforestry programs aimed at reducing atmospheric CO_2 and mitigating local temperature rise.

Keywords: Carbon Sequestration; High-Albedo Plants; C3 Plants; C4 Plants; Reflective Properties; Climate Change Mitigation; Chlorophyll Content

Introduction

Climate change, driven largely by the increasing concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2), is causing profound shifts in global weather patterns, rising sea levels, and extreme weather events. These impacts pose significant risks to ecosystems, agriculture, and human societies [6]. As part of efforts to mitigate climate change, various strategies are being explored to reduce atmospheric CO_2 and limit global warming. One promising approach involves leveraging the natural processes of carbon sequestration and albedo modification through the use of plants [8,10].

Plants, particularly in terrestrial ecosystems, play a crucial role in mitigating climate change by capturing CO_2 through photosynthesis, storing it in plant biomass and soils, and thus reducing the amount of CO_2 in the atmosphere [5]. C3 and C4 plants, which are the two primary photosynthetic types, exhibit differences in their ability to fix carbon. C3 plants, including species such as Acacia, Mango, and Papyrus reeds, dominate in cooler and temperate climates, whereas C4 plants such as Napier grass, Speargrass, and Buffel grass are adapted to hot and arid environments, where they perform more efficiently due to their specialized carbon fixation pathway [12,15].

In addition to carbon sequestration, plant species influence the Earth's radiative balance through their albedo, the reflectivity of a surface. Albedo is a key factor in determining how much solar radiation is reflected back into space versus absorbed by the Earth's surface [13]. High-albedo plants, characterized by light-colored, reflective surfaces, can help mitigate the urban heat island effect and contribute to local cooling [9,17]. These plants are particularly effective in regions that experience high solar radiation, where their reflective properties reduce the need for energy-intensive cooling systems [14,17].

The interaction between carbon sequestration and albedo is particularly important in tropical and subtropical regions, which are characterized by high solar radiation and temperatures. In these regions, the combined effects of plant carbon sequestration and albedo modification could help mitigate both atmospheric CO_2 concentrations and local temperature increases. However, the question remains: which plant species offer the best balance between high carbon sequestration and high albedo to maximize climate change mitigation [2]? Understanding how different plant species contribute to both of these processes is crucial for developing effective climate adaptation and mitigation strategies.

Visible light, including red around 670 nm, blue around 450 nm, and green around 550 nm, absorbs more energy compared to NIR (near-infrared). The absorption of visible light by chlorophyll and other plant pigments leads to the conversion of light energy into chemical energy through photosynthesis. However, when visible light is not absorbed-such as in non-photosynthetic areas-it can increase surface temperatures. Red light around 670 nm has relatively high energy, and when not absorbed by chlorophyll, it contributes significantly to heating. Vegetated areas with higher chlorophyll content tend to reflect more NIR light, which can influence the surface temperature, hence affecting climate change [10]. This is why vegetation is often a cooler surface in remote sensing observations due to high NIR reflectance and lower absorption of solar energy. Chlorophyll content can indirectly affect local temperature by changing the reflectance properties of the vegetation. Healthy vegetation with high chlorophyll content reflects more NIR light, reducing the amount of energy absorbed by the surface and helping to moderate temperatures [5].

This study aimed to assess the carbon sequestration and reflective properties of high-albedo C3 and C4 plant species commonly found within Tharaka University in Tharaka Nithi County, Kenya. The research employed laboratory-based methods to measure chlorophyll content, which serves as an indicator of carbon fixation potential, and albedo, which were determined through spectrophotometric analysis. The primary goal of the study was to identify plant species that offer optimal benefits for regional climate resilience. Reflectance in the NIR region is often used to determine the albedo of a surface, which plays a role in how much solar energy is reflected versus absorbed, influencing the temperature of the surface.

Materials and Methods

This research used a laboratory-based experimental approach to assess the carbon sequestration capabilities and reflective properties (albedo) of selected C3 and C4 plant species. The primary objective was to compare the differences in carbon capture efficiency and light reflectivity between the two photosynthetic pathways.

