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To cite this article: Ezrah Natumanya *et al* 2024 *Environ. Res.: Ecology* **3** 015001

View the article online for updates and enhancements.

ENVIRONMENTAL RESEARCH
ECOLOGY

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OPEN ACCESS

RECEIVED
4 June 2023

REVISED
30 October 2023

ACCEPTED FOR PUBLICATION
21 November 2023

PUBLISHED
27 December 2023

PAPER

Assessment of conservation status of riparian vascular plant species in a dry season exposed flood plain area of the Incalaue river catchment, Niassa Special Reserve, Northern Mozambique

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Keywords: conservation, riparian, species, vegetation

Abstract

Riparian vegetation usually gets less focus in biodiversity assessments and yet species diversity is important knowledge when applying patch specific conservation value in the Niassa Special Reserve (NSR). This study assessed the composition and conservation status of riparian species in an exposed river basin downstream location. Purposive sampling was used in the selection of sites and respondents to maximize data collection. The study found 19 species belonging to 15 families with 52.63% of them having a frequency of $\geqslant$50% in sampling plots. There were 10 species that are endemic to the sub-Sharan Africa Region. Fabaceae was the dominant family with 5 species. The species with the highest population was *Flacourtia indica* (Burm. f.) Merr. Species richness ranged from 0.35 to 0.98 with a mean of 0.66 ± 0.22. The IVI ranged from 34.70 (*F. indica* (Burm. f.) Merr) to 4.43 (*Tribulus cistoides* L.) with a mean of 15.79 ± 7.79. Threats of species loss and ecosystem disturbance were agriculture, infrastructure development and plant harvests. There was a reported decline in species availability over the previous 10 years by 18.7% of the respondents. The results added to existing studies and records of vegetation species of conservation value in areas exposed to loss in the NSR. This study advances research on vegetation range dynamics in the NSR and presents a need to mitigate human land use impacts on riparian vegetation species composition.

1. Introduction

Information on vegetation cover patches is important to help understand specific conservation needs [1–3]. Data on the diversity, distribution and population structure of riparian vegetation ecosystems are important for monitoring degradation and loss of biodiversity [4–6]. This is of concern if human land use is unregulated in river catchments in conservation areas. Variations in vegetation species frequencies follow landscape disturbance, spatial and temporal dynamics and this information is important in the management of natural ecosystems in conservation areas [7]. Characterization of species availability and frequencies has been previously recommended as essential for monitoring baseline data for mitigating ecosystem degradation pressures [8].

In drought-prone regions of the world, studies of vegetation species abundance in seasons of water deficits have proven particularly powerful for understanding ecosystem stability [9]. Dry season vegetation distributions in a landscape reflect interplay among a species water needs, the soils physical and chemical properties, biotic interactions, and historical factors, such as, disturbances [10]. In semi-arid areas, vegetation distribution and density are key indicators of a species dorminance, competition and adaptation to seasonal water reduction within riverine communities [11].

It is important to determine vegetation species which are resilient to dry season water stress conditions in a wildlife conservation area like the Niassa Special Reserve (NSR) as these are habitats for dependent wildlife ecosystems [12]. In rangeland vegetation ecosystems, it is important to protect the dry season resilient riparian vegetation to conserve endemic species diversity [13]. Vegetation spatial-temporal dynamics is important knowledge for the NSR managers and conservationists because it influences fauna wildlife habitats most especially in the dry season [14].

Landscape drainage affects seasonal soil water availability for vegetation ecosystems, which is important information for hotspot ecosystem protection, in conservation area management [15, 16]. Landscapes drain toward riparian vegetation in river bed sections during the dry season. Therefore, knowledge of vegetation ecosystems in these areas is important for the protection of adapted and unique floral diversity, especially in areas that are exposed to degradation by human land use [17, 18]. Riparian vegetation ecosystems are wildlife and human population interaction points; and get more exposure to risks of human land use caused degradation and destruction in the dry season as other areas upstream dry up gradually [19, 20]. Human land use activities leading to plant removal and destruction are degradation threats for the riparian vegetation ecosystems [5]. This is the situation in the Incalaue river catchment in the NSR that hosts human settlement areas [21, 22].

Riparian vegetation in Incalaue is evidently useful for both wildlife and human populations during the dry season, presenting a socio-ecological degradation risk. Riparian vegetation ecosystems are the center of attraction for human activities in the dry season as the main source of water and livelihoods. Downstream and riverbed vegetated places are the last sources of greener vegetation and water for social-economic activities in the dry season as upstream areas dry up.

The area is hilly with mainly sandy soils that dry-up easily as the dry season grows upstream. The NSR has been reported to have a higher fire frequency, especially in areas with human settlements and related land use, which is a threat for riparian plant species [23–25]. This makes it important to derive seasonal facts and figures to support the conservation of vegetation species, composition and diversity [26].

