NYIKA-VWAZA TRUST RESEARCH STUDY REPORT

Conservation Status of *Juniperus procera* in Nyika National Park, Malawi

By

ANDREW KANZUNGUZE
(Nature-WEB Africa)
akanzunguze@natwebafrica.org +265(0)-991-205-780

April 2022

SUMMARY

Background: With funding from the Nyika-Vwaza (UK) Trust subsequent to an excursion to the Juniper Forest in Nyika National Park in 2019 (October), a survey was carried out to assess the conservation status of the forest following decades of deliberate fire management in the area to encourage regeneration of the species.

Objectives: The key objectives were to;

- Determine the structure (and condition) of the Juniper Forest population.
- Map the distribution of Juniper trees beyond the current forest boundary.

Methodology: The survey was carried out in two phases; an inventory of the Juniper Forest in October (2020) and a survey of the adjoining environs of the Juniper Forest (1.5km away) for the presence of Juniper trees in October (2021).

Key findings: The current juniper forest covers about 107.26 hectares with average tree height and diameter 23.1m and 21.2cm respectively, and largest recorded height and diameter of 75.4m and 161cm respectively. Size distribution of *J. procera* trees is continuous, with a majority of trees (62.8%) falling in the 10-30cm diameter class and 29.1% of sampled individuals being randomly distributed regenerants (<10cm dbh) within the forest precincts. The trees are neither distributed in a clumped nor even pattern and no significant correlations ($p>0.05$, $-0.1<r<0.1$) were observed between number and distribution of regenerants with any forest attributes such as canopy cover, stocking density, basal area and location. *J. procera* trees are randomly distributed along streams and forest patches at the mouths of valleys beyond the main forest, occurring as both individual trees and clusters of up to 40 trees. No regenerants were observed beyond the plantation, as no evidence of significant damage to the existing *J. procera* trees were observed.

Conclusion and Recommendations: The survey concluded that the fire management program has played in favour of conserving the *J. procera* forest population in Nyika National Park. In light of the common occurrence of fires on the Nyika, and susceptibility of *J. procera* trees to the same, it was recommended that the program be intensified and continued. Furthermore, research towards propagation of the species is recommended in view of the low regeneration rates and reports over prior successful efforts in propagating the species.

ACKNOWLEDGEMENTS

Nyika-Vwaza Trust (UK) is greatly thanked for the financial assistance towards this work. The Department of National Parks and Wildlife is also thanked for allowing the research work to be done in Nyika National Park and supporting with logistics. I acknowledge the insights of Mr. G. Z. Nxumayo and Prof. L. Mwabumba in the early stages of the survey design to ensure it remains relevant for both park management and the scientific community. Further recognition goes to Cosmas Dambo, Justice Mughogho, Henry Chabwera and Eric Gowero for their support during both phases of the survey. In a special way, I also acknowledge the unselfish support of Sopani Sichinga in especially helping make sense of the collected data and developing the report. Last but not least, I thank my wife for being supportive and constantly pushing for completion of the work when my energies had waned.

Contents

LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

DNPW	Department of National Parks and Wildlife Malawi
DBH	Diameter at Breast Height
GPS	Geographic Information System
NNP	Nyika National Park
PPF	Peace Parks Foundation
QGIS	Quantum Geographic Information Systems
WGS	World Geodetic System

INTRODUCTION

Background of the Study

A recent excursion to the Juniper Forest in Nyika National Park in October 2019 revealed that the DNPW initiative of making firebreaks to protect *Juniperus procera* populations may have actually been a success, as evidenced in regenerants growing on the margin of the original forest boundary. This raised two major questions for enquiry. Firstly, what is the current population structure of the Juniper Forest? Secondly, is there any regeneration of *J. procera* occurring within or beyond the Juniper Forest? If yes, what is their condition and status? Lumped together, these questions were thought to help shed light on the conservation status of *J. procera* in relation to efficacy of the DNPW fire management initiative towards conservation of the forest in Nyika National Park.

Description of the *J. procera*

Juniperus procera (African pencil cedar), an Afromontane tree, is a conifer species distributed in tropical regions of Africa, often reaching 30-35m high and sometimes up to 50m, and is the largest tree of its genus (Negash 2010; Palgrave, 2002). Although a widespread genus in the northern hemisphere, *J. procera* is the only species to occur in the southern hemisphere (Burrows, 1995). Specifically, *J. procera* is indigenous to the mountainous regions and highlands of eastern African countries (Farjon, 2013), and has its widest distribution in the highlands of Ethiopia and the Arabian Peninsula among others (Burrows, 1995; Timberlake & Osborne, 2014). Whilst the species is of 'least concern' at the global level according to the IUCN red-list of endangered species, its populations in local areas across its range[1] are reported as declining and therefore threatened (Farjon, 2013). The pressures contributing to this include illegal tree felling and/or logging activity, little natural regeneration, and recruitment failure of seedlings to maturity due to seedling damage and mortality.

The Juniper forest in Nyika National Park

Juniperus procera forest in Nyika National Park (Malawi), was first discovered in around 1920-30 (Carter, 1954). Located on the rocky higher altitudes (between 2135-2230m) in the south eastern corner of the park, this Juniper forest is of special importance as it represents the most southerly viable stand of *Juniperus procera* in Africa (Johnson, 2017), although the very southernmost is represented by a single (protected) tree only found in

[1] Specifically, Democratic republic of Congo, Djibouti, Eritrea, Ethiopia, Kenya, Malawi, Saudi Arabia, Somalia, Uganda, Yemen and Zimbabwe

the Inyanga mountains of Zimbabwe (Burrows 1995). According to Msekandiana and Mlangeni (2002), this population is also considered threatened.

Historically, this relic patch of Juniper forest was the first area of Nyika to receive official protection when it was declared a forest reserve in 1948, and this marked the genesis of today's Nyika National Park (Briggs 1998; Willis et al. 2001; Gordon, 1993). Upon its discovery, a good lot of the forest is reported to have been logged to support construction of the church and other infrastructure at Livingstonia Mission up to about the mid-1900s. Much later in between 1970-75, Juniper logs were also used in construction of the Chalets at Chelinda camp on the Nyika plateau (Gordon, 1993). Evidence of such logging activity (e.g., old abandoned sawing pits and logs) can still be seen today within the forest precincts (**Error! Reference source not found.**).

As a way to protect and conserve the forest in Nyika, a fire protection program was introduced by the department of forestry (then) soon after its discovery largely owing to its susceptibility to damage by fires (Gordon, 1993). Since then, regular area patrols and firebreak maintenance activities have remained a priority to DNPW as part of conservation efforts of Juniper Forest.

