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First finding of *Heritiera littoralis* and its significance for Mauritian mangrove conservation

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Abstract

This study reports the first confirmed presence of Heritiera littoralis in the Rivière des Créoles, Mauritius, challenging previous assumptions that only Rhizophora mucronata and Bruguiera gymnorhiza were mangrove species in the country. This discovery is crucial for understanding the history, adaptation, and vulnerability of Mauritian mangrove ecosystems to climate change. When comparing mangrove forests of the same estuary type, it is found that forest structure and soil properties (e.g., bulk density, EC, and total organic matter content) are influenced by physical stress. The presence of a nearby lagoon attenuates wave attack, leading to more mature mangroves with lower density and higher DBH. Heritiera littoralis in the study site is growing in intertidal zones mixed with Rhizophora mucronata, despite its physiological vulnerability to high salinity. Mangrove habitat widths in the study sites are notably narrow, measuring only 25 meters wide. Furthermore, its habitat is threatened by the invasion of terrestrial trees such as Pongamia pinnata (PP). Given the limited inland migration space for mangroves due to rising sea levels, integrated coastal planning and land-use policies are essential to ensure natural adaptation space for mangrove ecosystems and enhance climate resilience in the face of climate change.

Keywords: *new range extension, coastal wetlands, climate change adaptation, estuary, coastal planning.*

Introduction

Importance of mangroves in Small Island Developing States (SIDS)

In Small Island Developing States (SIDS) like Mauritius, mangroves are particularly important for strengthening their resilience to climate change, providing important habitats for marine life as fishery resources, and food security and livelihoods for coastal communities [1]. Mangroves act as a natural barrier against natural disasters, especially storms and floods and have the capacity to prevent more than US$65 billion in damage annually by reducing coastal flood risk in areas inhabited by an estimated 15 million people [2].

In SIDS, mangroves function as natural barriers against storms, erosion, and flooding, and have the capacity to prevent more than US$65 billion in damage annually by reducing coastal flood risk in areas inhabited by an estimated 15 million people [3]. Mangroves capture sediments and pollutants that can run off into the ocean, while seagrass beds provide an additional barrier to prevent mud and silt from covering coral reefs. Coral reefs, on the other hand, protect seagrass beds and mangroves from strong waves. Therefore, the collapse of any of its components can lead to the collapse of the entire system, meaning that an integrated coastal ecosystem management (ICEM) approach is essential to ensure the overall health and resilience of island coastal areas [4].

Status of mangrove ecosystems in Mauritius and conservation issues

Mauritius was previously thought to be home to only two species of mangrove plants [5-7], with Rhizophora mucronata (RM) being the most dominant, and Bruguiera gymnorhiza (BG). Bunting et al. (2022), using a global satellite dataset called Global Mangrove Watch (GMW), reported the mangrove area in Mauritius to be about 4.32 km^2 [9]. Mangroves are distributed along the northeast, east, and southeast coasts, with smaller patches in southwestern regions. The mangrove forests in the southeastern region, where this study was conducted, are the most developed and mature, as evidenced by their tall tree heights and large tree sizes.

The factors that determine mangrove expansion and productivity vary depending on the type of mangrove forest (delta, marine, estuarine, lagoonal), so it is important to understand the environmental factors specific to each type [10, 11]. In each type, mangrove area is not determined by a single factor, but by a complex interplay of multiple factors such as hydrology (tides, waves, current velocity), freshwater and nutrient supply, sediment supply and stability, salinity, and human activities. Mangroves in Mauritius are predominantly estuary and lagoon type [6]. Salinity gradients and human activities are thought to have distinctive effects on mangrove forests in estuarine types, while wave activity and water quality in the lagoons are distinctive factors affecting mangrove forests in lagoonal types.

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JICA Project for the Development of an Integrated Coastal Ecosystem Management System in the Republic of Mauritius

Since 1995, the Government of Japan, through the Japan International Cooperation Agency (JICA), has made long-term contributions to the conservation and restoration of Mauritius' coastal ecosystems, as well as the preservation of coastal fisheries resources and the environment. In 2022, JICA, in cooperation with the Government of Mauritius, launched the technical cooperation project titled "The Project for the Development of Integrated Coastal Ecosystem Management System." The overall goal of this project is to promote the conservation and restoration of coastal ecosystems through integrated coastal ecosystem management systems, aiming for healthier and more resilient states. This research was conducted as a component of this initiative.