The Incalaue is a tributary of the Lugenda River in the wider landscape and is drained also partly by the Rovuma river. The area gets a harsh dry season where vegetation stays largely in sandy riparian areas in the dry season [27].

In the wet season, riparian vegetation is available across the NSR except for localized species, non-vegetated Inselberg areas, human land settlement areas and roads. However, in the dry season, vegetated areas shrink and vascular plants, apart from some tall trees, remain largely in the riparian areas and small valleys.

Conservation focused research in the NSR has focussed on fauna [27, 28]. The area is re-known for having the largest section of conserved miombo woodland ecosystem left in Africa [29]. The reserve provides habitats to some critical biodiversity fauna species and threatened mega-fauna [28]. The 800 species of plants, half of which are endemic, have been reported in the NSR [27, 29].

A series of reports by the Government of Mozambique have acknowledged that there is a growing threat of biodiversity loss associated with human activities and many vegetation species threatened with extinction [30–32]. Research studies have shown that there is need for endemic plant species composition and classification in the center and north, where the study area is located [33, 34]. The only study that involved sampling, closest to riparian vegetation, collected data on vegetation species diversity focused on those associated with moist forests along the plateau edge and highlands [22]. This landscape patch-focused study found 326 species and this shows the need for more studies including for riparian area ecosystems.

This study planned to explore the potential to provide an addition to species diversity in the NSR with a specific focus on riparian ecosystems.

Data on vascular plant species composition and frequency analysis are presented and vulnerability discussed, based on exposure to existing land use. This study additionally explores the regional and global conservation status of the species found. We believe this data is important for conservationists and reserve managers to inform prioritization and planning conservation. This study provides riparian ecohydrology data in an infrequently studied miombo woodland ecosystem region of Mozambique.

2. Methodology

2.1. Study area

The Incalaue river catchment (697.02 km^2) is located in the NSR in Northern Mozambique. The reserve is the largest remaining conserved block of pristine Miombo woodland ecosystem in Southern Africa, therefore, the addition of more data is important both nationally and globally [35]. Miombo woodlands

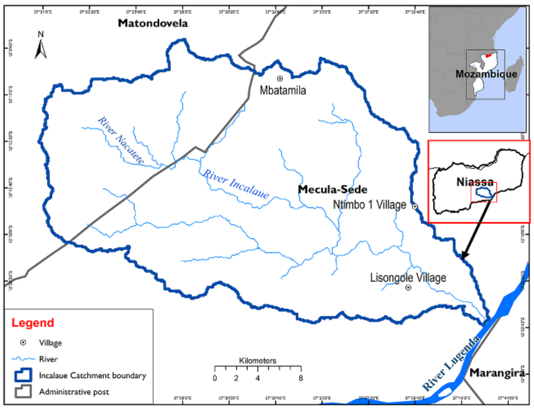

Figure 1. Incalaue catchment.

cover two-thirds of the Sudan-Zambezian phytoregion (approx. 2.7 million km^2) in parts of Angola, the Democratic Republic of the Congo, Malawi, Mozambique, Tanzania, Zambia [28].

The Incalaue river catchment is in a wildlife conservation area hosting human population settlement areas. The catchment is in the district of Mecula; and partly in the administrative posts of Mecula-sede and Matondovela (figure 1). The human settlement areas in the catchment are Lisongole and Ntimbo 1 as well as the NSR's main administrative campsite of Mbatamila.

The Incalaue is a seasonal river that makes downstream, flood plain, riparian vegetated areas a key wildlife habitat area for both vegetation and water in the upper catchment dry-up. Areas in proximity of the river are important zones for fauna wildlife during the season as this area is a migratory corridor for wildlife to the permanent river Lugenda during the dry season.

The catchment has a sharp topographic gradient of 360 m a.sl to 580 m a.sl with the rising Inselberg's intermittently spread across the landscape. It is located in an agro-ecological zone where soils are mostly sandy-clays with rainfall in the range of 1000 mm yr^{-1} to 1400 mm yr^{-1} with the annual rainfall occurring for 4–5 months between December to May [36–38]. The area has shallow soils underlain by a granite rock which makes them well drained [39].