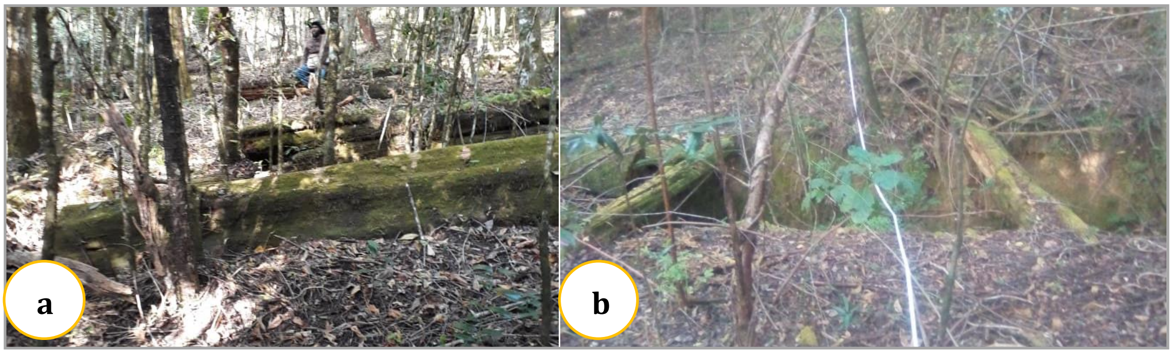

Figure 1: Old sawn logs of Juniperus procera (a) and sawing pits (b) within Juniper forest in Nyika National Park, Malawi

Problem Statement

Despite the sustained effort to protect and conserve the *Juniperus procera* population in Nyika National Park through the DNPW fire protection program, an appraisal of its effectiveness has been wanting. To date, there has been little information, if any, generated on the *J. procera* population in terms of its structure and/or forest condition, recruitment potential and/or regeneration status since a fire protection program commenced. Additionally, its ecological status in relation to the immediate environs in general has remained speculative as to warrant any further management attention or action. This study therefore purposed to fill this information gap towards conservation of this southernmost *J. procera* population.

Objectives & Research Questions

Specific objectives and associated research questions guiding the survey were as follows;

Objective 1: To determine the structure (and condition) of the Juniper Forest in NNP.

Research questions*:*

- What is the current vegetation structure of trees within the Juniper Forest in Nyika National Park?
- Where is regeneration successfully occurring within the Juniper Forest?
- Is the regeneration of *Juniperus procera* seedlings episodic or continual?

Objective 2: To map the distribution of *Juniperus procera* population beyond the current forest boundary in NNP.

Research questions*:*

- Are there any patches of *Juniperus procera* beyond the original firebreak?
- What is their condition relative the DNPW fire management practice?
- Is there a pattern to the distribution of Juniper patches beyond the firebreak?

Significance of the Study

It is expected that the information generated will be of primary use to DNPW in appraising the implications of their fire management program in protecting the forest and encouraging seedling regeneration. Additional insights produced on the population structure and ecological dynamics of the *J. procera* forest will provide a basis from which effective and sustainable management strategies for conservation of Juniper Forest can be developed, including a possible ecological monitoring and management plan, with strong possibilities of revitalizing ecotourism aspects associated with the species and its immediate environment on the Nyika plateau. Finally, the findings are also expected to contribute to the existing literature on *J. procera* ecology by being compiled into at least a manuscript for journal publication.

METHODOLOGY

The methodology employed to address both objectives and associated research questions are outlined in the following subsections;

Study Area

The study was conducted in Nyika National Park wherein is a population of *Juniperus procera* forming part of its vegetation types. The Nyika Juniper forest, located at 10° 45' 0" S; 33° 52' 59" E, is a discrete patch covering 107.28ha in the south-eastern corner of the park (Figure 2). It occurs on higher altitude slopes at between 2135-2230m (7,000-7,500 ft.) in an expanse of grassland, separated by an annually managed firebreak from the rest of the grassland plateau, and split by a stream into north-western and south-eastern patches. The forest is generally semi-open with scattered shrubs and small trees. Alien invasives (e.g., Himalayan raspberry and Bracken fern) dominate the forest margins and openings/clearings on the northern portion of the patch (Figure 3).

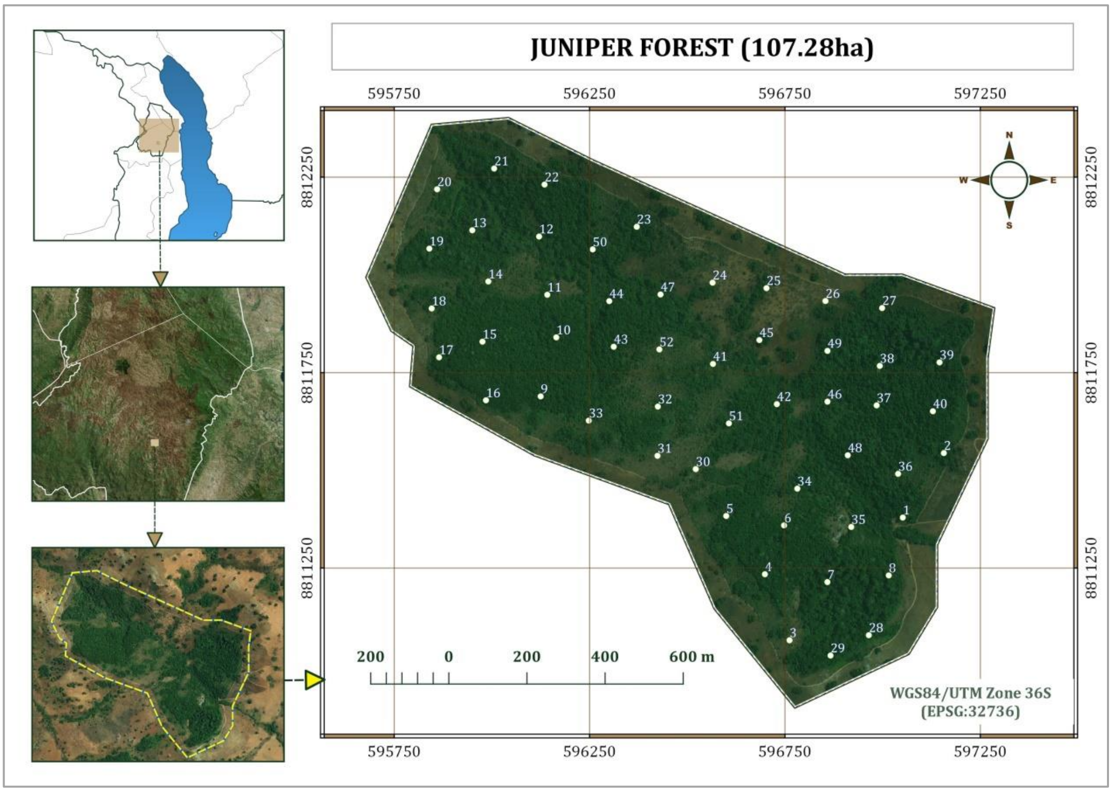

Figure 2: Location of the Juniper Forest in NNP and distribution of sampling plots.