Study site

The research was conducted at Tharaka University and Chuka University both located in Tharaka Nithi County Kenya.

Sample collection

Eleven plant species representing a mix of C3 and C4 pathways were selected based on their common occurrence, photosynthetic characteristics, and potential relevance for carbon sequestration and albedo studies. These species include:C3 Species: Acacia (*Acacia spp.*), Terminalia (*Terminalia brownii*), Tamarind (*Tamarindus indica*), Bamboo (*Bambusa spp.*), Neem Tree (*Azadirachta indica*), Mango (*Mangifera indica*), Lantana (*Lantana camara*), Banana (*Musa spp.*), and Papyrus Reeds (*Cyperus papyrus*). C4 Species: Napier Grass (*Pennisetum purpureum*) and Boma Rhodes Grass (*Chloris gayana*).

Experimental design

Healthy, mature leaves were collected from each species. The leaves were washed, air-dried, and kept under similar hydration conditions before measurement. Leaf pigments were extracted using an 80% acetone solution. Each sample was ground to a fine paste and filtered to obtain a clear solution. Absorbance readings were taken at wavelengths of 663 nm (chlorophyll a) and 645 nm (chlorophyll b) using a UV-Vis spectrophotometer to evaluate chlorophyll content and its absorption of light. Each measurement was repeated thrice to ensure accuracy. To determine the Relectance (albedo) absorbance readings were taken at 850nm NIR region and measurement taken in triplicate.

Data analysis

Chlorophyll content was used as a proxy for carbon fixation since the rate of photosynthesis, and therefore carbon sequestration, correlates with chlorophyll concentration. results in lower reflectance. The chloropyhll content was determined using equations developed by **Arnon (1949)**, to quantify chlorophyll content based on absorbance at 645 nm and 663 nm

Chlorophyll a (μg/ml) = 12.7 × A663-2.69 × A645……………………….1

Chlorophyll b (μg/ml) = 22.9 × A645-4.68 × A663……………………….2

Where

- A663 = Absorbance at 663 nm
- A645 = Absorbance at 645 nm

Total Chlorophyll (mg/L) = 20.2×A645+8.02×A663……………………3

Reflectance (R), leaf albedo was estimated using Beer-Lambert Law, developed by August Beer (1852). Relectance (R) is inversely proportional to absorbance (A).

$R = 10^{-A}$ ……………………………………………………………4

The data collected from the spectrophotometric analyses were subjected to statistical analysis using SPSS software. For each species, the chlorophyll content and albedo values were compared using Analysis of Variance (ANOVA) to determine if significant differences existed between the species. Post-hoc pairwise comparisons were performed using the Tukey HSD test to identify which plant species showed the highest carbon sequestration and albedo values.

Results and Discussions

This study investigates the carbon sequestration potential and reflective properties (albedo) of various plant species, focusing on their chlorophyll content, measured at wavelengths of 663 nm (for Chlorophyll a) and 645 nm (for Chlorophyll b), and their reflectance at 850 nm.

Common Name	Botanical Name	Photosynthetic Pathway	A663	A645	Chlorophyll_a	Chlorophyll_b	Total chlorophyll
Acacia	*Acacia spp.*	C3	0.550cd	0.440bcd	5.801bc	7.502ab	13.300cde
Bamboo	*Bambusa spp.*	C3	0.687ab	0.547ab	7.250ab	9.306ab	16.550ab
Banana	*Musa spp.*	C3	0.597bcd	0.487abcd	6.269abc	8.352ab	14.615bcd
Boma Rhodes Grass	*Chloris gayana*	C4	0.610bc	0.480abcd	6.456abc	8.137ab	14.588bcd
Lantana	*Lantana camara*	C3	0.633abc	0.530abc	6.618abc	9.173ab	15.785abc
Mango	*Mangifera indica*	C3	0.730a	0.587a	7.693a	10.018a	17.705a
Napier Grass	*Pennisetum purpureum*	C4	0.670ab	0.530abc	7.083ab	9.001ab	16.0794abc
Neem Tree	*Azadirachta indica*	C3	0.500d	0.373d	5.346cd	6.209bc	11.551e
Papyrus Reeds	*Cyperus papyrus*	C3	0.360e	0.230e	3.953d	3.582c	7.533f
Tamarind	*Tamarindus indica*	C3	0.603bcd	0.497abcd	6.326abc	8.550ab	14.871abc
Terminalia	*Terminalia brownii*	C3	0.497d	0.390cd	5.259cd	6.607bc	11.861de
		SEM	0.02	0.02	0.19	0.34	0.50
		P value	<.0001	<.0001	<.0001	<.0001	<.0001

