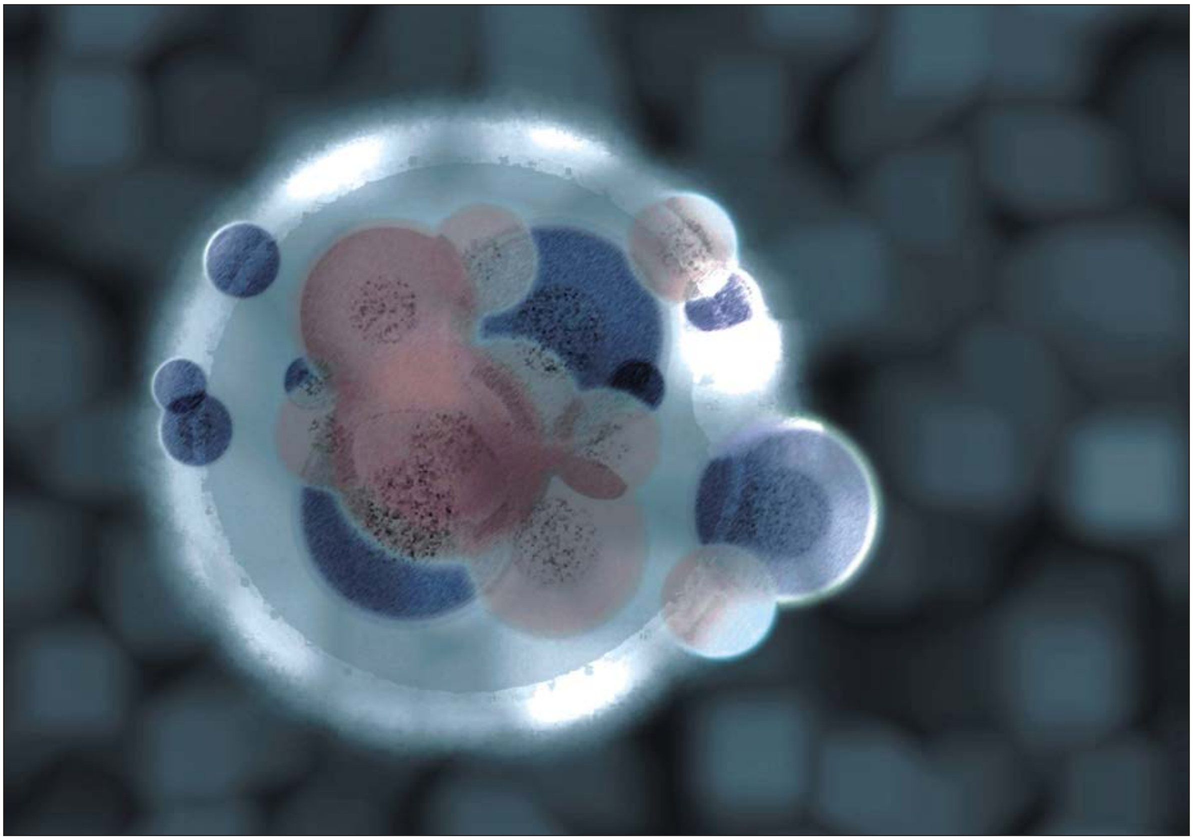

Journal of Biological Sciences

ISSN 1727-3048

OPEN ACCESS Journal of Biological Sciences

ISSN 1727-3048
DOI: 10.3923/jbs.2017.288.297

Research Article
Floristic Composition and Diversity in Tsitsa River Catchment Area, the Eastern Cape Province, South Africa

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Abstract

Background and Objective: Assessment of vegetation in catchment areas need to be assessed and understood in terms of plant diversity, ecological processes and functions that support appropriate ecosystem goods and services. The aim of this study was to assess plant species composition and diversity within the Tsitsa river catchment area in the Eastern Cape province, South Africa. **Materials and Methods:** Nineteen square plots measuring 5×5 m were established in Tsitsa river catchment area. Within each plot, environmental data and species present were recorded including Braun-Blanquet cover-abundance values for all species present in the plot. Vegetation and environmental data were analyzed using palaeontological statistics (PAST) version 3.06. **Results:** In total of 78 plant species were recorded belonging to 24 families and 57 genera. Among the documented species, 11.5% are exotic to South Africa. Plant families with the highest number of species were: *Asteraceae* with 15 species, followed by *Poaceae* with 14 species, *Cyperaceae* (10 species), *Fabaceae* and *Rubiaceae* (5 species each), *Lobeliaceae* (3 species), *Acanthaceae*, *Asphodelaceae*, *Lamiaceae*, *Oxalidaceae*, *Polygalaceae*, *Scrophulariaceae*, *Verbenaceae* and *Vitaceae* (2 species each). Six main floristic clusters were identified from the hierarchical cluster analysis (HCA) and detrended correspondence analysis (DCA). Results from canonical correspondence analysis (CCA) revealed that species composition was mainly influenced by calcium, carbon, erosion, magnesium, potassium and the slope of the landscape. **Conclusion:** The diverse species diversity and composition documented is due to several environmental factors particularly calcium, carbon, erosion, magnesium, potassium and the slope of the landscape.