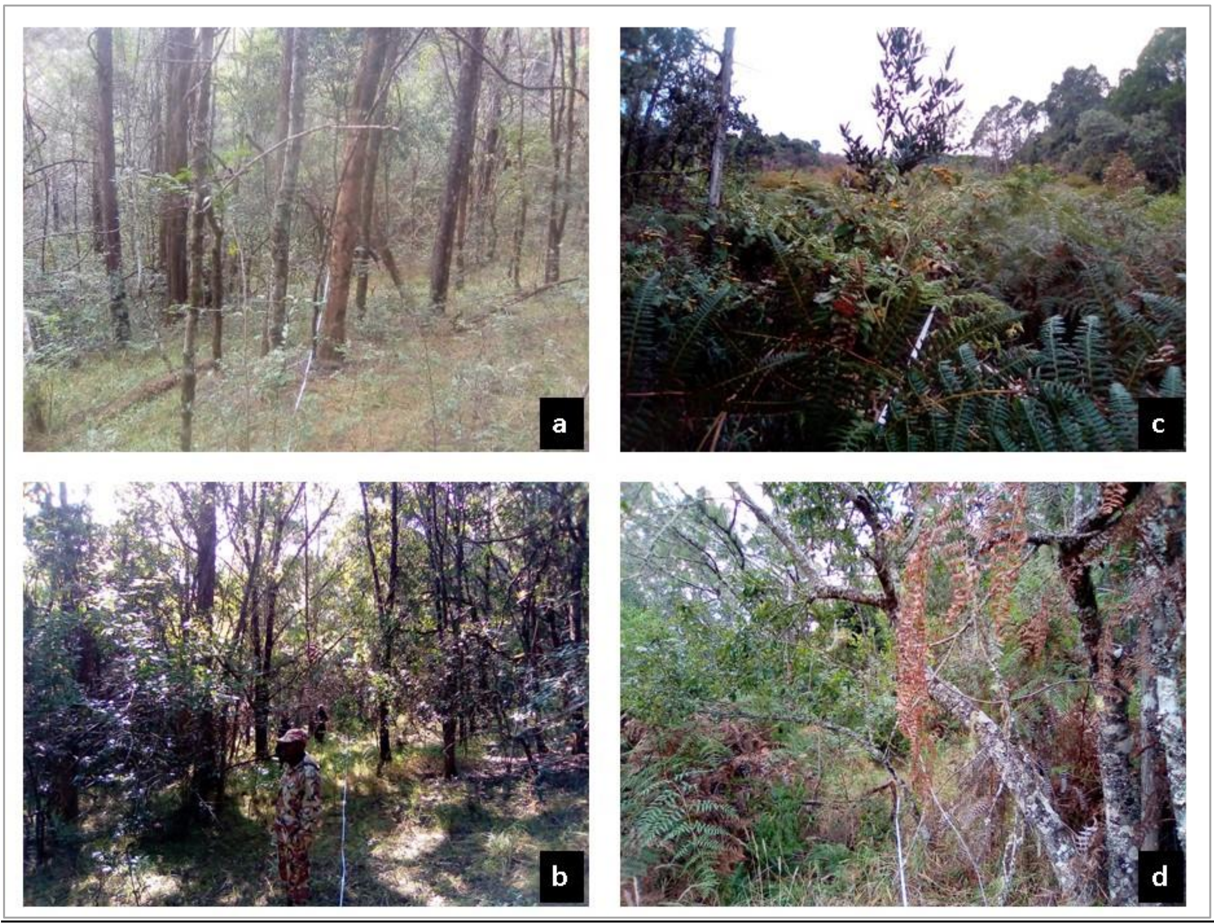

Figure 3: Typical Juniper forest in the North (a), and South (b) portions, with bracken fern patches in openings (c) and fringes (d)

Sampling Procedure

Both plots and transects were used to collect data from field surveys carried out in October of 2020 and 2021. A total of 52 plots (25m x 25m each) were determined for use in sampling the entire forest area. These were randomly distributed with a minimum inter-plot distance of 150m using the research tools vector functions in QGIS (Figure 2), and adjusted accordingly where the terrain proved a barrier to access. Four transects were trekked around the Juniper Forest in the north, south, east and western directions within a 1.5km buffer of the Juniper Forest. This buffer consisted of the immediate environs of the Juniper Forest enclosed within a ridgeline/watershed, including all rivers and streams (**Error! Reference source not found.**).

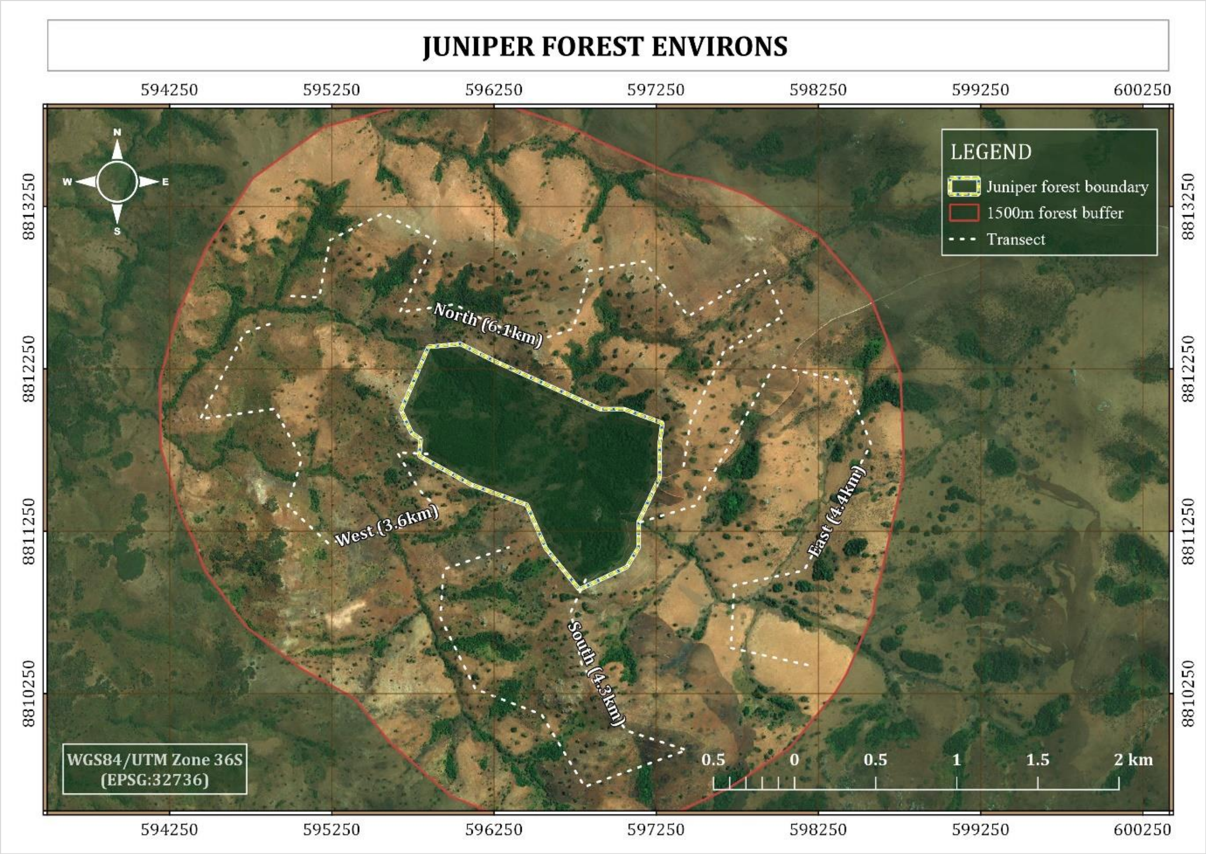

Figure 4: Transects surveyed beyond Juniper Forest boundary

Data Collection

At each plot (accessed using a GPS device), canopy cover (%), slope (°), aspect, tree height (m), diameter (cm), number of trees, and number of regenerants (i.e., trees ≤10cm dbh) were recorded. Canopy cover was determined using a spherical densiometer. Tree height, slope and aspect were recorded with the use of a campus-clinometer, and tree diameter was determined using a diameter tape.