Table 1: Estimation of Total Chlorophyll.

Results

The chlorophyll content of each species was determined using absorbance measurements at 663 nm for Chlorophyll and 645 nm for Chlorophyll b, wavelengths known to optimize photosynthesis. The calculated total chlorophyll content highlighted significant variability across species, impacting their carbon sequestration potential. Mangifera indica (Mango) had the highest total chlorophyll content at 17.705 mg/L, suggesting a superior capacity for photosynthesis and carbon sequestration. Bambusa spp. (Bamboo) and Pennisetum purpureum (Napier Grass) also exhibited high chlorophyll content, with values of 16.550 mg/L and 16.079 mg/L, respectively. These results imply effective atmospheric CO_2 capture by these species. Moderate chlorophyll levels were recorded for Musa spp. (Banana), Lantana camara (Lantana), and Tamarindus indica (Tamarind), ranging from 14.615 to 15.785 mg/L, indicating moderate carbon sequestration potential.The species with the lowest chlorophyll contents were Cyperus papyrus (Papyrus Reeds) at 7.533 mg/L and Azadirachta indica (Neem Tree) at 11.551 mg/L, indicating lower efficiency in carbon fixation.

Reflectance (R), which serves as an indicator of albedo, was measured using absorbance at 850 nm table 3.2. Albedo is a critical factor in climate mitigation, as higher albedo values indicate a greater capacity to reflect sunlight, contributing to localized cooling effects. The study revealed significant differences in reflectance among the species.

Mangifera indica (Mango), Bambusa spp. (Bamboo), and Pennisetum purpureum (Napier Grass) exhibited the highest albedo values, approximately 0.795. This suggests that these species can effectively reflect solar radiation, potentially aiding in surface temperature reduction while also offering high carbon sequestration capacity. Lantana camara (Lantana) and Tamarindus indica (Tamarind) showed intermediate albedo values, ranging between 0.710 and 0.735. These species contribute moderately to both carbon sequestration and solar reflectance. Cyperus papyrus (Papyrus Reeds) had the lowest albedo at 0.636. Combined with its low.

Chlorophyll content, this indicates a limited role in both carbon sequestration and solar reflectance, reducing its effectiveness in mitigating climate change.

The regression analysis presented in Table 3.3 assesses the relationship between the reflectance (R) of various plant species and

Common Name	Botanical Name	Photosynthetic Pathway	Total chlorophyll	Absorbance_A850	Reflectance_R
Acacia	*Acacia spp.*	C3	13.300cde	0.157ab	0.698ab
Bamboo	*Bambusa spp.*	C3	16.550ab	0.090cd	0.795a
Banana	*Musa spp.*	C3	14.615bcd	0.157ab	0.713ab
Boma Rhodes Grass	*Chloris gayana*	C4	14.588bcd	0.140b	0.713ab
Lantana	*Lantana camara*	C3	15.785abc	0.133bc	0.735ab
Mango	*Mangifera indica*	C3	17.705a	0.080d	0.794a
Napier Grass	*Pennisetum purpureum*	C4	16.0794abc	0.090cd	0.795a
Neem Tree	*Azadirachta indica*	C3	11.551e	0.160ab	0.687b
Papyrus Reeds	*Cyperus papyrus*	C3	7.533f	0.190a	0.636b
Tamarind	*Tamarindus indica*	C3	14.871abc	0.153ab	0.710ab
Terminalia	*Terminalia brownii*	C3	11.861de	0.150ab	0.696ab
		SEM	0.5	0.006	0.01
		P value	<.0001	<.0001	<.0001

Table 2: Determination of Reflectance (Albedo).