The catchment is an area mainly covered by dry to mesic Miombo woodland on relatively sandy, nutrient-poor soils [22]. The dominant vegetation species in Miombo woodlands in Southern Africa are *Julbernardia globiflora* (Benth.) Troupin., *Brachystegia spiciformis* Benth., *Brachystegia boehmii* Taub., *Pseudolachnostylis maprouneifolia* Pax., *Diplorhynchus condylocarpon* (Mull. Arg.) Pichon., *Terminalia sericea* Burch. ex DC., *Sclerocarya birrea* (A. Rich.) Hochst., *Burkea africana* Hook., *Pterocarpus angolensis* DC., *Brachystegia manga* De Wild., *Brachystegia allenii* Burtt Davy & Hutch., *Diospyros kirkii* Hiern., *Albizia versicolor* Welw. Ex Oliv., *Terminalia stenostachya* Engl. & Diels., *Tamarindus indica*. L., *Combretum collinum* Fresen., *Strychnos spinosa* Lam. *Dalbergia nitidula* Welw. ex Baker., *Crossopteryx febrifuga* (Afzel. ex G. Don) Benth., *Hugonia orientalis* Engl. *Albizia adianthifolia* (Schumach.) W. Wight., *Pericopsis angolonsis* (Baker) Meeuwen., *Combretum adenogonium* Steud. Ex A. Rich. *Combretum hereroense* Schinz., *Vachellia sieberiana* (DC. Kyal. & Boatwr., *Catunaregam taylorii* (S. Moore) Bridson and *Combretum zeyheri* Sond [25, 40, 41]. Vegetation in the area is characterized by leaf-shed for 4–5 months of the dry season every year between June and November [21]. The study was planned in the dry season, to be able to get the range of species composition during the dry season peak times and exposure to loss due to human land use. This is an important assessment to inform conservation efforts on botanical diversity, focusing on inter-season species composition loss threats and exposure [42].

2.2. Research conceptualisation

It was conceptualized that human land use activities create potential loss of resilient exposed vegetation species and sampling in the season gives conservation status and needs in the dry season (figure 2). Vegetation exposure to potential disruptions of resilient ecosystems was conceptualized to contribute to species loss.

2.3. Sampling

The purposive sampling method was used to maximize data collection on vegetation species composition and exposure to land use activities in the dry season [8, 43, 44]. Plant species composition varies at short distances in riverine flood plain areas and intensive sampling is useful to maximize sampling [42].

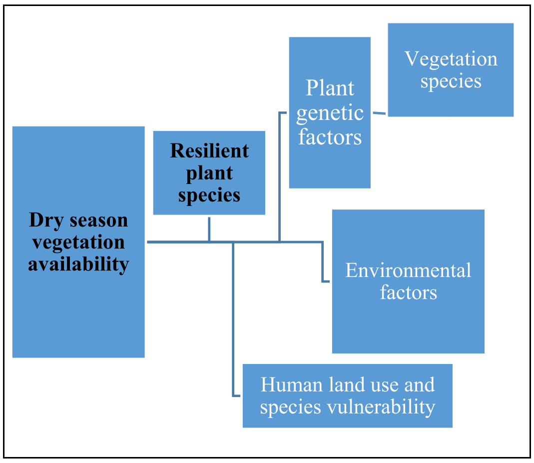

Figure 2. Land use threat to species availability.

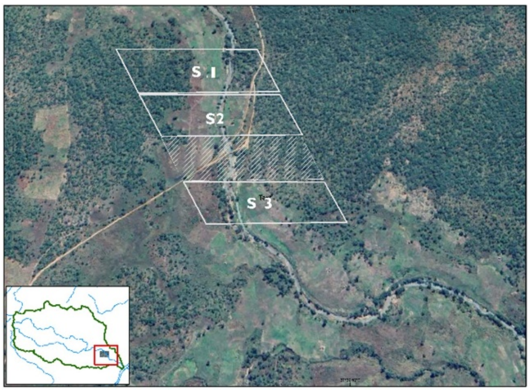

Figure 3. Sampling segment sections.

The riparian vegetated section in the dry season was reported by local people to be an estimated 2 km; and an estimate of 300 m as the last vegetated area in the dry season interestingly near community gardens and crossed by a road. Sampling was done in the vegetated area at the time of sampling, which was 253 m. That sampled section was close to gardens with visible human interference, all of which were considered to be potential loss agents for species (figure 2).

Vegetation was found growing in almost sandy soil deposit segments of around 60 m so this was chosen for the layout design of the sampling segments. The sampled riparian vegetated river section was therefore divided into three segments (S1, S2 and S3) in the downstream direction (figure 3). There was a bridge with a lot of activities around it like car washing and residents fetching water between S2 and S3. Sampling was designed to avoid an expected, potential road construction and its effects on vegetation [45, 46].

Each one of the 60 m segments was split into sub-sections of 20 m lengths along the river flow up to the width of the sampling segment. This would result into 6 sampling plots (3 on either side) for each segment and 3 were randomly selected for sampling. Sampling was also done in the whole dry river channel in a segment to capture any vegetation there (S10, S20, S30). The river channel section ends where marked based on available flood flow stop-marks and vegetation edges.