Along each transect where a juniper species was sighted, an estimate of the tree height (for single trees) or dominant height (for a cluster of trees) was made using a tape measure and campus-clinometer to record the distance to the tree (meters) and two angles to the top and base of the selected dominant trees (at least 3). Distances were estimated from experienced judgement of three foresters where the terrain was inaccessible. Tree diameters were determined using a diameter tape, and also estimated using the experienced judgement of three foresters where the terrain was inaccessible. A GPS coordinate (in WGS 84 datum) was recorded at each sighting and are all presented in Annex 1.

Data Analysis

Using plot data, Dominant height (H_{dom}), Quadratic mean diameter (D_q), Stocking density (S), Stand Basal Area ($\mathcal{G}$) and Canopy Cover (C) were calculated. As for transect data, distances from the main forest, tree heights and diameters, as well as abundance (size) of patches were summarized and visualised using spatial mapping functions in QGIS. Inferential statistics for vegetation parameter associations (i.e., correlations) and multiple group comparisons (independent T-test/ Mann-Whitney test and ANOVA/Kruskal Wallis) were carried out using paleontological statistics (PAST) version 3.

FINDINGS

Structure (and condition) of the *J. procera* forest population

What is the current vegetation structure of trees within the Juniper forest?

Results revealed that the spatial distribution of *Juniperus procera* trees across the forest precincts is neither even nor necessarily clumped. Juniper trees toward the north-eastern side of the forest are fairly mixed with other large tree species, with the mid-section of the forest largely semi-open with juvenile trees of Juniper, and the western side of the forest having a fair share of mature trees. In addition to trees in large openings within the forests being smaller, juniper trees with large diameters (>60cm) and tall heights (>20m) were more characteristic of the forest interiors than margins (Figure 5).

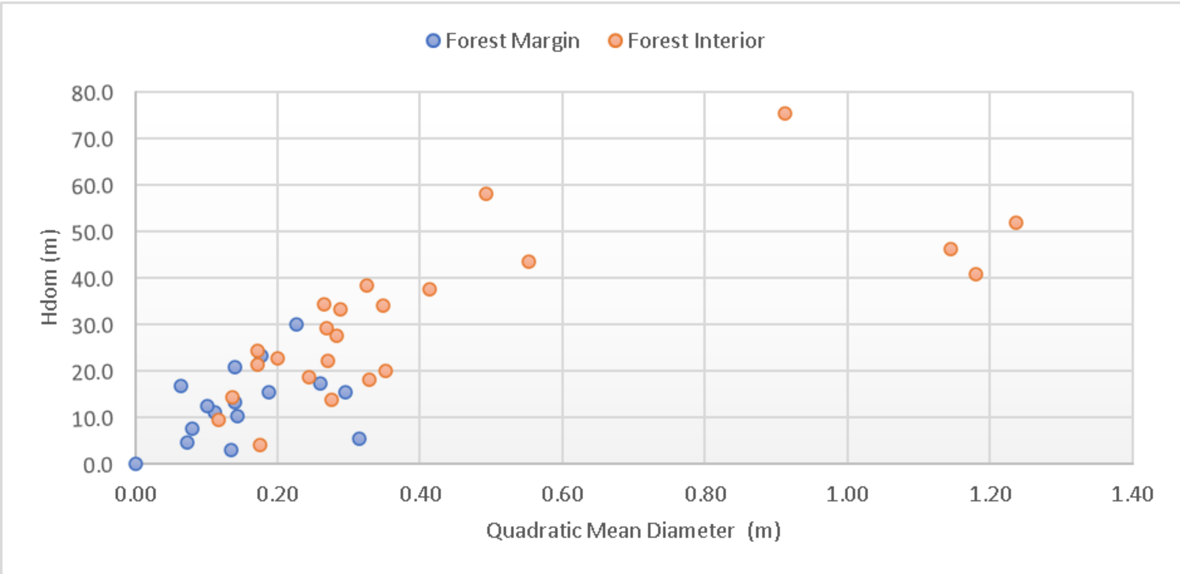

Figure 5: Association between H_{dom} and D_q, segmented by plot location.

The average dominant height (H_{dom}) and diameter of trees in the forest were 23.1m and 21.2cm respectively, with largest diameter and height recorded of up to 161cm and 75.4m respectively. The largest stocking density recorded was 752stems per hectare, which was negatively correlated to the stem diameter (r,-0.316; p, 0.047) as is expected that trees with smaller stem sizes can occupy more space. Canopy cover (%) was moderately correlated with dominant height (r, 0.501; p, 0.001) and diameter (r, 0.318; p, 0.023) as is expected of large healthy trees. Juniper trees were generally significantly shorter (p, 0.028) on the forest margins (16.1m) than interiors (26.2m) of the forest. Table 1 presents a summary of the vegetation characteristics of juniper trees within the Juniper Forest.

Table 1: Summary statistics of vegetation characteristics of the Juniper Forest.

Plot ID	# Trees	# Regenerants	Dominant Height (Hdom)	Quadratic Mean Diameter (Dq)	Stocking density (stems/ha)	Basal Area (sqm/ha)	Canopy Cover (%)	Location
1	16	7	22.7	0.20	256	8.0	56.6	interior
2	12	3	16.8	0.06	192	0.6	56.9	interior
3	7	6	5.3	0.31	112	8.7	9.1	margin
4	21	5	15.4	0.19	336	9.2	78.8	interior
5	22	4	10.2	0.14	352	5.8	59.8	interior
6	45	16	14.4	0.14	720	10.6	70.6	interior
7	2	0	40.8	1.18	32	35.0	67.8	interior
8	5	0	46.3	1.15	80	82.5	70.4	interior
9	9	0	18.2	0.33	144	12.2	69.3	interior
10	10	0	37.5	0.41	160	21.5	71.2	interior
11	20	3	18.7	0.24	320	14.9	74.1	interior
12	18	8	24.2	0.17	288	6.7	51.7	interior
13	**7**	**0**	**75.4**	**0.91**	**112**	**73.1**	**65.4**	**interior**
14	11	5	9.5	0.12	176	1.9	40.4	interior
15	26	3	19.9	0.35	416	40.4	68.1	interior
16	14	0	15.3	0.29	224	15.3	58.9	margin
17	29	1	17.3	0.26	464	24.5	59.8	margin
18	41	14	23.3	0.18	656	16.1	63.3	margin
19	26	20	20.8	0.14	416	6.4	67.1	margin
20	10	11	12.4	0.10	160	1.3	69.1	margin
21	5	2	43.4	0.55	80	19.2	71.1	margin
22	19	13	22.0	0.27	304	17.5	68.3	margin
23	19	25	33.3	0.29	304	19.8	65.9	margin
24	3	4	4.6	0.07	48	0.2	9.1	margin
25	24	14	13.3	0.14	384	5.9	62.6	margin
26	0	0	0.0	0.00	0	0.0	15.7	margin
27	1	1	2.9	0.14	16	0.2	46.2	margin
28	1	0	4.1	0.18	16	0.4	74.1	margin
29	4	0	51.7	1.24	64	76.8	67.1	margin
30	23	56	11.1	0.11	368	3.6	16.6	margin
31	8	12	7.6	0.08	128	0.7	18.1	margin
32	47	18	13.7	0.28	752	44.7	68.3	interior
33	33	3	29.9	0.23	528	21.2	65.6	interior
34	38	7	34.3	0.26	608	33.4	75.0	interior
35	32	6	21.4	0.17	512	11.7	67.9	interior
36	7	7	27.4	0.28	112	7.1	72.4	interior
37	11	1	34.1	0.35	176	16.7	61.4	interior
38	6	2	29.1	0.27	96	5.4	76.1	interior
39	4	0	58.0	0.49	64	12.2	74.4	interior
40	11	0	38.3	0.33	176	14.6	68.3	interior
43	18	14	6.8	0.30	288	14.0	*	interior
44	22	0	33.6	0.30	352	30.4	*	interior
45	20	0	24.5	0.30	320	17.4	*	interior
46	27	24	3.9	0.10	432	6.0	*	interior
47	2	0	2.2	0.40	32	3.8	*	Margin
48	19	6	23.5	0.20	304	7.9	*	interior
49	1	0	16.0	0.10	16	0.2	*	margin
50	7	0	11.5	0.10	112	1.1	*	interior