Coefficients	Estimate	Std Error	t-value	p-value
Intercept	-14.413	4.201	-3.431	0.000172**
Reflectance (R)	39.264	5.779	6.794	1.31e-07***
Multiple R-squared	Adjusted R-squared	F-statistic	P-value	
0.5982	0.5853	46.16 (df = 1, 31)	1.31×10^{-7}	

Table 3: Regress in Beta Estimate.

their corresponding carbon sequestration capacity, using chlorophyll content as a proxy.

The highly significant reflectance coefficient suggests that plants with higher reflectance values are likely to have greater chlorophyll content, and hence a higher carbon sequestration capacity. This finding aligns with the study's goal of identifying plant species with both effective carbon fixation and reflective properties for climate change mitigation.

While the model provides meaningful insights, the R-squared value under 60% indicates that other factors influencing chlorophyll content, such as species type, environmental conditions, soil quality, and water availability should be considered in future studies to improve the model's accuracy.

This relationship can be leveraged to select plant species for bio-geoengineering initiatives. By focusing on high-albedo species with effective carbon sequestration, it is possible to mitigate climate change impacts in Tharaka Constituency. The regression model can guide the selection of plant types for large-scale planting projects aimed at maximizing carbon capture and reflective cooling.

Discussion

The differences in chlorophyll content among the studied species reflect their varying abilities to sequester carbon, a key component in addressing climate change. The choice of measurement wavelengths-663 nm for Chlorophyll a and 645 nm for Chlorophyll b-was pivotal because these wavelengths correspond to peak absorption ranges, which maximize light capture for photosynthesis. This ensured that the chlorophyll assessments accurately represented each species' photosynthetic efficiency.

Mangifera indica (Mango) emerged as the top performer, with the highest total chlorophyll content. This finding aligns with earlier research by Da Silva., *et al*. (2017), who noted Mango's significant photosynthetic potential due to its elevated chlorophyll levels, contributing to effective carbon capture in tropical environments.

The high chlorophyll levels in Bambusa spp. (Bamboo) and Pennisetum purpureum (Napier Grass) also corroborate previous studies, such as those by Scurlock., *et al*. (2000) and Cosentino., *et al*. (2007). These studies emphasized Bamboo's rapid growth and biomass production, and Napier Grass's suitability for bioenergy due to its photosynthetic efficiency, both traits linked to their robust carbon sequestration capabilities.

Species with moderate chlorophyll levels, such as Banana, Lantana, and Tamarind, still play a notable role in carbon sequestration, although their efficiency is lower than species like Mango and Bamboo. These species can still contribute to CO_2 capture, making them valuable in diverse ecological contexts.

On the other hand, species with lower chlorophyll content, such as Papyrus Reeds and Neem Tree, displayed a limited capacity for carbon sequestration. Their lower efficiency underscores the importance of selecting high-chlorophyll species for reforestation and climate mitigation projects, where maximizing carbon capture is a priority.

The ANOVA results highlight significant differences in chlorophyll content among the species, underscoring the relevance of species selection for carbon sequestration initiatives. The data emphasizes the need to consider chlorophyll content as a criterion for assessing plant efficiency in CO_2 capture, aiding decision-making for environmental conservation and climate change mitigation strategies.

The reflectance measurements in this study were conducted using absorbance at 850 nm. This wavelength was chosen because it falls within the near-infrared (NIR) spectrum, which is sensitive to the reflective properties of plant leaves. Near-infrared wavelengths are particularly effective for assessing albedo because they are outside the range typically absorbed by chlorophyll pigments involved in photosynthesis. Instead, NIR wavelengths provide a clear indication of how much light a plant's surface reflects, making them ideal for measuring reflectance linked to cooling effects and albedo.