Key words: Anthropogenic activities, braun-blanquet, floristic composition, grassland biome, riparian vegetation

Citation: Pelisa Ngcaba and Alfred Maroyi , 2017. Floristic composition and diversity in tsitsa river catchment area, the Eastern Cape province, South Africa. J. Biol. Sci., 17: 288-297.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Vegetation in catchment areas is being lost at an alarming rate mainly due to land use changes[1], as artificial alterations of the hydrological cycle and the drowning of alluvial riparian vegetation influences growth, survival and species composition resulting in major negative impact on their functions and conservation. Such land use changes result in rapid transformation in plant and animal communities, drastically altering not only the ecological processes and functions that maintain appropriate ecosystem goods and services but also adversely impacting the livelihood needs of local communities. Van Rooyen *et al.*[2] argued that species habitats and their diversity need to be assessed and understood as knowledge on habitat types, environmental determinants, dynamics and biodiversity enable researchers to evaluate impacts of major developmental projects such as dam construction and plan for conservation of biodiversity in catchment areas. According to Kuma and Shibru[3] plant diversity, regeneration status, floristic composition and vegetation structure are crucial elements to clearly visualize the anthropogenic activities as well as environmental factors affecting the vegetation of an area. Therefore, information on floral diversity is a fundamental requirement to understand ecosystem type, biodiversity composition and other ecological parameters pertaining to biodiversity management and conservation planning at local, regional and global levels. Other researchers such as Ssegawa and Nkuutu[4] argued that botanical assessments are crucial in identifying plant diversity, protecting threatened and economic species, monitoring the status of reserves and understanding the extent of plant diversity in natural ecosystems. Hence, the vegetation analysis enables us to build a mental picture of an area under investigation, compare and ultimately classify communities of the vegetation and understand the relationship that exists within communities and among their environments[5]. It is within this background that an assessment of floral composition and diversity in the Tsitsa river catchment area, site of the proposed Ntabelanga dam in the Eastern Cape province, South Africa was carried out.

The Department of Water and Sanitation, South Africa commissioned the construction of Ntabelanga dam on the Tsitsa river catchment area in the Eastern Cape province, South Africa. The proposed Ntabelanga dam is an integrated multi-purpose dam aimed at rejuvenating domestic and industrial water supply, irrigation and hydroelectric power purposes, tourism, conservation and other related activities. According to the Department of Water and Sanitation (DoWS)[6], the proposed Ntabelanga dam has a storage capacity of 490 million m^3 and is estimated to supply potable water to 730,000 people by the year 2050. The dam will also provide water to irrigate approximately 2,900 ha of arable land and there will be a small hydropower plant at the dam to generate between 0.75 and 5 MW (average 2.1 MW)[6]. Research by Van Tol *et al.*[7] revealed that large dams play an important role in rejuvenating economic and social development but are often associated with environmental degradation through permanent inundation of previously dry areas, alteration of stream flow regimes, reduction in natural flooding and fragmentation of river ecosystems, thereby reducing species diversity. Overall, there is a dearth of detailed vegetation phytosociological studies in Southern Africa showing plant diversity in catchment areas, floristic composition and pattern. Such vegetation studies can be used to understand the pattern and processes influencing vegetation occurrence in catchment areas and ecological impacts of dam construction in catchment areas. The present study therefore, was aimed at filling this knowledge gap by assessing plant species composition and diversity within the Tsitsa river catchment area in the Eastern Cape province, South Africa.

MATERIALS AND METHODS

Study area: The study was conducted in the Tsitsa river catchment area within Elundi Local Municipality in the Joe Gqabi District Municipality of the Eastern Cape province, South Africa. The Eastern Cape province is characterized by landlessness, pervasive chronic poverty, low levels of education, economic activity, vulnerability, lack of basic services, a dearth of employment opportunities and high levels of dependency on welfare[8]. Tsitsa river catchment area is located on 31°7 35.9 S and 28°40 30.6 E. The study area receives an annual rainfall of about 749 mm, with most of it falling in December and January, with the lowest (15 mm) average rainfall received in June and the highest (108 mm) in January[9]. The study area is underlain by sedimentary rocks of the Tarkastad subgroup and Beaufort karoo supergroup with post karoo doleritic intrusions[9]. Tsitsa river catchment area is characterized by highly unstable soils that are prone to erosion as evidenced by extensive areas of severe gully erosion on the inter-fluvial areas adjacent to stream channels and these erosional and piping characteristics are suggestive of the presence of dispersive soils[9]. Mucina and Rutherford[10] described the vegetation of the study area as sub-escarpment grassland and sub-escarpment savanna bioregions dominated by moist grasslands and *Acacia* spp. This vegetation type occurs at an altitude of 880-1860 m above sea level with the landscape characterized by moderately rolling hills[10].

Households in Tsitsa river catchment area have small permanent arable land between 0.1 and 0.5 ha of the 1 ha homestead land allocated to them by the tribal authorities to subsistence agriculture[7]. The arable lands are typically consolidated rainfed farming areas, which can be made up of several plots (1-3 ha or more)[7]. With high levels of poverty, low levels of economic activity and the poor quality of land allocated to Tsitsa river catchment area residents, non-farm activities are potentially an important source of livelihood for the residents.