The study area was crossed by a road from Lisongole Lisongole to Ntimbo 1. The plots were coded basing on the bank-side directions with 'A' as the Lisongole direction and 'B' on the Ntimbo 1 direction (table 1).

Vegetation data collection was done in the channel plots (S10, S20 and S30) and three river-side plots were randomly sampled out of 6 in each segment. The bank-side plots randomly sampled were S1A1, S1B2, S1B3, S2A1, S2A3, S2B2, S3A3, S3B2 and S3B3 (table 2).

Plants of height >25 cm in each of the selected unit plots were identified, classified, counted and recorded. Counted plants were marked using weather proof paint to avoid duplication. Sampling was in the months of September and October (year 2021) in the dry season, the rainy season had stopped in June that year.

Table 1. Sampling segments.

SIDE A	S1 S2	SIDE B
Lisongole side	:	Ntimbo 1 side
	S3	

Table 2. Sampled plots are labeled in bold.

S1A1		S1B1
S1A2		**S1B2**
S1A3	**S10**	**S1B3**
S2A1		S2B1
S2A2		**S2B2**
S2A3	**S20**	S1B3
	Buffer (35 m)	
	Road	
	Buffer (35 m)	
S3A1		S3B1
S3A2		**S3B2**
S3A3	**S30**	**S3B3**

Plate 1. Community guided species identification.

A community-based approach was used to support the effectiveness of classification using available databases. In this approach, community identification of vegetation species was used along with verification from existing datasets (Plate 1).

The vernacular names of plants and their classification were checked against available databases on Miombo woodland vegetation species in Mozambique [47–49]. The use of these checklists was additionally supplemented by online databases. Species names were available from plants of the world online database (www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:492423-1), African plant database (https://africanplantdatabase.ch/) as well as the website of South African National Biodiversity Institute (http://newposa.sanbi.org/). In these online databases, pictures of plant leaves, stems and flowers exist and botanical names are given and these would be used for comparisons against community given names.

Where the above approach was incomprehensive during fieldwork, plant leaves, stems and fruits were picked for further classification. Where possible, pictures of plant leaves, stems and flowers are taken for further identification by the community, since there are two local languages (Yao and Makua). Local names were confirmed by three community members >30 years old with at least 10 years stay in the area. If different names were given, the majority name was recorded. The above community-based method has been proven in vegetation classification [15].

Community members were asked to give their track memory over 10 years regarding changes and trends in riparian vegetation species. We used household surveys by randomly selecting household heads or an available adult member of the family >30 years in a home. The respondent in the home were asked to give information on riparian species composition and trends.

There were 123 households, where 56 were in Ntimbo 1 and 67 in Lisongole. A sample of 100 households were chosen in the two villages using a stratified random sampling [50]. That meant that we sampled 67.39% of the households in Ntimbo 1 and 76.1% of the households in Lisongole. Photographs of plants that were taken in the field and six plants that could not be classified primarily, were brought to the herbarium at Eduardo Mondlane University in Maputo for classification and confirmation. The herbarium agreed with field results and classified the six that were missing.

During sampling, data on potential ecological disturbances causative land use factors were collected for each plot. Land use activities were recorded if they could be observed existing in the plot (O) and otherwise N/A.

2.4. Data analysis

Data were organized and analysis done to assess species frequencies and diversity and later alone conservation status discussed [51].

The proportion of plots that contain a species was as its frequency species (F).

$$F = \frac{\text{Number of plots in which species occur}}{\text{Total number of plotts sampled}} \times 100.$$

The quantitative composition structure of species were calculated assessing the importance value index (IVI) of each species, which indicates the dominance of species in the ecosystem. The IVI is a measure that combines the relativeness of density, frequency and abundance where in a vegetation ecosystem and these were calculated using the equations below

(a) $\text{Density } (D) = \dfrac{\text{Total number of individuals of a species}}{\text{Total number of plots}}$

(b) $\text{Relative density (RD) \%} = \dfrac{\text{Total No. of individuals of the species}}{\text{Total No. of individuals of all the species}} \times 100$

(c) $\text{Relative frequency (RF) \%} = \dfrac{\text{Frequency of one species}}{\text{Total frequency}} \times 100$

(d) $\text{Abundance of a species } (A) = \dfrac{\text{Total noumber of individuals in all plots}}{\text{Total number of plots in which the species occured}}$

(e) $\text{Relative Abundance (RA) \%} = \dfrac{\text{Abundance of one species}}{\text{Total abundance}} \times 100$

(f) $\text{IVI} = \text{Relative density} + \text{Relative frequency} + \text{Relative abundance}$

Species richness (α-diversity) in each of the plots was used for comparative analysis of interspecific interactions between and within the ecological community [52]. The value of α was used to refer to species availability relative to others in the vegetation community

$$\text{Species richness } (\alpha) = \frac{\text{S}}{\sqrt{\text{N}}}$$

where:

S is the number of observed species

N is the total number of individuals

3. Results

A total of 206 individuals of 19 species were recorded belonging to 15 families (table 3). Species were evenly distributed, occurring across all the sampling plots. River channel plots had a higher number of species than river banks and an averagely decreasing number of species in the downstream direction.