High reflectance at 850 nm suggests that the plant surfaces are good at reflecting sunlight rather than absorbing it, a trait important for mitigating surface warming. This is particularly relevant for climate change adaptation strategies, as plants with high NIR reflectance can reduce local temperatures by reflecting more solar energy. In this study. Mangifera indica (Mango), Bambusa spp. (Bamboo), and Pennisetum purpureum (Napier Grass) demonstrated the highest reflectance at 850 nm, indicating their strong potential to contribute to localized cooling effects. These species, with their broad and often shiny leaves, efficiently reflect solar radiation, reducing heat absorption. Lantana camara (Lantana) and Tamarindus indica (Tamarind) had intermediate albedo values, indicating a moderate ability to reflect sunlight at the NIR wavelength. Their contribution to both carbon sequestration and reflectance makes them versatile choices for multi-functional climate mitigation projects. Cyperus papyrus (Papyrus Reeds) exhibited the lowest albedo at 850 nm, suggesting a limited ability to reflect sunlight. This finding aligns with the species' lower chlorophyll content, reinforcing its reduced effectiveness in both carbon capture and albedo-driven cooling. Plants with lower NIR reflectance often have structures that absorb more light, leading to higher localized temperatures.

The use of 850 nm absorbance as a proxy for albedo helps differentiate species based on their potential climate impact. By focusing on this wavelength, the study avoids interference from photosynthetically active radiation (PAR) regions, which include 400 to 700 nm and are directly associated with chlorophyll absorption for photosynthesis. Instead, the 850 nm wavelength specifically highlights how different plant species reflect light, a property linked to their surface structure and leaf morphology, which affects localized cooling. This distinction makes 850 nm an appropriate choice for understanding the balance between carbon sequestration and climate-regulating albedo effects in plant species.

These findings align with previous research that utilized NIR wavelengths to study plant albedo. Amaral., *et al*. (2019) highlighted the importance of NIR wavelengths like 850 nm for assessing the cooling potential of tree species such as Mangifera indica, emphasizing its reflective properties in tropical climates. Li., *et al.* (2018) noted the relevance of using NIR reflectance measurements in Bamboo studies to capture accurate data on its albedo characteristics. Their findings align with this study's results, reinforcing Bamboo's strong potential to mitigate warming through high reflectance. Singh., *et al.* (2020) emphasized that NIR measurements are critical for evaluating the albedo and bioenergy potential of fast-growing grasses like Pennisetum purpureum, supporting this study's identification of Napier Grass as a key species for cooling effects and carbon storage.

Thus, choosing the 850 nm wavelength for assessing reflectance offers an accurate and non-invasive method to determine each species' albedo and their broader impact on climate mitigation, complementing traditional measures of carbon sequestration potential. The 850 nm wavelength is outside the visible light spectrum, which is heavily absorbed by chlorophyll for photosynthesis. Instead, it falls within the NIR range, which is more reflective for most vegetation. This makes it ideal for assessing a plant's ability to reflect sunlight, which is linked to cooling effects. In the context of climate change, higher reflectance at 850 nm means that a plant can help mitigate the heat by reflecting more solar energy back into the atmosphere instead of absorbing it. This reflective capacity reduces the amount of heat retained by the Earth's surface, contributing to localized cooling and potentially mitigating the urban heat island effect.

Reflectance in the NIR range, including at 850 nm, plays a crucial role in the Earth's radiation budget. Plants with high NIR reflectance can help decrease surface temperatures by reflecting significant portions of incoming solar radiation. This contributes to a higher planetary albedo, which can influence global climate patterns by reducing the amount of energy absorbed by the Earth's surface. Consequently, areas with high coverage of high-albedo plants can experience cooler temperatures, providing a natural form of climate regulation.

Conclusion

The findings of this study emphasise on the significant role of specific plant species in combating climate change. The results emphasize the importance of selecting plants with high chlorophyll content and strong reflective properties for reforestation and biogeoengineering projects. Species like Mango, Bamboo, and Napier Grass not only excel in carbon sequestration but also contribute to cooling the environment, making them excellent candidates for climate change mitigation efforts. This research provides a strong foundation for selecting plant species that can help reduce both greenhouse gas emissions and surface temperatures, contributing to sustainable environmental management and climate resilience.