Sampling data collection: Fieldwork was conducted between March and November, 2016 in Tsitsa river catchment area. Nineteen plots measuring 5×5 m, based on the results of a species-area curve[11] determined prior to the sampling process were used to assess plant species composition and abundance via the Braun-Blanquet survey technique[11]. The exact locality of each plot was recorded using Global Positioning System (GPS). Within each sample plot, the habitat information and species present were recorded. A cover-abundance value was assigned to each species present in a sample plot according to the Braun-Blanquet cover-abundance scale[11-14] as shown in Table 1. Plant species were identified in the field and the taxon names conform to those of Germishuizen *et al.*[15]. Unknown plant species were collected, pressed, dried and identified by taxonomists of the Giffen Herbarium (UFH), University of Fort Hare. The following environmental data were collected from every quadrat following methods outlined by Omar *et al.*[16]: C (%), Ca (cmol kg^{-1}), clay (%), erosion (%), herb height (cm), K (cmol kg^{-1}), litter cover (%), Mg (cmol kg^{-1}), Na (cmol kg^{-1}), NH_4-N (mg L^{-1}), NO_3-N (mg L^{-1}), pH, rock cover (%), sand (%), silt (%), slope (%), total vegetation cover (%) and tree height (cm). Multivariate data analysis was performed on the vegetation data to explore the floristic variation, to detect and visualize similarities in the plots[16].

Data analysis: Canonical correspondence analysis (CCA) was performed using Palaeontological Statistics[17], version 3.06. Patterns of plant species composition in relation to the measured environmental factors were analyzed using CCA. Detrended correspondence analysis (DCA) was performed on the same data set using Palaeontological Statistics[17]. According to Legendre and Legendre[18], CCA and DCA are direct gradient analysis techniques that relate species composition and abundance to environmental variation enabling the significant relationship between plant species and environmental variables to be determined. Factors hypothesized to influence vegetation composition and abundance in this study were captured in a spreadsheet as environmental variables.

RESULTS

In total 78 plant species were recorded from the study conducted within the Tsitsa river catchment area and these plants are grouped into 24 families and 57 genera (Table 2). Among recorded plant species, 11.5% are exotic to South Africa and the rest are indigenous to the country. Plant families with the highest number of species were: *Asteraceae* with 15 species, followed by *Poaceae* with 14 species, *Cyperaceae* with 10 species, *Fabaceae* and *Rubiaceae* with

Table 1: Braun-Blanquet cover-abundance codes, values and median values[11-14]

Braun-Blanquet code	Cover (%)	Median cover (%)
R	<5	1
+	<5	2
1	<5	3
2m	<5	4
2a	5-12.5	8
2b	12.5-25	18
3	25-50	38
4	50-75	68
5	75-100	88

Table 2: List of plant species recorded from eight sites in Tsitsa river catchment area. Species marked with an asterisk (*) are exotic to South Africa

Scientific name	Family	Plots in which species were recorded
Acacia karroo Hayne	*Fabaceae*	18
Aloe arborescens Mill.	*Asphodelaceae*	12
Aloe ferox Mill.	*Asphodelaceae*	6
Andropogon eucomus Nees.	*Poaceae*	5, 17
Anthospermum galioides Rchb. f. spp. galioides	*Rubiaceae*	6, 7, 8, 18, 19
Aristida congesta Roem. and Schult. spp. *barbicollis* (Trin. and Rupr.) De Winter	*Poaceae*	4, 5, 6, 7, 8, 10, 15, 16, 19
Asparagus laricinus Burch.	*Asparagaceae*	6
Berkheya discolor (DC.) O. Hoffm. and Muschl.	*Asteraceae*	6
Berkheya bipinnatifida (Harv.) Roessler ssp. *bipinnatifida*	*Asteraceae*	12
Bulbine abyssinica A. Rich.	*Asphodelaceae*	1, 2, 3
Bulbostylis contexta (Nees) M. Bodard	*Cyperaceae*	2, 17
Bulbostylis densa (Wall.) Hand.-Mazz. ssp. *afromontana* (Lye) R. W. Haines	*Cyperaceae*	6
Bulbostylis hispidula (Vahl) R. W. Haines ssp. *pyriformis* (Lye) R. W. Haines	*Cyperaceae*	4, 5, 10
Cineraria spp.	*Asteraceae*	14
Chamaecrista capensis (Thunb.) E. Mey. var. *capensis*	*Fabaceae*	16