NB: Cells with asterisk (*) did not have data collected due to lack of field equipment. Plot 13 had the largest trees.

It is reported by Gordon (1993) and Johnson (2017) that there were attempts to cultivate and plant juniper seedlings in the past (about mid-90s). Such attempts appear to have shown success as it is currently evident in the field where some areas of the juniper forest structurally resemble typical man-made plantations when it comes to espacement commonness of diameters and height. Most of the south-central portion of the forest is made of trees about 15m height and 30cm dbh and standard espacement of about '4m x 4m' in contrast to other portions of the forest with more variability of the same parameters (see Figure 6). This observation perhaps explains why Happold and Happold (1989) as well as Johnson (2017) report an estimated total coverage of this 'relic Juniper Forest patch' to have been about 10ha and 9ha respectively (though the methods for attaining such figures are unavailable) while the current study recorded a total coverage of the forest of 107.28 ha. The difference could be attributed to the assumption that the current stated hectares (107.28) combine the entire area of the juniper forest, including other trees and riverine features within the road boundary/firebreak regardless of whether the juniper was planted or not.

Figure 6: Forest variations in Juniper understorey as managed (a) and natural (b) in NNP

Where is regeneration successfully occurring within the Juniper Forest?

Regeneration of *Juniperus procera* was random, being observed in both open and closed spaces within the fire-protected areas of the Juniper forest. The distribution of regenerants (<10cm DBH) within the defined forest precincts was considered random across the area, seeing as there were no significant correlations ($p>0.05$, $-0.1<r<0.1$) between number of regenerants and any forest attributes such as canopy cover, stocking density, basal area and location (Table *1*Table *2*). Kruskal Wallis test revealed no significant differences (p, 0.653) in the abundance of regenerants at different levels of canopy exposure (i.e., closed, semi-closed, semi-open, open) whether compared against stocking density (Figure 7) or basal area (Figure 8). The same was true for distribution of regenerants between the interior and exterior plots based on the Mann-Whitney test, where differences in distribution of regenerants were not significant (p, 0.437). This strongly suggests that more factors influence the regeneration of *J. procera* besides the 'window of opportunity' created for seedling establishment in open spaces.

As Juniper is diecious (that with separate male and female trees), the random distribution of *J. procera* regenerants could give a hint on the distribution pattern of seed trees within the forest as equally random. However, it doesn't shed much light on the prevailing narrative that *J. procera* regeneration is significantly influenced by canopy exposure. Based on additional observations by Aynekulu et al., (2009) who also observed no significant difference in *J. procera* seedling density between open and closed/protected sites of a juniper forest in northern Ethiopia, this pattern could be natural of the species. Taking into account the observations of Couralet and Bakamwesiga (2007) as reported by Timberlake and Osborne (2014) that regeneration of *J. procera* may not be limited because of a lack of viable seed, further enquiry could be essential to elucidate the germination trends and any other ecological/environmental factors influencing regeneration of the species in-situ.

Table 2: Correlation outputs for number of regenerants with canopy cover (%), stocking density (stems/ha) and basal area (m^2/ha)

Correlation statistic	**Cover** (%)	**Stocking density** (stems/ha)	**Basal Area** (m^2/ha)
Pearson's r	0.078	-0.065	0.079
P-value	0.631	0.659	0.593

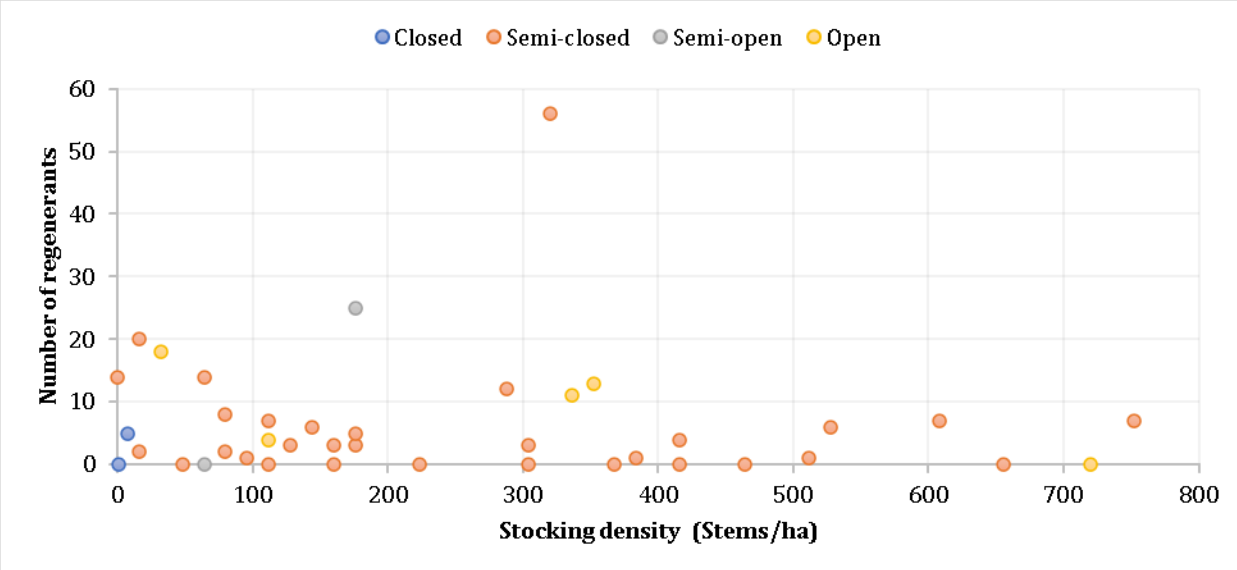

Figure 7: Correlation between number of regenerants and stocking density by canopy cover.