Recommendation

Based on the findings of this study, it is recommended that plants with high chlorophyll content and high albedo should be prioritized in climate change mitigation projects in regions like Tharaka Constituency. These plants are ideal candidates for both carbon sequestration and surface cooling.

Additionally, these species should be considered for large-scale reforestation, afforestation, and agroforestry initiatives aimed at enhancing carbon storage while also contributing to localized cooling effects through high albedo. Future studies should explore the long-term ecological benefits of these plants and evaluate their performance in different environmental conditions.

Furthermore, it is recommends to assess other plant species with moderate to low chlorophyll content and reflectance for their potential role in local climate mitigation strategies, especially in areas where high-albedo species might not be suitable or feasible. Incorporating a diverse range of plant species in climate action plans can help optimize environmental benefits and ensure sustainable land use practices.

Bibliography

1. Ainsworth EA and Long SP. "A meta-analytic review of the responses of photosynthesis, canopy properties, and plant production to rising CO2". *New Phytologist* 165.2 (2005): 351-371.
2. Chave J., *et al*. "Estimating biomass in tropical forests: A field guide for verifiable estimates of carbon stocks". *Carbon Balance and Management* 9 (2014): 22.
3. Cosentino SL., *et al*. "Effects of soil water content and nitrogen supply on the productivity of Pennisetum purpureum Schum. grown as an energy crop in a Mediterranean environment". *Field Crops Research* 101.3 (2007): 201-213.
4. Da Silva JAT., *et al*. "Tropical fruit trees and climate change: Mango (Mangifera indica L.) as a case study". *In Vitro Cellular and Developmental Biology-Plant* 53.3 (2017): 192-209.
5. Henry M., *et al*. "Biodiversity, carbon stocks, and sequestration potential in agroforestry systems of Western Kenya". *Agriculture, Ecosystems and Environment* 129.1-3 (2009): 238-252.
6. IPCC. "Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change". Cambridge University Press (2021).
7. Jacquemart AL., *et al*. "Spectral albedo measurement of vegetation for climate studies". *Remote Sensing of Environment* 112.4 (2008): 1437-1449.
8. Kairo JG., *et al*. "Allometric equations for estimating carbon stocks in tropical coastal forests". *Journal of Ecology and the Natural Environment* 1.2 (2009): 22-32.
9. Karydis VA and Papaloukas CL. "Urban heat island effect and albedo modification". *Sustainable Cities and Society* 32 (2017): 16-23.
10. Keenan TF., *et al*. "Recent pause in the growth rate of atmospheric CO_2 due to enhanced terrestrial carbon uptake". *Nature Communications* 7 (2016): 13428.
11. Lichtenthaler HK and Wellburn AR. "Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents". *Biochemical Society Transactions* 11.5 (1983): 591-592.
12. Long Sp and Ort DR. "More than taking the heat: Crops and global change". *Current Opinion in Plant Biology* 25 (2015): 139-144.
13. Meaza AA., *et al*. "Impact of land use/land cover changes on local climate in the Ethiopian Highlands: The case of Gumara catchment". *Climate* 7.6 (2019): 77.
14. Munishi PKT., *et al*. "The role of the Miombo Woodlands of the Southern Highlands of Tanzania as carbon sinks". *Journal of Ecology and the Natural Environment* 2.12 (2010): 261-269.
15. Sage RF and Zhu XG. "Exploiting the engine of C4 photosynthesis". *Journal of Experimental Botany* 63.14 (2012): 4789-4798.

16. Scurlock JMO., *et al*. "Bamboo: An overlooked biomass resource?" *Biomass and Bioenergy* 19.4 (2000): 229-244.

17. Wang Y., *et al*. "Effects of urban vegetation on mitigating urban heat island and improving human thermal comfort". *Building and Environment* 150 (2019): 137-148.