The number of individuals of individual species available was in the order S2 > S3 > S1 (figure 4). The species *Flacourtia indica* (Burm. f.) Merr was present in all the plots. The species *Landolphia kirkii* Dyer ex Hook. f. had the highest total number of individuals (20).

Table 3. Species list.

	Species name	Family	Genus	Local name
1	*Senegalia goetzei* (Harms) Kyal. & Boatwr. subsp *goetzei*	Fabaceae	*Senegalia* Raf.	Nangware
2	*Brachystegia boehmii* Taub	Fabaceae	*Brachystegia* Benth	Ndjombo
3	*Casuarina junghuhniana* Miq.	Casuarinaceae	*Casuarina* L.	Nakajenjema
4	*Cissampelos pareira* L. var. *hirsuta* (Burch. ex DC.) Forman	Menispermaceae	*Cissampelos* L.	Nakananduru
5	*Combretum kraussii* Hochst.	Combretaceae	*Combretum* Loefl	Rwevera
6	*Combretum mossambicense* (Klotzsch) Engl.	Combretaceae	*Combretum* Loefl	Njanjajuni
7	*Croton gossweileri* Hutch.	Euphorbiaceae	*Croton* L.	Likoba
8	*Cyphostemma spinosopilosum* (Gilg & M.Brandt) Desc.	Vitaceae	*Cyphostemma* (Planch.)	Lijumba
9	*Dichrostachys cinerea* (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt	Fabaceae	*Dichrostachys* (A.DC) Wight & Arn.	Nhacanunganunga
10	*Flacourtia indica* (Burm. f.) Merr.	Salicaceae	*Flacourtia* Comm. ex L'Hér	Ntava
11	*Jacaranda mimosifolia* D.Don	Bignoniaceae	*Jacaranda* Juss	Nakangwale
12	*Julbernardia globiflora* (Benth.) Troupin	Fabaceae	*Julbernardia* Pellegr.	Ntchenga
13	*Landolphia kirkii* Dyer ex Hook. f.	Apocynaceae	*Landolphia* P.Beauv	Nakakunde
14	*Pterocarpus lucens* Lepr. ex Guill. & Perr. subsp. *antunesii* (Taub.) Rojo	Fabaceae	*Pterocarpus* Jacq	Nzomba
15	*Strychnos spinosa* Lam.	Loganiaceae	*Strychnos* L.	Nakalunga
16	*Syzygium guineense* (Willd.) DC. subsp. guineense	Myrtaceae	*Syzygium* Gaertn	Ntepera
17	*Vachellia davyi* (N.E.Br.) Kyal. & Boatwr.	Fabaceae	*Vachellia* Wight & Arn.	Nalundatara
18	*Tribulus cistoides* L.	Zygophyllaceae	*Tribulus* L.	Ntimbamwizi
19	*Tapiphyllum velutinum* Robyns	Rubiaceae	*Velutinum* Juss	Ndururu

A big percentage (52.63%) of species had more individuals in the river channel than on the riparian bank; with the exception of *Tribulus cistoides* L., all species were available both in the river channel area and on the bank sides.

Human activities that could result in species loss and ecosystem disturbance that were recorded.

(i) Cutting of trees to make shade in the gardens in preparation for wet season, removing vegetation to create routes for water access, gardens on river edges, river crossing informal bridges (observed at S1, S2 and S3; and also reported by the community).
(ii) Plant harvest for domestic and medicinal purposes (reported by the community),
(iii) Uprooted dead plants and clearing of riparian vegetation in preparation of bankside agriculture (S1, S2 and S3); and
(iv) Walking through, across the river were observed to result in cut stems and plucking of leaves (observed in S1); and uprooting of plants on pathways, leading to water pools, that remain in the river meander rock enclaves (S1 and S3).

All household heads reported that families pick and use parts of green plants of riparian species. There were 47.96% of household heads/representatives who expressed uncertainty over changes in riparian area species; 18.7% reported a decrease; 5.7% reported no change; and 27.64% reported an increase. The harvested parts of the plants were reported by respondents as leaves (43.82%), stems (29.21%) and fruits (26.97%). Specific ecosystem degrading activities that were recorded at plot locations during sampling. These activities were recorded if they existed as O and if not as N/A (table 4).