Table 2: Continued

Scientific name	Family	Plots in which species were recorded
Commelina africana L. var. *africana*	*Commelinaceae*	18
Conostomium spp.	*Rubiaceae*	5
**Conyza bonariensis* (L.) Cronquist	*Asteraceae*	2
Crabbea hirsuta Harv.	*Acanthaceae*	1, 2, 19
Crassula setulosa Harv. var. *setulosa*	*Crassulaceae*	12
Cussonia paniculata Eckl. and Zeyh. spp. *paniculata*	*Araliaceae*	6
Cynodon dactylon (L.) Pers.	*Poaceae*	2, 3, 4, 6, 9, 10, 16
Cyperus brevis Boeck.	*Cyperaceae*	7, 8, 15, 18
Cyperus congestus Vahl	*Cyperaceae*	6
Cyperus esculentus L. var. *esculentus*	*Cyperaceae*	6
Cyperus spp.	*Cyperaceae*	17
Cyphostemma spp.	*Vitaceae*	6
Digitaria ternata (A. Rich.) Stapf	*Poaceae*	14
Eragrostis chloromelas Steud.	*Poaceae*	1, 4, 5, 6, 7, 11, 14
Eragrostis gummiflua Nees	*Poaceae*	4, 5, 17
Erigeron spp.	*Asteraceae*	1
Euphorbia inaqualatera Sond. var. *inaqualatera*	*Euphorbiaceae*	16
Ficinia brevifolia Kunth.	*Cyperaceae*	1
Ficinia deusta (P. J. Bergius) Levyns	*Cyperaceae*	7, 8, 14, 15, 18, 19
Helichrysum cerastioides DC. var. *cerastioides*	*Asteraceae*	6
Helichrysum glomeratum Klatt	*Asteraceae*	1, 3, 4, 6, 7, 8, 13, 15, 16, 17, 18, 19
Helichrysum odoratissimum (L.) Sweet	*Asteraceae*	2, 10, 11, 14
Hermannia parviflora Eckl. and Zeyh.	*Malvaceae*	6
Hyparrhenia hirta (L.) Stapf	*Poaceae*	5, 7, 9, 11, 12, 14, 16, 17, 18, 19
Hyparrhenia spp.	*Poaceae*	13
Hypoestes forskaolii (Vahl) R. Br.	*Acanthaceae*	2, 12
Hypoxis argentea Harv. ex Baker var. *sericea* Baker	*Hypoxidaceae*	1, 7, 15, 18
Indigofera spp.	*Fabaceae*	6, 8, 19
Kalanchoe rotundifolia (Haw.) Haw.	*Crassulaceae*	6
Kyllinga alata Nees	*Cyperaceae*	2, 4, 10, 14
Lantana rugosa Thunb.	*Verbenaceae*	6
Lobelia flaccida (C. Presl) A. DC. ssp. *flaccida*	*Lobeliaceae*	17
Lobelia spp.	*Lobeliaceae*	10
Lobelia thermalis Thunb.	*Lobeliaceae*	13
Melinis repens (Willd.) Zizka ssp. *repens*	*Poaceae*	5
Microchloa caffra Nees	*Poaceae*	4, 6, 7, 8, 11
Nidorella pinnata (L. f.) J. C. Manning and Goldblatt	*Asteraceae*	12, 13, 14, 19
**Oenothera rosea* L'Hér. ex Aiton	*Onagraceae*	16
Oxalis smithiana Eckl. and Zeyh.	*Oxalidaceae*	13
Oxalis spp.	*Oxalidaceae*	2, 4, 6, 16
**Paspalum distichum* L.	*Poaceae*	13
Polygala amatymbica Eckl. and Zeyh.	*Polygalaceae*	1, 8
**Richardia brasiliensis* Gomes	*Rubiaceae*	18
**Richardia humistrata* (Cham. and Schltdl.) Steud.	*Rubiaceae*	4, 6, 7, 8, 9, 10, 11, 13, 14, 16, 17, 19
Rubia spp.	*Rubiaceae*	2
Rumex spp.	*Polygonaceae*	2
**Schkuhria pinnata* (Lam.) Kuntze ex Thell.	*Asteraceae*	16
Selago spp.	*Scrophulariaceae*	16
Senecio decurrens DC.	*Asteraceae*	1
Senecio inaequidens DC.	*Asteraceae*	6
Senecio retrorsus DC.	*Asteraceae*	11, 12, 15, 19
Setaria sphacelata (Schumach.) Moss var. *sericea* (Stapf) Clayton	*Poaceae*	2
Sporobolus africanus (Poir.) Robyns and Tournay	*Poaceae*	6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19
Sporobolus fimbriatus (Trin.) Nees	*Poaceae*	9, 10, 12, 13, 16, 17
Stachysa ethiopica L.	*Lamiaceae*	12
Sutera cooperi Hiern	*Scrophulariaceae*	6
**Taraxacum officinale* Weber	*Asteraceae*	2, 3, 4, 5, 8, 9, 13, 14, 17, 18
Tephrosia capensis (Jacq.) Pers. var. *acutifolia* E. Mey.	*Fabaceae*	12, 13
Teucrium trifidum Retz.	*Lamiaceae*	6, 19
Tulbaghia acutiloba Harv.	*Alliaceae*	1, 18
**Verbena* spp.	*Verbenaceae*	17
**Zinnia peruviana* (L.) L.	*Asteraceae*	6
Zornia capensis Pers. ssp. *capensis*	*Fabaceae*	7, 8, 9, 13, 18