Aims of this study

Although the ecological and socio-economic importance of mangroves is recognized, scientific research on mangroves in Mauritius is still limited. In Mauritius, only two mangrove species have been identified, RM and BG [6]. While this recognition has been going on for a long time, this study confirmed for the first time that *Heritiera littoralis* (HL) is present in Rivière des Creoles (hereinafter called RC). The goal of this study is to scientifically document its presence, understand the growing conditions in which HL thrives, and provide a basis for ensuring its long-term health and sustainability of the mangrove ecosystem in RC and other coastal areas of Mauritius.

Materials and methods

Site description and mangrove survey Insert Fig. 1 here The same estuary-type mangrove as that found at RC (where HL was found) is also present 2 km north at Rivière Nyon (RN) (Fig. 1). They belong to different estuarine systems regarding freshwater inputs from different rivers, different catchment characteristics, and different estuary shapes and openings to the sea. 3 plots (C1, C2, C3) and 3 plots (N1, N2, N3) with the size of 20 x 25m were set up at RC and RN, respectively.

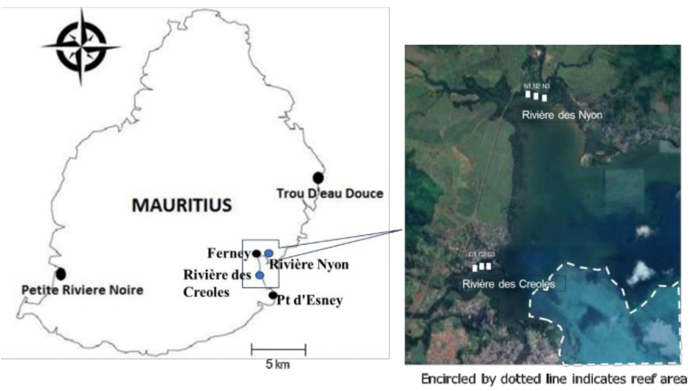


Figure 1: Study locations (●) and mangroves stands studied in other studies (●) Image
Source: *Google Earth, © 2025 Airbus, Maxar Technologies*

All stems were tagged with numbering tape. 555 trees at 6 plots in RC and RN were measured for height and diameter at breast height (DBH), and from which basal area and stand density were calculated. The position of measured trees also was also determined. RM sometimes has plural stems in one single tree. In that case, the ground level measurement was done at 30 cm above the prop roots. Tree heights were subsequently measured with a measuring pole and/or by visual observation.

Ground level survey

Topography, or ground elevation, determines the dynamics of water flow and nutrient inputs within mangrove forests. It is considered the most important factor for mangrove growth [12, 13] and is recognized as crucial for the distribution of mangrove species [14]. Topography is closely related to soil properties, and in turn soil properties are closely related to plant growth. Therefore, mangrove growth can be better explained when soil properties are taken into consideration with topography [15].

Ground level measurements were taken at 5-meter intervals from the coast inland through the mangrove forests in both the RC and RN plots. These measurements were performed using an Ushikata pocket compass (Model S-25, Ushikata Surveying Instruments Co., Ltd., Japan).

Soil analysis

For the assessment of soil moisture and bulk density, undisturbed soil samples were obtained using 100 cm^3 stainless steel sampling tubes (Daiki Rika Kogyo Co., Ltd., Japan) at different depths with 5 cm intervals till 30 or 35cm. The pH and electrical conductivity (EC) of the fresh soil samples were measured after shaking for 1 h at a soil-to-water ratio of 1:10. The measurements were taken using a pH meter Φ72 (Beckman; Beckman Coulter, Inc., Fullerton, CA, USA) and a CyberScan Con300 (Iuchi Co. Ltd.; Osaka, Japan), respectively. Soil organic matter content was estimated by the loss on ignition (LOI) method. Approximately 10 g of oven-dried soil (dried at 105°C for 24 hours) was weighed into a pre-weighed ceramic crucible. The crucibles containing the soil samples were then placed in an electric muffle furnace and ignited at 550°C for 4 hours. After ignition, the crucibles were carefully removed, allowed to cool in a desiccator, and re-weighed. The loss in weight was calculated as the LOI and expressed as a percentage of the initial dry soil weight, representing the organic matter content.

Results

Growing Status of *Heritiera littoralis* in RC

HL was found in RC growing in intertidal zones in contact with RM (Figure 2). There are two species in the genus Heritiera: *littoralis* and *fomes*. Based on the characteristics of the leaves and the shape of the seeds, this species was identified as *littoralis*. Only three specimens remain in RC, and the tree is speculated as quite old from large DBH.