The IVI ranged from 34.70 (*F. indica* (Burm. f.) Merr) to 4.43 (*T. cistoides* L.). The IVI had a mean of 15.79 $\pm$ 7.79 among the species. High standard deviation means data are not clustered around the mean, which shows species have a wider range in number of plants sampled. The relative density ranges from 15.53 (*F. indica* (Burm. f.) Merr) to 0.49 (*T. cistoides* L).

The number of plants in a single sampling plot ranged from 6 to 54 with average of 17.7. This showed that plants were well distributed in the plots. Species richness ranged from 0.3484 to 1.0451 with a mean of 0.6561 $\pm$ 0.2118. Species are, on average, well balanced in occurrence in the riparian zone, with about half of

Figure 4. Totals of individuals of species in sampling segments.

Table 4. Potential threats to vegetation species.

	Cultivation within 20 m from the river	Up- rooted and cut vegetation	Human walking paths	Cutting of trees and broken stems
S1A1	N/A	O	N/A	N/A
S1B2	O	N/A	N/A	O
S1B3	N/A	O	N/A	N/A
S2A1	N/A	N/A	N/A	N/A
S2A3	O	N/A	N/A	N/A
S2B2	N/A	O	N/A	N/A
S3A3	N/A	N/A	N/A	N/A
S3B2	N/A	N/A	N/A	O
S3B3	N/A	N/A	O	N/A

Table 5. Species frequencies.

Species	Total number	RD (%)	RF (%)	RA (%)	IVI
Senegalia goetzei (Harms) Kyal. & Boatwr. subsp *goetzei*	5	2.43	3.70	3.78	9.91
Brachystegia boehmii Taub	13	6.31	5.56	6.54	18.41
Casuarina junghuhniana Miq.	9	4.37	4.63	5.44	14.44
Cissampelos pareira L. var. *hirsuta* (Burch. ex DC.)	18	8.74	7.41	6.80	22.94
Combretum kraussii Hochst.	5	2.43	3.70	3.78	9.91
Combretum mossambicense (Klotzsch) Engl.	11	5.34	5.56	5.54	16.43
Croton gossweileri Hutch.	7	3.40		3.52	12.48
Cyphostemma spinosopilosum (Gilg & M.Brandt) Desc.	5	2.43	4.63	4.23	11.29
Dichrostachys cinerea (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt	23	11.17	6.48	9.93	27.57
Flacourtia indica (Burm. f.) Merr.	32	15.53	11.11	8.06	34.70
Jacaranda mimosifolia D.Don	4	1.94	3.70	3.02	8.67
Julbernardia globiflora (Benth.)	8	3.88	6.48	3.45	13.82
Landolphia kirkii Dyer ex Hook. f.	20	9.71	7.41	7.55	24.67
Pterocarpus lucens Lepr. ex Guill. & Perr. subsp. *antunesii* (Taub.) Rojo	5	2.43	3.70	3.78	9.91
Strychnos spinosa Lam.	3	1.46	2.78	3.02	7.25
Syzygium guineense (Willd.) DC.	16	7.77	7.41	6.04	21.22
Vachellia davyi (N.E.Br.) Kyal. & Boatwr.	15	7.28	6.48	6.47	20.24
Tribulus cistoides L.	1	0.49	0.93	3.02	4.43
Tapiphyllum velutinum Robyns	6	2.91	2.78	6.04	11.73

them above the mean IVI (table 5). Sampling plot S2 generally had higher numbers of plants for the different species (figure 4).

The study found species that were not on the records of vegetation in the NSR which is in conservation focus and research invitation [47–49]. The limited regional and global distributions of most species found, further shows the uniqueness and conservation value of riparian ecosystems (table 6).

4. Discussion

There were two Combretaceae family species *(Combretum kraussii* Hochst. and *Combretum mossambicense* (Klotzsch) Engl.) These were reported to exist in areas near water bodies [47]. Much as there were no specific studies on riparian biodiversity in the river catchment, the presence of *Syzygium* spp. in vallies and near rivers has also been documented in the Niassa region [40]. The species *Syzygium guineense* has been found to be a dominant in riverine ecosystems in forest rivers of Paraibuna, Ipiranga, and Grande rivers in Brazil [53].

It has previously been shown that vegetation frequency class distribution understanding is crucial for forest conservation [54]. Frequency class distribution studies help to evaluate the factors that control the availability and concentration of species [54]. The results of this study agree with previous work that woodland vegetation species frequency and distribution in arid and semi-arid areas in the dry season is patchy in nature [4].

Most of the species on the river bank plots are characteristically found in river flood plain areas [55]. The riparian vegetation species recorded in this study showed a balanced existence of species in all plots, which is

Table 6. Species global distribution.