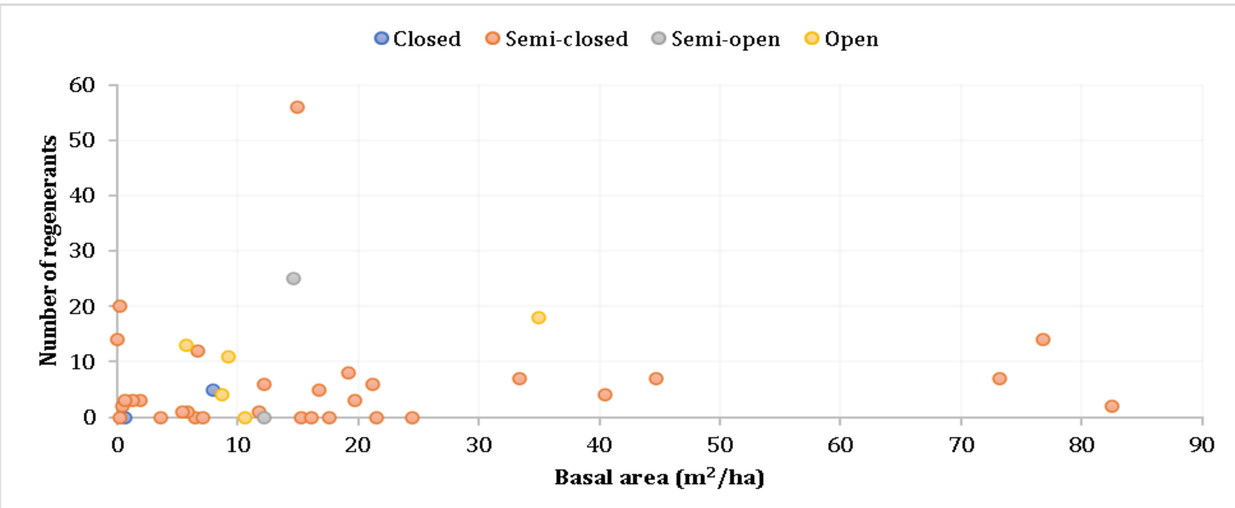

Figure 8: Correlation between number of regenerants and basal area by canopy cover.

Is the regeneration of Juniperus procera episodic or continual?

Results revealed that regeneration of *Juniperus procera* is continual. Based on a distribution of diameter classes (Figure 9), 29.1% of the sampled individuals were regenerants (<10cm DBH), 62.8% were between the 10cm and 30cm diameter classes (32.1% in 11-20cm class; 20.4% in 21-30cm class), 6.8% comprising stems with diameters between 41cm and 100cm, and the remaining 1.3% comprising stems greater than 100cm in diameter.

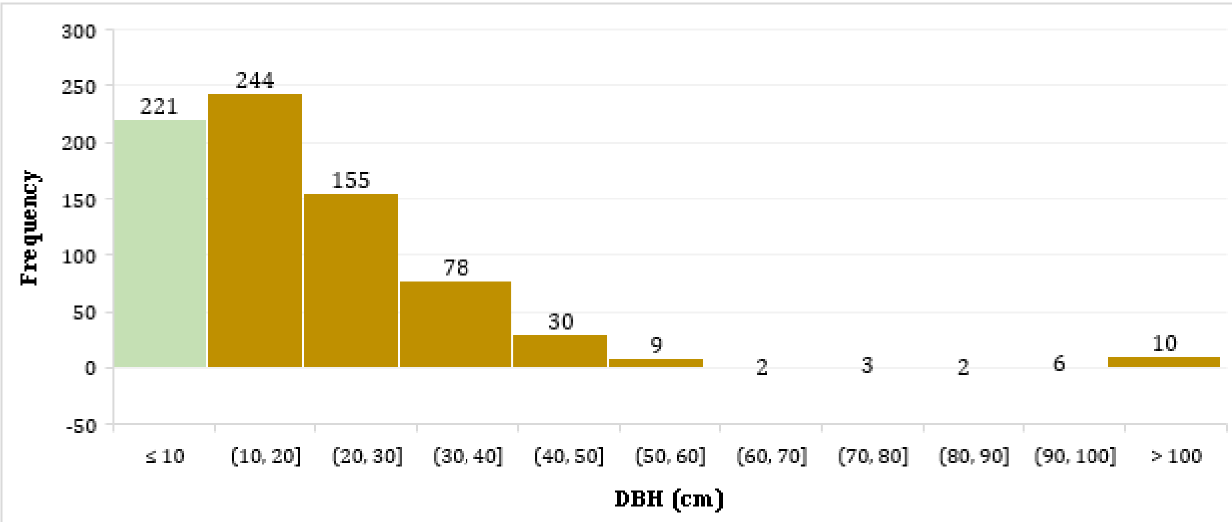

Figure 9: *Juniperus procera* tree distribution according to diameter at breast height (DBH) classes.

Further observation of the regenerants however revealed very low abundance of seedlings/or saplings[2] (<20) within the main forest. This is consistent with prevalent assertions regarding the germination, growth and survival of *J. procera* seedling within the forest in the absence of major disturbances (e.g., fire; Mamo et al., 2006) that create an opening and abundance of resources (i.e., through reduced competition for light, growth and soil nutrients). The scarce and scattered numbers of seedlings observed present an expected but grim outlook towards continued regeneration within the forest.

Distribution of *J. procera* beyond the current forest precincts

Are there any patches of juniper trees beyond the original firebreak/plantation boundary?

Figure 10 shows the distribution of *Juniperus procera* beyond the main Juniper Forest precincts (within 1.5 km radius) in Nyika National Park. Occurring either in clusters or as individuals, a majority of juniper trees are randomly distributed spatially, though more common (including with the furthest point) in the north-western direction. Most of the scattered *J. procera* trees occur along streams and at the mouth of valleys (Figure 11), with very little observed on the ridge tops. Of particular interest was one solitary juniper tree (approx. 25m height) observed on a rocky outcrop on a ridge top (>200 m) in the western

[2] Sapling is defined as a seedling that has survived the dry season and enters the second growing season as a sapling (Wigley et al., 2020), and not exceeding 0.5 m high

direction[3]. Its roots reach down to the ground three meters below by a crack in the rock (Figure 12).

In terms of size however, large juniper tree clusters (≥20 individuals) were mostly observed in the south while the largest (80-100cm dbh) individual juniper trees were observed in both south and eastern direction (Figure 13).