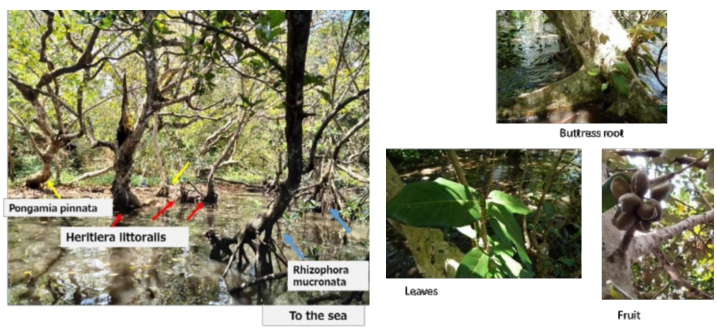


Figure 2: Heritiera littoralis in Rivière des Creoles

Table 1: Difference in characteristics between Heritiera littoralis and H. fomes

Characteristic	Heritiera littoralis	Heritiera fomes
Leaf	Underside of leaves covered with silvery-white scales; lustrous appearance	Underside less silvery-white than H. littoralis; somewhat shiny
Seed Shape	Large, oval to ovate fruit with a pronounced keel-like ridge; woody and buoyant	Smaller fruit with a wing-like structure
Buttress Root	Very pronounced, sinuous buttress roots	Less wavy and less elevated than H. littoralis
Bark	White-gray to pinkish-gray; smooth but peels and cracks with age	Gray, generally darker than H. littoralis
Growing Environment	Grows at the land edge of mangrove forests and riverside forests near sea level	Dominant in inland mangrove forests with lower salinity

Distance from the sea front to RM 1 is 8.6 m, and 4.4 m from RM 1 to the Heritiera tree. The relative ground level difference between HL and RM 1 is approximately 19 cm (1.14m - 0.95m), while it is approximately 42 cm (1.56m - 1.14m) between HL and the invasive species PP (Table 2). This indicates that HL typically grows at a slightly higher elevation than RM, and PP being a terrestrial invader, occupies even higher ground. Furthermore, the HL and PP individuals show significantly larger DBH values (43.1 cm and 33.3 cm, respectively) and greater tree heights (6.9 m and 9.2 m) compared to RM, suggesting a more mature or favorable growth environment further inland.

Table 2: Position and tree attributes of respective species

Parameter	Sea front	*Rhizophora* 3	*Rhizophora* 2	*Rhizophora* 1	*Heritiera*	*Pongamia*	End of wetland
Distance from sea front (m)	0	3.4	6.4	8.6	13	20.5	24
Relative ground level (m)	0	0	0.91	0.95	1.14	1.56	1.58
Tree height (m)	—	6.19	4.92	2.91	6.9	9.2	—
DBH (cm)	—	8.2	14.5	11.5	43.1	33.3	—

Mangrove Stands in RC and RN

The mean height, basal area, and DBH in RC are larger than in RN (Table 3). Stand density and the number of trees were lower in RC. Generally, tree stand density decreases and basal area increases as a forest stand matures. From this perspective, RC is more mature, while RN is a younger stand.

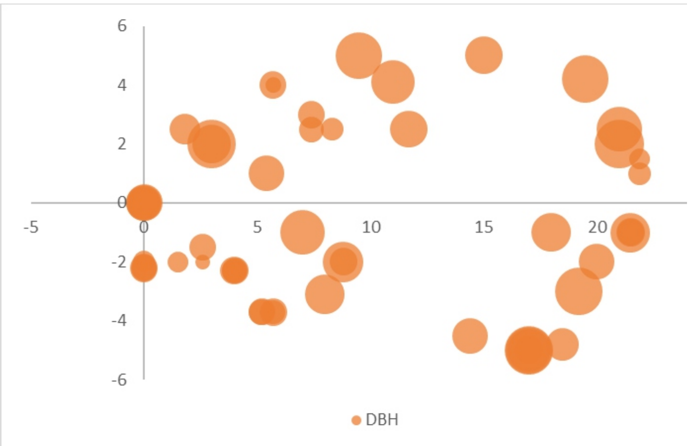
Compared with other mangroves in Mauritius (Figure 1), the DBH of trees in RC is as large as in Ferney, indicating a similar level of maturity (Table 4). However, Ferney's stand density is not as low as RC', possibly due to its location being more inland, resulting in less impact from wind and wave attacks. The low DBH and high density of Petite Rivière ~~des~~ Noire and Pt d'Esny indicate that their forest stands are still in an immature stage.