Species name	Distribution
Senegalia goetzei (Harms) Kyal. & Boatwr. subsp *goetzei*	Angola, DRC, Ethiopia, Kenya, Tanzania, Mozambique, Zambia, Zimbabwe.
Brachystegia boehmii Taub	Angola, DRC, Tanzania, Malawi, Mozambique, Zambia, Zimbabwe and Botswana.
Casuarina junghuhniana Miq	Java, Lesser Sunda Isl., Thailand, Laos, Vietnam, Myanmar, trop. Africa
Cissampelos pareira L. var. *hirsuta* (Burch. ex DC.) Forman	Latin America, DR Congo, Tanzania, Angola, Zambia, Comors and Madagascar.
Combretum kraussii Hochst.	Mozambique, Swaziland and South Africa.
Combretum mossambicense (Klotzsch) Engl.	Angola, Botswana, Kenya, Malawi, Mozambique, Namibia, South Africa, and Zambia, Zimbabwe.
Croton gossweileri Hutch.	Angola.
Cyphostemma spinosopilosum (Gilg & M.Brandt) Desc.	Afghanistan, Algeria, Angola, Bangladesh, Benin, Botswana, Burkina, Burundi, Cabinda, Cameroon, Cape Provinces, Caprivi Strip, Central African Repu, Chad, China South-Central, Comoros, Congo, Djibouti, East Himalaya, Egypt, Eritrea, Ethiopia, Free State, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Gulf of Guinea Is., Gulf States, India, Iran, Iraq, Ivory Coast, Kenya, Kuwait, KwaZulu-Natal, Laccadive Is., Lebanon-Syria, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Myanmar, Namibia, Niger, Nigeria, Northern Provinces, Oman, Pakistan, Palestine, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Sinai, Socotra, Somalia, Sri Lanka, Sudan, Swaziland, Tanzania, Thailand, Togo, Uganda, Vietnam, Western Sahara, Yemen, Zambia, Zaïre, and Zimbabwe.
Dichrostachys cinerea (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt	Widespread in Africa including Mozambique, Cape Verde and Zanzibar; and Asia.
Flacourtia indica (Burm. f.) Merr.	Central Africa, China, Indonesia, Malawi, Madagascar, Mozambique, India, Sri Lanka, South Africa and Swaziland and Zimbabwe (reported to be widely distributed in Tropical Africa south to northern South Africa).
Jacaranda mimosifolia D.Don	Australia, southern Africa, Hawaii, south-eastern USA, southern South America, Kenya, Uganda and Tanzania.
Julbernardia globiflora (Benth.) Troupin	Botswana, Burundi, DR Congo, Tanzania, Namibia, Zimbabwe and Mozambique.
Landolphia kirkii Dyer ex Hook. f.	Democratic Republic of the Congo, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Somalia and South Africa.
Pterocarpus lucens Lepr. ex Guill. & Perr. subsp. *antunesii* (Taub.) Rojo	Angola, Botswana, Malawi, Mozambique Namibia, Zambia and Zimbabwe.
Strychnos spinosa Lam.	South Africa, Swaziland, Namibia, Botswana, Malawi, Mozambique, Zambia, Zimbabwe, Kenya, Tanzania, Uganda, D.R. Congo (Zaire), Gambia, Senegal, Guinea-Bissau, Guinea, Ivory Coast, Burkina Faso, Sierra Leone, Liberia, Togo, Ghana, Sudan, South Sudan, Cameroon, Nigeria, Equatorial Guinea, Central African Republic, Gabon, Congo (Brazzaville), Benin, Angola, Somalia, Ethiopia, Seychelles, Madagascar, Mauritius, La Runion, Comores and USA.
Syzygium guineense (Willd.) DC. subsp. guineense	Botswana, Namibia, Saudi Arabia, Senegal, Somalia, South Africa and Yemen.
Tribulus cistoides L.	Cape Verde, Eritrea Kenya, Mozambique, Tanzania, South Africa, Togo, Zanzibar, Madagascar, Mauritius, Kenya, Bolivia, Columbia, Ecuador, -Galapagos Islands, Peru, Venezuela, Papua New Guinea, New Caledonia, Marshall Islands, Kiribati, Guam, French Polynesia, Cook Islands, Western Australia, Queensland, Hawaii, Jamaica, Puerto Rico, South Wales, Australia, USA, Trinidad and Tobago, Puerto Rico, Panama, Mexico, Jamaica, Honduras, Guatemala, Grenada, Bahamas, Dominican Republic, Antigua and Barbuda, Anguilla, Taiwan, India, Sri Lanka, Indonesia, Yunnan, Hainan and China
Tapiphyllum velutinum Robyns	Burundi, Malawi, Mozambique, Zambia, Zimbabwe.
Vachellia davyi (N.E.Br.) Kyal. & Boatwr.	South Africa

an indicator of unique season resilient vegetation community species that support inter- and intra-ecosystem functions.