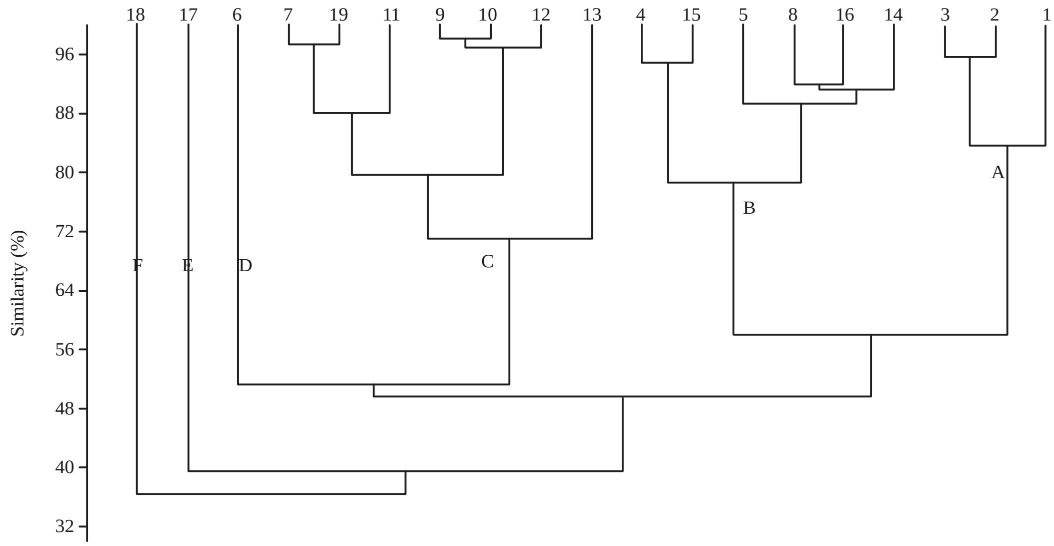

Fig. 1: Hierarchical cluster analysis dendogram classification of vegetation plots based on weighted species presence

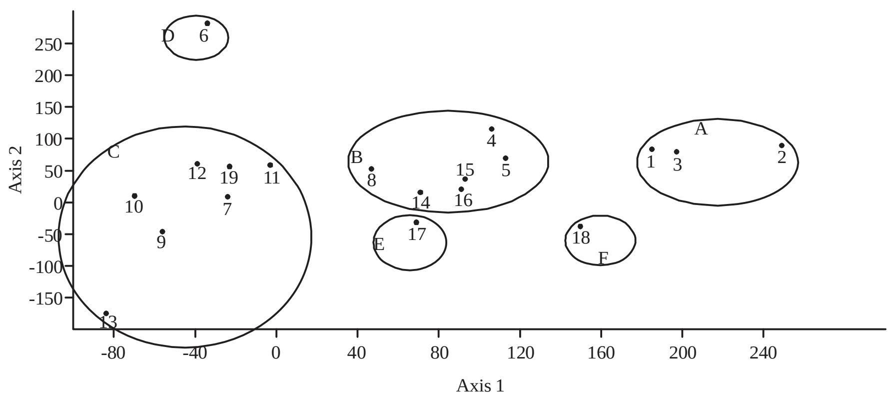

Fig. 2: Detrended correspondence analysis (DCA) ordination diagram showing the grouping of six vegetation types (A-F) identified in Tsitsa river catchment area

5 species each, *Lobeliaceae* with 3 species and *Acanthaceae*, *Asphodelaceae*, *Lamiaceae*, *Oxalidaceae*, *Polygalaceae*, *Scrophulariaceae*, *Verbenaceae* and *Vitaceae* with 2 species each. The rest of the plant families were represented by a single species each (Table 2). The most common genera in descending order of frequency were *Cyperus* with four species followed by *Bulbostylis*, *Helichrysum*, *Lobelia* and *Senecio* with three species each and *Berkheya*, *Eragrostis*, *Finicia*, *Hypparrhenia*, *Oxalis*, *Richardia* and *Sporobolus* with two species each (Table 2).

Six main floristic clusters were derived from the hierarchical cluster analysis (HCA) out of nineteen sampled plots (Fig. 1). The analysis presented about 35% similarity among the six clusters (Fig. 1). Similar results were obtained by detrended correspondence analysis (DCA) which separated 19 plots into six main clusters (Fig. 2). Results from canonical correspondence analysis (CCA) revealed that species composition was mainly influenced by calcium, carbon, erosion, magnesium, potassium and the slope of the landscape (Fig. 3).

The floristic and environmental characteristics of the six clusters are summarised below:

Cluster A: A total of 19 species were recorded on this cluster, ruled by way of perennial herbs and grasses namely *Bulbine abyssinica*, *Crabbea hirsuta*, *Cynodon dactylon*, *Helichrysum glomeratum* and *Taraxanum officinale* with *Bulbine abyssinica* recorded in this cluster scarcely (Table 3). Some of the plots were rocky, with an overage rock cover of