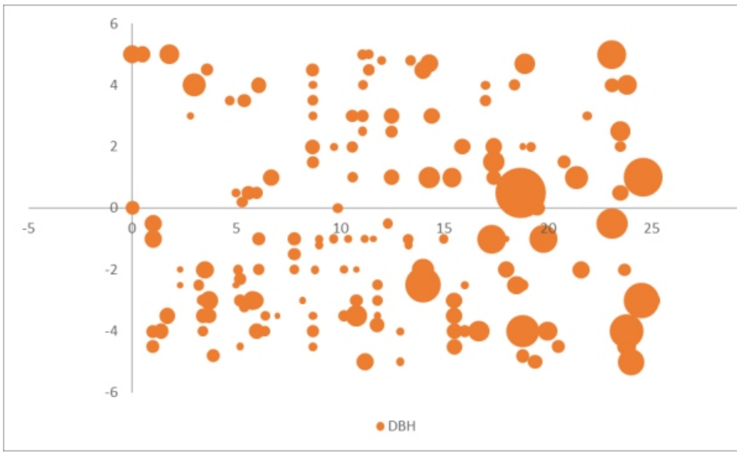
Table 3: The mean height, basal area, DBH in RC are larger than RN

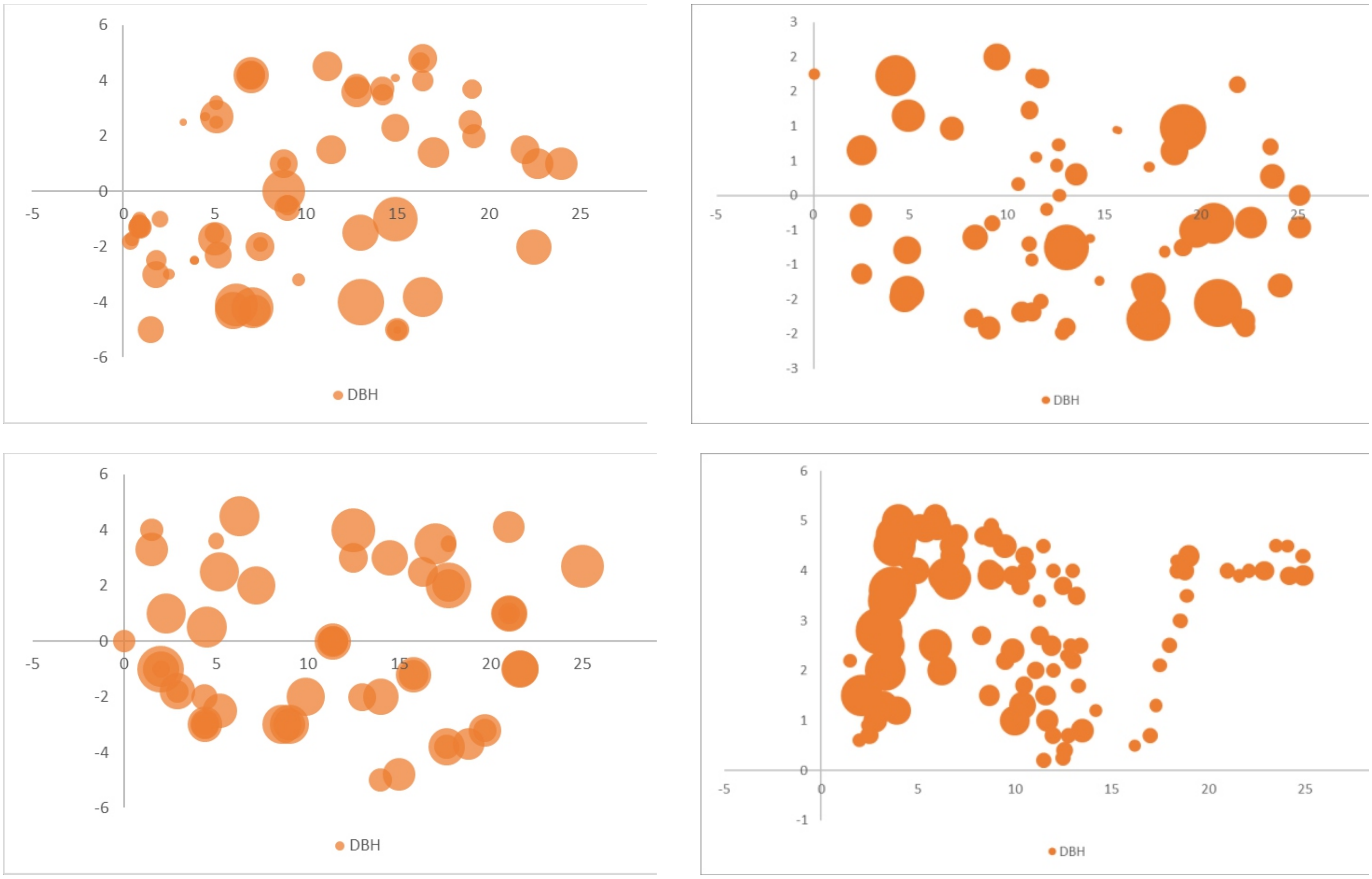
Site	Plot	No of trees	Height (m) – Range	Height (m) – Mean	DBH (cm) – Range	DBH (cm) – Mean	Basal area (m^2/ha)	Stand density (trees/ha)	Occupancy of *Bruguiera gymnorrhiza* (%)
Rivière des Créoles	1	55	6.0–13.0	10.4	6.8–22.5	14.7	40.4	2,900	—
	2	67	2.0–13.0	7.4	3.2–20.9	10.9	29.1	2,680	—
	3	66	1.5–12.0	8.8	4.8–17.2	11.5	29.4	2,640	—
Rivière Nyon	1	204	2.5–12.0	7.1	2.5–18.6	8.1	20.7	8,160	20.9
	2	61	2.0–8.4	4.4	1.6–10.0	4.7	5.1	2,440	11.5
	3	102	2.5–8.7	4.0	2.5–9.8	4.4	17.7	10,200	—

