Selecting Tree Species for Sustainable Harvest and Calculating their Sustainable Harvesting Quota in Tshanini Conservation Area, Maputaland, South Africa

Research

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Abstract

The process of calculating a sustainable harvesting quota for tree species is presented for the Sand Forest and Woodlands of Tshanini Conservation Area. The study area lies within the Maputaland Centre of Plant Endemism, in South Africa, which is threatened by human utilization outside conservation areas. In a defined harvesting area in the Sand Forest and Woodland communities the concept of species grain was first used to establish which species can be harvested. Then, by developing a method to establish sustainable harvesting quotas from which sustainable harvesting rates per year per species are derived. Sustainable harvesting is possible for seven, four, and three tree species in the Tall Sand Forest, Closed Woodland, and Open Woodland communities respectively. A comparison with another sustainable harvesting method produced similar results, although the present method is useful to determine sustainable harvesting quotas on a species basis rather than on the community level.

Introduction

The reality of life in underdeveloped northern Maputaland of South Africa, implies for humans the necessity of relying upon all available natural resources to make a living. Extended families survive on an annual income of approximately ZAR 6 500 (Els 2000). In this context, the concept of sustainable utilization of renewable natural resources contained within conservation areas appeals to local rural communities (Obiri *et al*. 2002). Thus, it has triggered a considerable number of land restitution and access to the natural resources claims. However, the concept of sustainable utilization is met reluctantly by nature conservation authorities of South Africa, even when such a program is conducted under their supervision. This reluctance on the part of the nature conservation authorities is mainly based on cases, where in the past, community control has resulted in resource degradation. The main reason for the degradation is commonly a lack of information on how to set quotas for sustainable use of these renewable natural resources (Laurance 1999, Obiri *et al*. 2002). In theory, any harvesting plan should consider the availability of resources, the rate of use, and the renewal rate of the resources. Thus, only plans that promote harvest below the resource regeneration threshold and that do not modify the natural prevalence of the harvested species should be used (Lawes & Obiri 2003).

In South Africa today, there is only little, if any, information available on such sustainable utilization and there are no clear guidelines on how to create an efficient program to establish and monitor the availability of the renewable natural resources. More importantly, there are few or no guidelines on how to define sustainable levels of utilization that are suitable to the wide variety of South African conditions (Everard *et al*. 1995). In the absence of such guidelines the nature conservation authorities have usually taken an extreme approach by forbidding utilization of natural resources contained in the parks and reserves of South Africa (Hartshorn 1995). This approach has elic-

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ited resentment and anger from local communities living around the conservation areas.

The rural community of Manqakulane, northern Maputaland, KwaZulu-Natal, South Africa, initiated an unusual project in allocating a portion of their tribal land to be developed as a community-run conservation area by the name of Tshanini Conservation Area (TCA), formerly known as Tshanini Game Reserve, before its official proclamation (Gaugris *et al*. 2004). In the present study, we determine the sustainably harvestable tree species and their sustainable harvesting quotas in the TCA. This evaluation is based on the following points (Lawes & Obiri 2003): ecological knowledge of the local environment, the abundance of the areas' renewable natural resources, the stem growth rate of tree species, and the utilization of woody resources by the local community.

Study area

TCA lies due south of Tembe Elephant Park (TEP) and encompasses 2420 ha. The area consists of a sandy plain that is interspersed with ancient littoral dunes, and the vegetation is made up of Sand Forest and Woodland communities. The Sand Forest is the major community covering 43.2% (1045.5 ha) of the reserve, and consists of the Short Sand Forest (77.0 ha) and Tall Sand Forest (968.5 ha) subcommunities (Gaugris *et al*. 2004). The Closed Woodland community covers 19.1% (463.0 ha) of the reserve. The Open Woodland community covers 37.7% (912.0 ha) of the reserve and based on species composition, vegetation density and physiognomy, it is subdivided into two different Open Woodland subcommunities (273.0 ha in total) and two different Sparse Woodland subcommunities (639.0 ha in total).

Methodology

Only plant species that are recognized as trees or tree-like plants are evaluated in this study. Tree like plants encompasses small shrubs and lianas with hard ligneous stems. Only the thickest stem of multi-stemmed trees was included in the density measurements. Density calculations are based on transect density, if a species did not occur in a particular transect the density for that species in that particular transect was zero. Density of a species in a vegetation community is defined as the mean of the transect density for all the transects in a particular vegetation community.

The size class distributions of the tree species were derived from 48 transects, which represented a total surveyed area of 23100 m^2. Depending on the transect density, the transect dimensions varied from a minimum of 50 by 5 m to a maximum of 100 by 10 m in length and width respectively (Gaugris 2004).