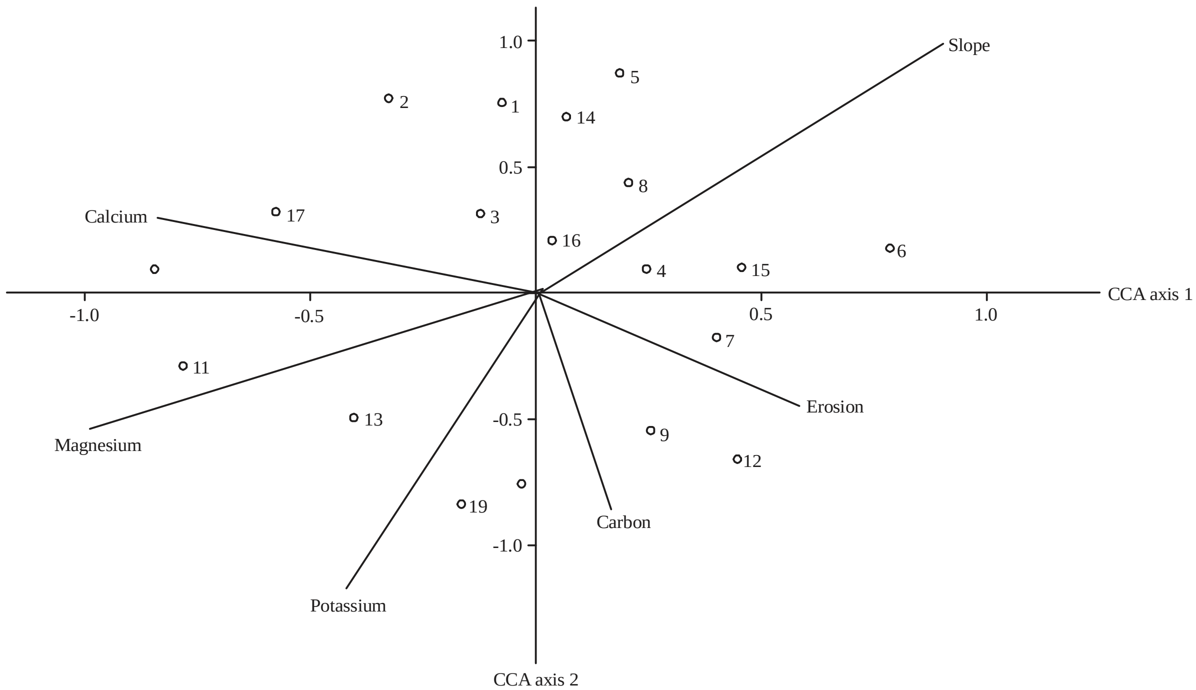

Fig. 3: Canonical correspondence analysis (CCA) ordination scatter plot indicating the influence of environmental variables on species composition in Tsitsa river catchment area

approximately 8.5%. This cluster had the least carbon and sodium content of 0.29% and 23.43 cmol kg^{-1} respectively (Table 3)

Cluster B: An overall of 33 species have been recorded on this cluster, dominated by annual and perennial herbs, shrubs and grasses specifically namely *Aristida congesta* spp. *barbicollis*, *Ficinia deusta*, *Helichrysum glomeratum*, *Hyparrhenia hirta*, *Richardia humistrata*, *Sporobolus africanus* and *Taraxanum officinale* (Table 3). Unique plant species recorded in this cluster only include *Chamaecrista capensis*, *Euphorbia inaqualatera* var. *inaqualatera*, *Cineraria* spp., *Conostomium* spp., *Digitaria ternata*, *Schkuhria pinnata* and *Selago* spp. (Table 3). This cluster had the highest average vegetation cover, carbon content and were commonly flat in comparison with other clusters

Cluster C: A total of 33 plant species have been recorded on this cluster was dominated by perennial herbs and grasses namely *Helichrysum glomeratum*, *Hyparrhenia hirta*, *Richardia humistrata*, *Sporobolus africanus*, *Sporobolus fimbriatus* and *Zornia capensis* (Table 3). This cluster had the lowest sand content and maximum silt and ammonium nitrogen contents (Table 3)

Cluster D: This cluster consisted of a single plot characterised through a total of 24 plant species. Thirteen plant species were recorded in this cluster only including annual plants such as *Bulbostylis densa* ssp. *afromontana* and *Zinnia peruviana*. The majority of the common plant life in this cluster were either perennial herbs, shrubs or trees, which included *Aloe ferox*, *Asparagus laricinus*, *Berkheya discolor*, *Cussonia paniculata* ssp. *paniculata*, *Cyphostemma* spp., *Helichrysum cerastioides* var. *cerastioides*, *Kalanchoe rotundifolia*, *Lantana rugosa*, *Senecio inaequidens*, *Sutera cooperi* and *Teucrium trifidum* (Table 3). This cluster had the lowest litter cover and maximum slope, tree height, pH, calcium, nitrate nitrogen and clay content in comparison with other clusters (Table 3)

Cluster E: This cluster consisted of a single plot characterised by a total of 12 plant species. Plant species common on this cluster and recorded in this cluster only included annual or perennial herbs such as *Cyperus* spp., *Lobelia flaccida* ssp. *flaccida* and *Verbena* spp. (Table 3). This cluster had the highest sand content and the lowest pH, potassium, calcium, magnesium, nitrate nitrogen, clay and silt contents in comparison with other clusters (Table 3)

Table 3: Summary of floristic associations with environmental variables assessed in eight sites within the Tsitsa river catchment area