Table 4: Comparison of Mangrove Stand Characteristics with Other Studies in Mauritius

Parameter	This study – Rivière des Créoles	This study – Rivière Nyon	Alib S., Appadoo C. (2012) – Trou D'eau Douce	Alib S., Appadoo C. (2012) – Petite Rivière Noire	Raghoobur et al. (2022) – Ferney	Raghoobur et al. (2022) – Pte d'Esny
DBH range (cm)	3.2–22.5	1.6–18.6	1.9–13.6	1.2–23.1	1.0–33.0	0.95–7.2
Tree height range (m)	1.5–13.0	2.0–12.0	3.8–8.4	2.0–5.2	7.0–11.0	1.0–3.6
Stand density (trees/ha)	$2.2–2.7 \times 10^3$	$0.24–1.02 \times 10^4$	2.8×10^4	3.0×10^4	3.0×10^4	4.5×10^4
Basal area (m^2/ha)	29.1–40.4	5.1–20.7	—	—	54.2	20.7







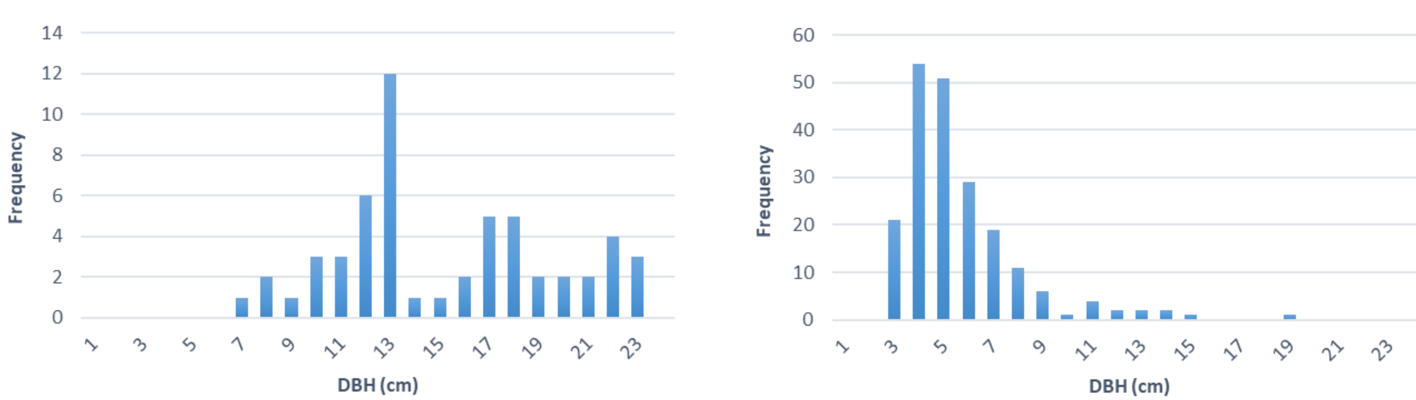
Rivière des RC **Rivière RN**

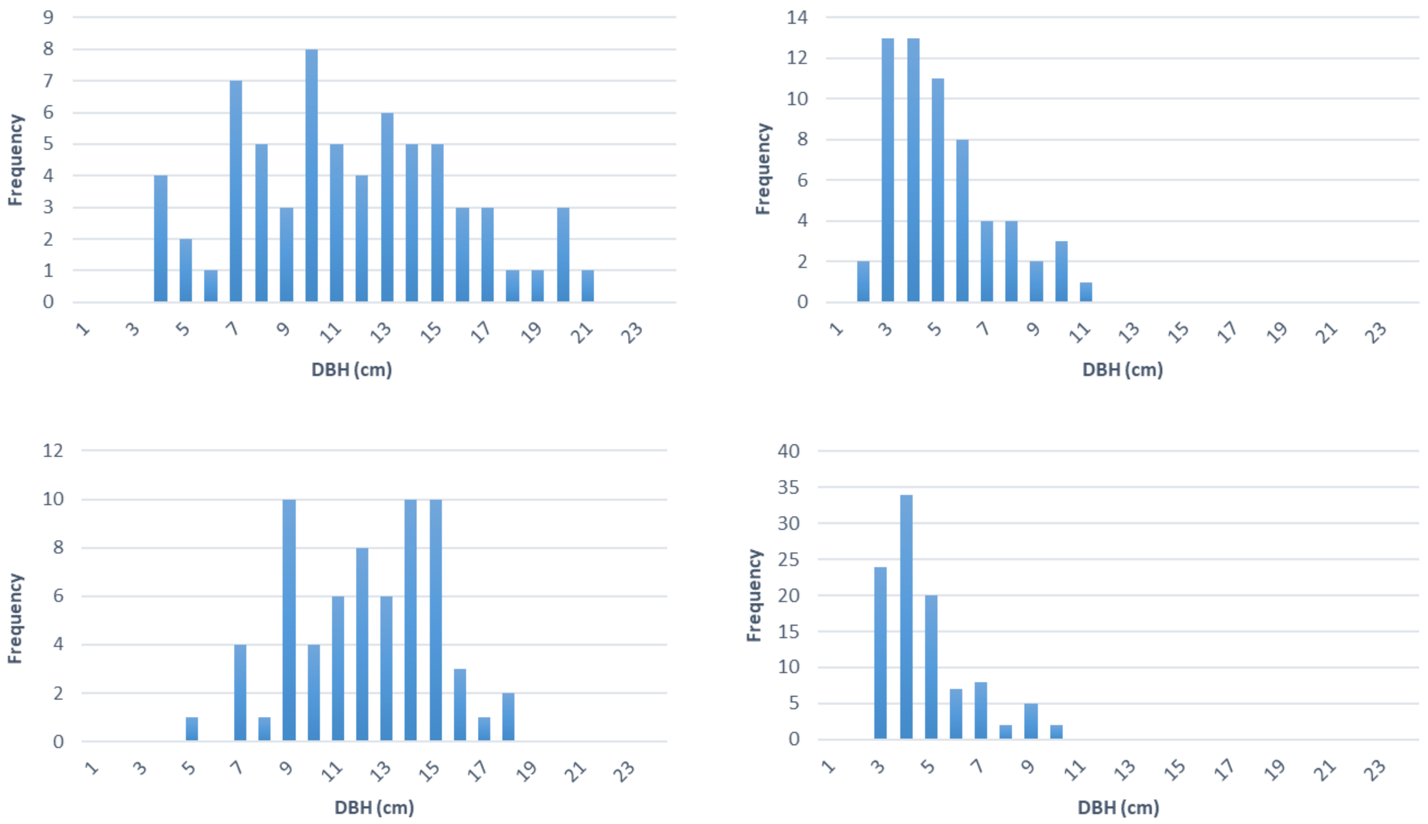
Figure 3: Tree distribution in 10 x 25 m at RC and RN

Many young trees are distributed with fewer large size trees in RN (Figure 3, Figure 4). This suggests RN stand is relatively new or has been disturbed in the past couple of years with the removal of large trees.

RC, in contrast, has a different size of trees having normal distribution of DBH, showing mature forest structure. The differences between the two sites may be attributable to varying environmental conditions (e.g., salinity, soil type, hydrological conditions), disturbance history like cyclone, or management practices.

RN's high-density forest, dominated by many young trees, may have a higher temporary carbon uptake due to the rapid growth rate of saplings, but it might not provide the more stable ecosystem services offered by mature forests, such as shoreline protection and biodiversity maintenance.