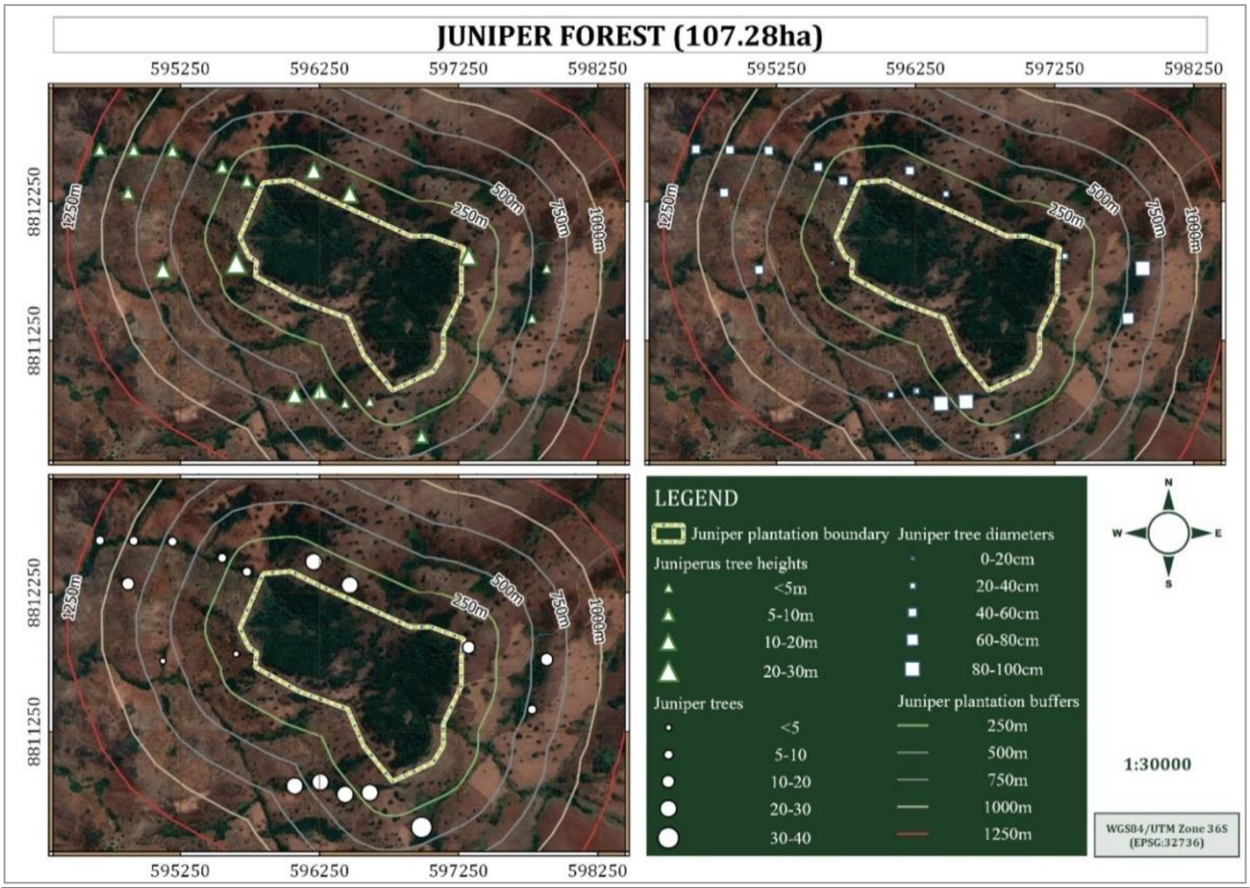

Figure 10: Distribution of isolated juniper trees beyond the plantation boundary in terms of heights, diameters and abundance.

[3] Possibly the same tree which is reported in Doward, (1993)

Figure 11: Some of the stream valleys (away from the core juniper forest) with Juniper trees in Nyika National Park

Figure 12: A solitary Juniper perched high on a rock

Figure 13: One of the largest juniper (97.2cm dbh) trees found in the eastern direction

Burrows (1995) and Jonson (2017) suggest that scattered juniper trees within a radius of 1.5 km are remnants of a much more extensive distribution that once covered a larger portion before it was ravaged by fire. However, there were no biological legacies observed in the field beyond the forest precincts to ascertain the sentiment. A change detection assessment highlighting the land-cover/vegetation changes from the earliest available satellite imagery could provide good insights on this matter in relation to typical dense forest cover of Juniper forests in the area.

What is their status and condition relative the fire management program?

During the survey, a thorough assessment on the health and condition of the *J. procera* species was not carried out. However, no observations were made that suggested illegal felling of the trees, significant pest and disease damage, or fire damage both within and beyond the forest confines. A few juveniles just below the eastern bloc of the main forest appeared to have been charred by fires (Figure 14) but nothing to suggest any significant damage. The same is true for a few mature individuals at the mouth of a valley south-west of the main forest plantation, As far as the eye could observe overall, both the forest and isolated patches beyond the main boundary appeared to be in a good condition (Figure 15).

Pertaining to regenerants (i.e., trees <10cm dbh) however, none were observed beyond the forest plantation.

The absence of significant fire damage to *J. procera* together with other associated trees[4] within could be attributed to the DNPW fire management programme, whereas the absence of the same on juniper populations beyond the plantation could be attributed to their location alongside streams and valleys where fires rarely reach for want of fuels. This speaks in favour of the current fire management programme in conserving the existing patch of the Juniper forest, but says little with regards to promoting regeneration beyond the forest precincts. It could be rightly argued that fires beyond the plantation firebreak are the main barrier to successful regeneration of *J. procera* beyond the main bloc, but the random distribution of regenerants within the current bloc itself suggests there could be a matrix of factors influencing successful regeneration of the species with or without fires.

Figure 14: The eastern bloc of the main forest appeared to have been charred by fires

[4] Including *Cupressus lusitanica* (which looks similar to *junipeus procrea*), *Prunus Africana, Olea capensis* welwitschii, *Hagenia abyssinica*, *Pordocarpus milanjianus*, *Acokanthera laevigata*, and *Ekebergia capensis*

Figure 15: Common appearance of Juniper forest understorey in Nyika National Park (Captured in October, 2019)

CONCLUSION AND RECOMMENDATION

Conclusion

In light of the common occurrence of fires on the Nyika, and susceptibility of *Juniperus procera* to the same, the survey has generally revealed that the fire management program has been effective in promoting conservation of the *Juniperus procera* population.

Consonant to the specific objectives of the survey are the following conclusions;

- The spatial distribution of *Juniperus procera* trees across the forest precincts is neither even nor necessarily clumped.
- *Juniperus procera* regenerants are randomly distributed in both open and closed spaces within the Juniper forest precincts, and none were observed beyond the forest boundary.
- The regeneration pattern of *Juniperus procera* trees is continual within the forest precincts.
- Juniper trees occur as both isolated individuals and clusters beyond the forest precincts in a random pattern. Howbeit a majority of the trees are common along streams and valleys in the north-western direction.
- No worrisome observations were made to suggest illegal felling of the trees, significant pest and disease damage, or fire damage within or beyond the forest boundary.

Recommendations

Based on the current findings, the following recommendations are suggested;

1) DNPW programme of fire control should be continued and intensified towards conservation the Juniper forest.
2) Action research towards propagation of *Juniperus procera* is recommended in light of low regeneration rates of the species and apparent evidence of success in previous enrichment planting efforts. If successful, management could consider expansion of the current forest vicinity and/or replanting of areas previously invaded by pines/wattle with the species.

REFERENCES USED

Aynekulu, E., Denich, M., Tsegaye, D. (2009). Regeneration response of Juniperus procera and Olea europaea subsp. cuspidata to exclosure in a dry Afromontane forest in northern Ethiopia. Mountain Research & Development 29(2): 143–152.

Briggs, P. (1998). A natural high. Travel Africa magazine. Edition 5.

Burrows, J. [J.E.] (1995). The conundrum of the African Pencil Cedar in south central Africa. Veld & Flora 81,1: 8–9

Burrows, J. W. and and Willis, C. K. (eds) 2005. Plants of the Nyika Plateau: an account of the vegetation of the Nyika National Parks of Malawi and Zambia. Southern African Botaincal Diversity Network Report No. 31. SABONET, Pretoria.

Chapman, J.D. & White, F. (1970). The Evergreen Forests of Malawi. Commonwealth Forestry Institute, Oxford

Carter, J. C. (1954) The Nyika Plateau, Nyasaland. Oryx Journal of the Faunal Preservation Society, 2(5), 1954.