	Floristic clusters					
	A	B	C	D	E	F
No. of plots	3	6	7	1	1	1
No. of species	19	33	31	24	12	13
No. of genera	18	31	29	22	11	13
No. of families	10	11	12	13	6	8
Common species	*Bulbine abyssinica, Crabbea hirsuta, Cynodon dactylon, Helichrysum glomeratum, Taraxanum officinale*	*Aristida congesta* spp. *barbicollis, Ficinia deusta, Helichrysum glomeratum, Hyparrhenia hirta, Richardia humistrata, Sporobolus africanus, Taraxanum officinale*	*Helichrysum glomeratum, Hyparrhenia hirta, Richardia humistrata, Sporobolus africanus, Sporobolus fimbriatus, Zornia capensis*	*Aloe ferox, Asparagus laricinus, Berkheya discolor, Bulbostylis densa* ssp. *afromontana, Cussonia paniculata* ssp. *paniculata, Cyphostemma* spp., *Helichrysum cerastioides var. cerastioides, Kalanchoe rotundifolia, Lantana rugosa, Senecio inaequidens, Sutera cooperi, Teucrium trifidum, Zinnia peruviana*	*Cyperus* spp., *Lobelia flaccida* ssp. *flaccida, Verbena* spp.	*Acacia karroo, Commelina africana* var. *africana, Richardia brasiliensis*
Unique species	*Bulbine abyssinica*	*Chamaecrista capensis, Euphorbia inaqualatera* var. *inaqualatera, Cineraria* spp., *Conostomium* spp., *Digitaria ternata, Schkuhria pinnata,*	0	*Aloe ferox, Asparagus laricinus, Berkheya discolor, Selago* spp. *Bulbostylis densa* ssp. *afromontana, Cussonia paniculata* ssp. *paniculata, Cyphostemma* spp., *Helichrysum cerastioides* var. *cerastioides, Kalanchoe rotundifolia, Lantana rugosa, Senecio inaequidens, Sutera cooperi, Teucrium trifidum, Zinnia peruviana*	*Cyperus* spp., *Lobelia flaccida* ssp. *flaccida, Verbena* spp.	*Acacia karroo, Commelina africana* var. *africana, Richardia brasiliensis*
Mean values of environmental variables						
Total vegetation cover (%)	71.70	82.50	80.30	65.00	75.00	60.00
Litter cover (%)	5.00	5.00	4.40	2.00	5.00	10.00
Rock cover (%)	8.30	0.00	0.00	0.00	0.00	0.00
Slope (%)	20.00	5.83	14.30	70.00	10.00	10.00
Erosion (%)	5.00	0.00	0.00	5.00	5.00	0.00
Tree height (cm)	120.00	40.00	150.00	500.00	0.00	0.00
Herb height (cm)	28.30	25.83	22.50	25.00	15.00	40.00
pH	5.04	5.36	5.05	5.68	5.00	5.17
K (cmol kg^{-1})	39.72	81.31	90.20	101.43	34.75	127.75
Na (cmol kg^{-1})	23.43	32.97	54.70	28.98	40.86	79.33
Ca (cmol kg^{-1})	479.08	808.32	843.50	1186.77	303.56	1035.02
Mg (cmol kg^{-1})	170.00	298.00	382.00	407.00	102.00	493.00
NO_3-N (mg L^{-1})	0.40	0.62	0.64	0.78	0.20	0.48
NH_4-N (mg L^{-1})	1.18	1.14	1.30	0.93	0.65	0.35
C (%)	O.29	5.06	1.11	0.99	0.66	1.52
Clay (%)	21.00	21.70	21.00	23.00	13.00	21.00
Silt (%)	16.00	17.30	19.90	13.00	10.00	16.00
Sand (%)	63.00	61.00	59.10	64.00	77.00	63.00

Cluster F: This cluster consisted of a single plot characterised by a total of 13 plant species. Plant species not usual in this cluster and recorded in this cluster only included *Acacia karroo*, perennial herbs such as *Commelina africana* var. *africana* and *Richardia brasiliensis* (Table 3). This cluster had the lowest vegetation cover and the highest litter cover, potassium, sodium, magnesium and ammonium nitrogen contents in contrast with other clusters (Table 3)

DISCUSSION

Results of this study provided baseline data such as species diversity and composition in Tsitsa river catchment area. With the exception of *Verbenaceae* and *Vitaceae*, the rest of major plant families recorded in this study *Acanthaceae*, *Asphodelaceae*, *Asteraceae*, *Cyperaceae*, *Fabaceae*, *Lamiaceae*, *Lobeliaceae*, *Oxalidaceae*, *Poaceae*, *Polygalaceae*, *Rubiaceae* and *Scrophulariaceae* are among the largest families in South Africa characterized by at least 100 species each[15]. Among the common species recorded in 30% of the plots included eight indigenous species namely, *Aristida congesta* spp. *barbicollis*, *Cynodon dactylon*, *Eragrostis chloromelas*, *Ficinia deusta*, *Helichrysum glomeratum*, *Hyparrhenia hirta*, *Sporobolus fimbriatus* and *Sporobolus africanus*. Exotic species recorded in 30% of the plots included *Richardia humistrata* and *Taraxacum officinale*. These two exotic species together with five additional exotic species recorded in this study namely *Conyza bonariensis*, *Oenothera rosea*, *Richardia brasiliensis*, *Richardia humistrata*, *Schkuhria pinnata*, *Taraxacum officinale* and *Zinnia peruviana* have been recorded in other provinces of South Africa[19]. All these exotic plant species recorded in this study are also recognized weeds in several countries throughout the word and are listed in the global compendium of weeds[20]. Documentation of exotic plants and weeds is important as such records can contribute to the global knowledge of invasive alien plants in South Africa[19] because one of the useful predictors of invasiveness is whether a species is invasive elsewhere in the world or not[21].