Rivière des RC *Rivière Nyon*

Figure 4: Histogram of tree DBH in RC and RN

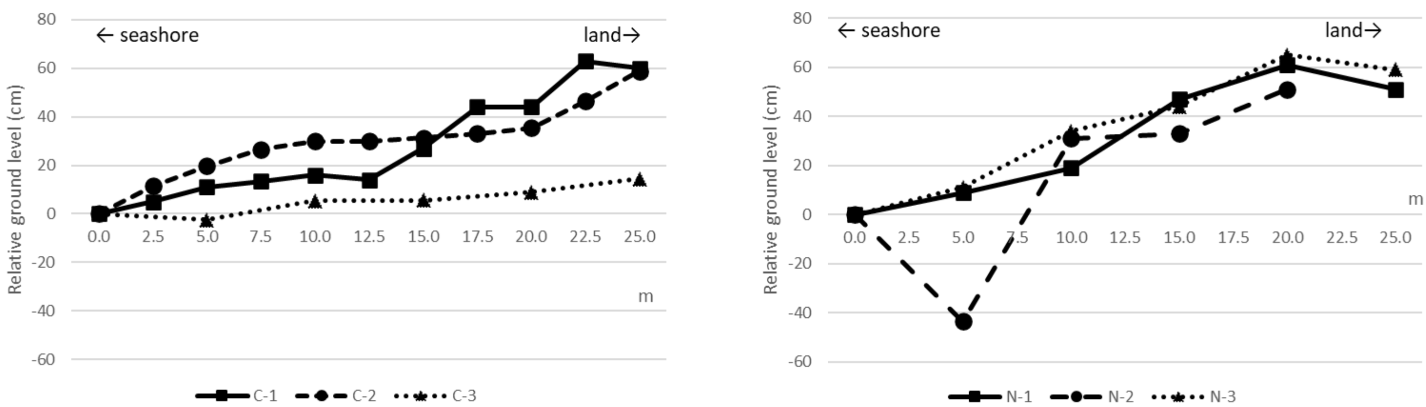
Forest biomass

Forest biomass is influenced by several major factors, including tidal frequency, forest age, and salinity. Rising salinity due to sea level rise and nutrient competition with fast-growing algae due to eutrophication/pollution) could significantly impact the health of mangroves and their ability to provide ecosystem services.

Table 5: Soil carbon and above-ground biomass in RC, RN and other studies mangroves

Variable	Plot	This Study — Rivière des Créoles	This Study — Rivière Nyom	Ragalibov et al. (2022) — Ferney	Ragalibov et al. (2022) — Pt d'Esny
Soil carbon (Mg ha^{-1})	—	145.14[D]	170.03[29]	128.87 ± 19.29	116.31 ± 19.27
Above-ground C (Mg ha^{-1})	1	374.9	131.5	273.78 ± 19.29	78.41 ± 19.27
	2	246.1	28.7	—	—
	3	239.8	99.0	—	—

The above-ground biomass in RC is larger compared to RN. However, soil carbon content is higher in RN (Table 5). This is likely because the source of organic matter accumulated in the soil is not primarily from mangroves, but rather from marine-derived organic matter (algae, detritus, etc.) transported by rivers and tides. Despite the high above-ground biomass in RC, the relatively low soil organic carbon is likely related to an environment where produced organic matter (leaf litter, dead wood, etc.) is either not accumulated much in the soil due to active decomposition or is easily exported by tides and river flow.



Rivière des RC *Rivière Nyon*

Figure 5: Changes of ground levels in RC and RN

Ground level

Mangrove habitat width from the seaward edge to the landward edge of mangrove forests is quite narrow with 25 m (Figure 5). This contrasts to 2500 m of Asian mangrove such as Thai mangrove [16]. A mangrove elevation gradient of 1 meter typically describes the vertical range where mangrove forests thrive [17]. In vast environments with long horizontal range and small elevational differences, subtle environmental gradients such as tidal inundation duration and frequency, salinity, and soil moisture content exist continuously, allowing diverse mangrove species adapted to different conditions to form zonation. However, in Mauritius, the narrow width and limited environmental gradients restrict mangrove species diversity, leading to a strong tendency for only a few dominant species to grow.