Farjon, A. (2013) *Juniperus procera*. The IUCN Red List of Threatened Species 2013:e.T33217A2835242. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T33217A2835242.en

Gordon, I. A. N. (1993) Some reminiscences of the Nyika National Park. In: Dorward, F. and Dorward, R. The Nyika Experience – Six Memoirs of the Nyika Plateau in Northern Malawi. p.48

Happold, D.C.D. & Happold, M. (1989). Biogeography of montane small mammals in Malawi, Central Africa. Journal of Biogeography 16: 253-367.

Legesse Negash (2010). A Selection of Ethiopia's Indigenous Trees: Biology, Uses and Propagation Techniques. Addis Ababa University Press, Addis Ababa, Ethiopia. ISBN 978-99944-52-27-9

Mamo N, Mihretu M, Miftah F, Tigabu M, Teketay D. (2006). Variation in seed and germination characteristics among *Juniperus procera* populations in Ethiopia. Forest Ecology and Management 225(1–3):320–327.

Msekandiana, G. C. & Mlangeni, E. (2002). Malawi, pp.31-42. In: J. Golding (ed.) Southern African Plant Red Data Lists. Southern African Botanical Diversity Network Report No. 14, South Africa.

Johnson, S.A. (2017). Nyika: A Guide to Nyika National Park, Malawi, second edition. Nyika Vwaza Trust, UK. 232 pp.

Timberlake, J.R. & Osborne, J. (2014). Condition and regeneration of juniper trees in Wof-Washa forest, Ethiopia. Report produced for Tree Aid/SUNARMA under the Darwin Initiative Award 2034. Royal Botanic Gardens, Kew, London. 46 pp.

Wigley, B. J., Charles- Dominique, T., Hempson, G. P., Stevens, N., TeBeest, M., Archibald, S., Bond, W.J., Bunney, K., Coetsee, C. & Donaldson, J. (2020). A handbook for the standardised sampling of plant functional traits in disturbance - prone ecosystems, with a focus on open ecosystems. Australian Journal of Botany.

Willis, C.K., Burrows, J.E., Fish, L., Phiri, P.S.M., Chikuni, A.C. & Golding, J. (2001). Developing a greater understanding of the flora of the Nyika. Syst. Geogr. Pl. 71:993-1008.

APPENDICES

Appendix 1; GPS Coordinates (in WGS 84 datum) for all plots

Plot ID	UTM		Degrees		Elevation
	X	Y	X	Y	
1	596970	8811681	33.88757	-10.7513	2276
2	597075	8811846	33.88853	-10.7499	0
3	596680	8811367	33.88493	-10.7542	2218
4	596617	8811536	33.88435	-10.7527	2213
5	596518	8811685	33.88344	-10.7513	2159
6	596666	8811661	33.88479	-10.7515	2175
7	596777	8811516	33.88581	-10.7528	2210
8	596934	8811533	33.88725	-10.7527	2177
9	596043	8811991	33.87909	-10.7486	2168
10	596083	8812142	33.87945	-10.7472	2142
11	596060	8812251	33.87924	-10.7462	2121
12	596039	8812400	33.87904	-10.7449	2114
13	595868	8812416	33.87748	-10.7447	2122
14	595909	8812285	33.87786	-10.7459	2133
15	595894	8812131	33.87772	-10.7473	2164
16	595903	8811981	33.87781	-10.7487	2181
17	595783	8812091	33.87671	-10.7477	2174
18	595764	8812216	33.87653	-10.7465	2152
19	595758	8812369	33.87647	-10.7452	2140
20	595778	8812521	33.87665	-10.7438	2103
21	595924	8812574	33.87798	-10.7433	2121
22	596053	8812533	33.87917	-10.7437	2153
23	596289	8812425	33.88133	-10.7446	2136
24	596483	8812282	33.8831	-10.7459	2126
25	596621	8812268	33.88437	-10.746	2130
26	596772	8812235	33.88575	-10.7463	2163
27	596917	8812217	33.88708	-10.7465	2181
28	596883	8811380	33.88679	-10.7541	2216
29	596785	8811328	33.88589	-10.7545	2228
30	596440	8811805	33.88272	-10.7502	2151
31	596342	8811839	33.88183	-10.7499	2160
32	596343	8811965	33.88183	-10.7488	2152
33	596166	8811929	33.88021	-10.7491	2167
34	596700	8811755	33.8851	-10.7507	2148
35	596838	8811657	33.88637	-10.7516	2171
36	596958	8811793	33.88746	-10.7503	2174
37	596903	8811968	33.88695	-10.7488	2172

38	596911	8812069	33.88702	-10.7478	2174
39	597064	8812078	33.88842	-10.7478	2217
40	597047	8811953	33.88827	-10.7489	2217
41	596566	8811772	33.88312	-10.7478	0
42	596729	8811669	33.88462	-10.7487	0
43	596312	8811816	33.8808	-10.7474	0
44	596300	8811933	33.88069	-10.7464	0
45	596685	8811833	33.8842	-10.7472	0
46	596859	8811676	33.8858	-10.7487	0
47	596432	8811950	33.88189	-10.7462	0
48	596911	8811538	33.88628	-10.7499	0
49	596859	8811805	33.8858	-10.7475	0
50	596258	8812065	33.8803	-10.7452	0
51	596607	8811620	33.8835	-10.7492	0
52	596429	8811809	33.88186	-10.7475	0

EPSG 4326 - WGS84 - UTM zone 36S

Appendix 2; Data collection sheet used for Permanent Sample plots (PSPs)

Juniperus procera FOREST INVENTORY (Permanent Sample Plots)

Plot ID: ______________ **Picture ID:** ______________ **Slope:** ______________ **Aspect:** ______________

X: ______________________ **Y:** ____________________________ **Z:** ________________

Canopy Cover

	Open	*Closed*		*Open*	*Closed*		*Open*	*Closed*		*Open*	*Closed*
1			5			9			13		
2			6			10			14		
3			7			11			15		
4			8			12			16		

Tree Inventory

	Ht	*Dbh*		*Ht*	*Dbh*		*Ht*	*Dbh*
1			21			41		
2			22			42		
3			23			43		
4			24			44		
5			25			45		
6			26			46		
7			27			47		
8			28			48		
9			29			49		
10			30			50		
11			31			51		
12			32			52		
13			33			53		
14			34			54		
15			35			55		
16			36			56		
17			37			57		
18			38			58		
19			39			59		
20			40			60		

Sheet #: ______

Appendix 3; Data sheet used for spatial distribution of regenerants

Juniperus procera FOREST INVENTORY (Spatial Distribution of Regenerants)

Point ID: ______________ **Picture ID:** ______________ **Slope:** ______________ **Aspect:** ______________

X: ______________________ **Y:** ______________________ **Z:** ______________________

Canopy Cover

	Open	*Closed*		*Open*	*Closed*		*Open*	*Closed*		*Open*	*Closed*
1			3			5			7		
2			4			6			8		

Tree Inventory

	Ht	*Dbh*		*Ht*	*Dbh*		*Ht*	*Dbh*
1			11			21		
2			12			22		
3			13			23		
4			14			24		
5			15			25		
6			16			26		
7			17			27		
8			18			28		
9			19			29		
10			20			30		

General Point Description (associated vegetation & ecological condition)

Sheet #: ______