Human activities that were recorded in the riparian area and proximity, as well as evidence of ecosystem destruction, are a danger for vegetation species conservation. These are inherent risks of ecosystem disturbance that may affect regeneration and diversity of species. There is a need for conservation managers to plan to mitigate vegetation ecosystem destabilization by human activities because the river catchment is in a wildlife conservation area and there are existing and growing ecosystem destruction threats.

There was a decrease in vegetation species frequencies downstream, which is possibly caused by impacts of the Marrupa—Mecula road passes between the last two segments (S1 and S3) downstream. The recorded land use activities and observed vegetation destruction are a challenge that calls for vegetation ecosystem protection from loss in the ecosystem.

The presence of sandy soil in riparian areas of rivers like the Incalaue means vegetation is shallow-rooted and vulnerable to uprooting, especially when accessible to people as water gets lower in the dry season [56]. The nature of hilly landscape with sandy soil in a forested landscape can explain the presence of more vegetation in the flood plain riparian areas because of erosion, seed and plant deposits [57, 58].

This study found rare and threatened species in the region and globally, which additionally calls for riparian vegetation ecosystems conservation. Some of the species of conservation value identified have been previously recorded in threatened riverine ecosystems in Southern Africa [59, 60]. The study found 10 species endemic to the East and South African Region. A fraction of the (21.05%) species identified are on record to exist only in the Southern Africa region by global distribution. Among species in the Southern Africa region, there were 36.84% already on record for other countries but not Mozambique. One species *Croton gossweileri* Hutch is on record to exist only in Angola in the sub-Saharan African region. The presence of new unique species initially not on record for Mozambique and the NSR calls for more research on species distribution across the reserve.

The presence of human land use pressure in the study area threatens ecosystem diversity with loss and destruction. The 1997 Mozambique National Land Policy established a clear rights-based approach to land rights that freely guarantees land for Mozambicans in community settlements within the NSR and under the Direito do Uso e Aproveitamento da Terra land tenure rights. This can provide communities a right to stay in the ecologically sensitive ecosystem areas they occupy, within a wildlife reserve, if land use planning for riparian species protection is not set well in advance.

Species that have IVI like *F. indica* (Burm. f.) Merr (34.70), *Dichrostachys cinerea* (L.) Wight & Arn. subsp. africana Brenan & Brummitt (27.57), *L. kirkii* Dyer ex Hook. f. (24.67), *Cissampelos pareira* L. var. hirsuta (Burch. ex DC.) (22.94), *S. guineense* (Willd.) DC. (21.22) and *Vachellia davyi* (N.E.Br.) Kyal. & Boatwr (20.24) may not necessarily be ecologically important, but rather could be due to an invasive nature or introduction into the community, which has made them dominant.

Species like *T. cistoides* L. (4.43), *S. spinosa* Lam (7.25) and *Jacaranda mimosifolia* D. Don (8.67) that had lower values of IVI became a conservation question, depending on the social and ecological values of the species given, that 100% of the respondents agreed with the community harvest and use of species. Species richness ranged from 0.3484 to 1.0451 with a mean of 0.6561 ± 0.2118 and the ecosystem had the lowest values in the plots near the road and human river crossing areas.

5. Conclusion

This study carried out species inventory using community based, species identification and classification from secondary and online databases. These proved useful and helped determine species composition and identify new species in the study area. A total of 206 individuals belonging to 19 species of 15 families were recorded.

There was species diversity beyond the Mozambique list for the Niassa region; and there was evidence of vegetation ecosystems being affected due to anthropogenic disturbances. The study found species of local and global conservation concern due to limited global distribution of the IUCN list of threatened species. There were new species not previously on record to exist in the NSR and those recorded to exist only in the Southern Africa region. This study showed a need for specific botanical inventory of riparian vegetation ecosystems in the NSR. The discovery of vegetation community uniqueness showed a need for adaptive ecological management in the NSR to promote conservation based on detailed landscape patch assessments.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

Acknowledgments

We acknowledge the PhD study fellowship for Dr Ezrah Natumanya from Regional Exchange for Enhanced Skills in Fragile Ecosystems Management in Africa project funded by the Intra-Africa Academic Mobility Schemene of the European Union which supported this research. We also acknowledge support from World Conservation Society for logistical support contribution during data collection. We have confirmed that any identifiable participants in this study have given their consent for publication. We acknowledge support that was provided by the local community leaders and the people of Ntimbo 1 and Lisongole communities who welcomed this research and mobilised people at different stage.

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