Table 6: Soil properties in RC and RN

Rivière des Créoles

Depth (cm)	Moisture (%)	Bulk density	EC (dS/m)	Loss of ignition (%)	Organic carbon (%)
5–8	41.7	0.77	1.20	20.8	6.5
8–10	41.3	0.64	6.25	22.1	6.5
13–15	44.3	1.15	4.03	17.5	6.2
18–20	49.4	0.66	0.73	18.8	5.8
23–25	41.7	0.87	4.26	19.3	5.8
28–30	35.3	0.84	11.57	20.0	6.0
33–35	41.0	0.60	8.17	20.3	6.1

Rivière Nyom

Depth (cm)	Moisture (%)	Bulk density	EC (dS/m)	Loss of ignition (%)	Organic carbon (%)
5–8	81.9	1.10	3.21	23.5	7.2
8–10	88.8	1.19	2.74	21.4	6.6
13–15	15.7	0.30	3.94	51.5	17.4
18–20	39.3	0.59	6.31	21.4	8.0
23–25	21.8	0.56	9.51	38.9	10.3
28–30	19.8	0.32	12.16	36.2	11.1

RN is considered to be organic soil due to its generally low bulk density (BD) and high organic carbon (OC) content, although there is a layer with slightly higher BD near the surface (Table 6). The significant variation in analytical values with depth in RN suggests considerable fluctuations in the depositional environment. RN is located in an estuary with a more complex water system than RC, and it is strongly influenced by tides and river water. It is thought that the type of sediment (mud/sand/organic matter), deposition rate, and salinity environment frequently change due to seasonal variations in freshwater inflow from the river, the strength of tidal influence, and flood events. Large fluctuations in EC values indicate periods in the past when salinity concentrations varied significantly, possibly due to changes in river channels, temporary salinization due to drying, or fluctuations in precipitation.

Discussion

Discovery of *Heritiera littoralis* and its ecological significance

The fact that only a few individuals remain suggests that the ecological environment in which HL grows is quite harsh, and understanding the situation on the ground is essential to protect the population.

HL is a mangrove tree in the family Acanthaceae. It's native to coastal areas like East Africa, Madagascar, India, Southeast Asia, Melanesia, and northern Australia [18]. While PROTA4U (n.d.) states that it "does not occur in the wild in Réunion and Mauritius, but has been introduced there," [19] there are no academic papers that specifically detail the habitat or population of HL in Mauritius, nor do they mention when or by whom it was introduced to support this claim of introduction.

Therefore, the newly discovered populations of HL are crucial for understanding the history, adaptation, and vulnerability of Mauritius's mangrove ecosystems to future climate change. This discovery also offers insight into broader ecological questions. If it is a naturally distributed remnant population, its ecological and genetic value is significant.

HLs in RC currently grow in the intertidal zone in contact with RM, and HLs lack specialized salt exclusion or salt excretion mechanisms, making them vulnerable to high salinity due to their physiological characteristics. [20, 21]. Due to the large elevation gradient in mangrove habitats, the frequency of tidal inundation varies greatly from site to site, resulting in large variations in soil salinity and EC values. Understanding how it survives in the harsh environment could provide important insights into the adaptability of mangroves in future climate change and invasive species management strategies.

Mangrove Stability Affected by Coral Reef Location

There is a clear difference in the distance to the offshore coral reefs (lagoon width) between RC and RN (Figure 1). RC has a wider, highly enclosed lagoon in front of it, which significantly attenuates oceanic waves as they travel through the lagoon, resulting in a much calmer wave and current environment. In contrast, RN has a wider opening. The wider mouth of the estuary allows waves and currents to efficiently penetrate deep into the estuary, affecting a broader area. This means that the RN experiences frequent physical disturbances from waves, tides and cyclones, making it difficult for large, mature trees to grow and creating an environment that consistently favors young and regenerating trees.

Mauritius Mangrove Climate Adaptation

Studies to predict changes in mangrove distribution under future climate scenarios (SSP126 and SSP245) in Mauritius have been carried out using models such as MaxEnt [22], suggesting that mangroves have the potential to migrate inland, but existing land uses may limit their movement. In Asia, where land elevation gradients are gentle, mangroves have the spatial capacity to easily migrate inland, even in the face of sea-level rise due to climate change. However, mangrove habitats in Mauritius are very narrow, at only 25 m (Figure 5). In addition, the invasion of terrestrial trees such as PP threatens mangrove habitats (Figure 2).These suggest that effective climate resilience strategies in SIDS may involve difficult trade-offs between development and conservation, requiring integrated land-use planning that addresses the dynamics of natural ecosystems, not just ecological restoration. Effective coastal planning will require zoning considering future climate change scenarios and rethinking land-use policies to ensure natural adaptation space for mangroves.

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