Plant species identified in this study as components of the six clusters shown in Fig. 2-3, as well as Table 2 and 3 corroborate earlier findings by Mucina and Rutherford[10] that the area is characterized by about six vegetation types. These vegetation types which are characteristic of Tsitsa river catchment area and its surrounding areas include the Bisho thornveld, Drakensberg foothill moist grasslands, East Griqualand grassland, Eastern valley bushveld, Mabela sandy grassland and Mthata moist grassland[10]. The following species which are key elements of the Bisho thornveld have been documented in this study (Table 2): *Cynodon dactylon*, *Eragrostis chloromelas*, *Hyparrhenia hirta*, *Hypoxis argentea*, *Kyllinga alata*, *Microchloa caffra* and *Sporobolus africanus*[10]. According to Mucina and Rutherford[10], Drakensberg foothill moist grasslands which was represented by *Eragrostis chloromelas, Helichrysum odoratissimum, Hyparrhenia hirta, Microchloa caffra, Senecio retrorsus* and *Sporobolus africanus* in the current study is moderately rolling and mountainous, incised by river gorges of drier vegetation. The following species which are key elements of East Griqualand grassland have been documented in this study: *Acacia karroo, Aristida congesta, Digitaria ternata, Eragrostis chloromelas, Hyparrhenia hirta, Microchloa caffra, Senecio retrorsus* and *Sporobolus africanus*[10]. In the current study, Eastern valley bushveld vegetation type was represented by *Aristida congesta*, *Hyparrhenia hirta*, *Melinis repens* and *Sporobolus fimbriatus*. Mabela sandy grassland vegetation type was represented by *Aristida congesta*, *Cynodon dactylon*, *Digitaria ternata*, *Eragrostis chloromelas*, *Eragrostis gummiflua*, *Hyparrhenia hirta*, *Microchloa caffra*, *Paspalum distichum* and *Setaria sphacelata*. Mthata moist grassland was represented by *Cynodon dactylon*, *Hermannia parviflora*, *Hyparrhenia hirta*, *Microchloa caffra*, *Richardia humistrata*, *Senecio retrorsus* and *Sporobolus africanus*. Previous studies by Mucina and Rutherford[10] revealed that alien species such as *Richardia humistrata* is widespread in Mthata moist grassland and regarded as a conservation concern.

The present study revealed that species composition is often influenced by environmental factors such as calcium, carbon, erosion, magnesium, potassium and the slope of the landscape. Similar results were obtained by Fonge *et al.*[22] showed that plant diversity, distribution and abundance in Lewoh-Lebang in the Lebialem highlands of southwestern Cameroon was affected by organic carbon, nitrogen, calcium and cation exchange capacity of the soil. Similarly, Ahmed *et al.*[23] found that calcium carbonate, magnesium, organic matter, pH, salinity (electrical conductivity) and sodium contributed to the distribution of plant species and plant communities in Omayed Biosphere reserve in Egypt. Many types of human-influenced disturbances such as dam construction in catchment areas are known to influence riparian ecosystems. Research by Ceschin *et al.*[24] revealed that severe alterations in the catchment's hydromorphological and biological features are associated with dam construction which usually lead to the development of riparian and aquatic communities. Such riparian and aquatic developments include an increase in the number of vegetation types in comparison with the natural aquatic environment pre-existing the dam construction[24]. Results obtained in this study are important for monitoring any changes in the vegetation and other environmental factors of Tsitsa river catchment area due to land use changes. Such baseline data will be used to assess any changes in the environmental factors, floristic diversity, composition and structure caused by the planned construction of Ntabelanga dam within Tsitsa river catchment area. After the dam has been constructed, vegetation succession is expected in response to several environmental factors and the identification of the principle environmental factors and dominant vegetation types are viewed as major challenges in trying to understand ecological processes in a transformed landscape.

CONCLUSION

The vegetation of Tsitsa river catchment area is fairly diverse, characterised by 78 plant species and at least six vegetation types. The identified vegetation types included the Bisho thornveld, Drakensberg foothill moist grasslands, East Griqualand grassland, Eastern valley bushveld, Mabela sandy grassland and Mthata moist grassland. Such diverse vegetation types may imply that the environmental conditions in Tsitsa river catchment are favourable for a wide range of plant species. Each of these vegetation types reflects the homogeneity of the plant communities in terms of plant species composition and dominance. Therefore, the uniqueness of each vegetation type documented in Tsitsa river catchment area may be due to a combination of various environmental factors such as such as calcium, carbon, erosion, magnesium, potassium and the slope of the landscape.

SIGNIFICANCE STATEMENTS

This study showed that catchment areas are characterized by diverse plant species and vegetation types. Key environmental factors found to influence plant species diversity and composition included calcium, carbon, erosion, magnesium, potassium and the slope of the landscape. Results of this study will help researchers to uncover critical environmental factors likely to have an effect on species diversity and composition. Thus, insights into vegetation ecosystem structure and composition should also evaluate environmental variables.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Water Research Commission (WRC, grant number K8/1027), National Research Foundation (NRF grant number T398) and Govan Mbeki Research and Development Centre (GMRDC, grant number C169), University of Fort Hare for financial support to conduct this study.

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