Terminology

To simplify the terminology of this study, the Short and Tall Sand Forest subcommunities are referred to as communities. Similarly, the two Sparse Woodland subcommunities are assimilated as the Sparse Woodland community, and the two Open Woodland subcommunities are assimilated as the Open Woodland community. The two Sand Forest communities are referred to as the Sand Forest vegetation and the three Woodland communities are referred to as the Woodland vegetation.

Identifying tree species for harvesting

For this study, only those tree species for which Gaugris (2004) sampled at least 60 or more individuals were taken into consideration and classified into three different size class increments groups, based on the spread of stem circumferences measured per species. This imposition of a minimum number of sampled trees meant that these trees were abundant locally and that size class distributions were meaningful. An exception was made for *Brachylaena huillensis* O. Hoffm., which was included despite only 33 sampled individuals. Its inclusion was motivated by the fact that local community people find it the most desirable species for building construction (Gaugris 2004), thereby making it a species of particular interest.

The grain of a forest is a concept developed by Midgley *et al*. (1990), and subsequently adapted by Everard *et al*. (1994, 1995). It is based on the presence or absence of species at both canopy and subcanopy levels and the proportion of different size class distribution (SCD) population structures in the vegetation community, which determines the scale at which regeneration processes take place in a forest (Everard *et al*. 1994, 1995, Obiri *et al*. 2002). Gaugris (2004) used and adapted the model developed by Peters (1996) to classify woody plant species according to their SCD, and then used the spread of various SCDs to determine the grain of the Sand Forest and Woodland communities. It was established that the Open and Closed Woodland communities of TCA have remarkable forest-like characters. Therefore, the concept was also applied to Woodland vegetation (Gaugris *et al*. 2004). Gaugris (2004) suggested that only the species with SCD typical of healthy climax population (inverse J-shaped SCD population curve) typical of fine-grained forests should be harvested.

In order to refine the selection of harvestable species proposed by Gaugris (2004), The method of Obiri *et al*. (2002) was applied to those proposed species. The grain of a species method is represented diagrammaticaly (Obiri *et al*. 2002, Lawes & Obiri 2003) and is a refined version of the grain of a forest concept with the purpose of identifying the tree species with a good potential for harvesting. However, in the present study three adaptations to the grain of a species method had to be made. Firstly the size class increments groups of Gaugris (2004) had to be further subdivided into seedling, subcanopy tree and canopy tree stages (Table 1). The selection of these stages was based on the established spread of size classes of the concerned species (suggested by Lawes & Obiri 2003). Adaptations two and three were necessary due to the density and nature of the vegetation in TCA. Secondly, once the stem density per hectare for the subcanopy and canopy was calculated for each harvestable woody plant species selected in all five vegetation communities, the graphical solution was difficult to read. Therefore the density values were transformed by using a natural logarithm transformation in the form of: ln (total density per stage + 1). The value of 1 was added to cater for species that had a count of zero in the selected stages to facilitate visualization. Thirdly, Obiri *et al*. (2002) set critical minimum values of 10 trees per ha for canopy trees and 30 trees per ha for subcanopy trees based on their knowledge and experience of the areas investigated and suggested that they may be altered for other regions. For the Sand Forest vegetation it was deemed possible to use the same values and they were similarly ln-transformed. However, for the three Woodland communities, the density of canopy trees was halved to a minimum of 5 individuals per ha, because Woodlands in TCA have a lower canopy and canopy cover than Sand Forest vegetation (Gaugris *et al*. 2004). Thus, following the method of Obiri *et al*. (2002) the ln-transformed values of subcanopy densities on the Y-axis against canopy densities on the X-axis, were plotted for each harvestable species. The species that fell within the fine-grained species harvestable limits were selected as species with a high harvesting potential.

As a last step in the identification of tree species for harvesting the frequency of each harvestable fine-grained species was calculated. Frequency was taken as the proportion of the total number of transects occupied by a species. A species may not be harvested if it occurs in less than 50% of the transects of a vegetation community (frequency < 0.5) (Lawes & Obiri 2003).

Establishing the sustainable tree harvest quota

Lawes & Obiri (2003) recommend including ecological knowledge of the local environment into any sustainable harvest plan. Therefore, the abundance of renewable natural resources in the area, the stem growth rate of tree species, and the utilization of woody resources by local community, as established by Gaugris (2004), were used to develop the following method of establishing a sustainable harvesting quota and rate per species per year per vegetation community.

To determine the sustainable harvesting rate, the linear regression slope coefficient of trendlines fitted for each species, calculated by Gaugris (2004) was compared with the mean linear regression slope coefficient within the same size class increment group in which it was classified. For this comparison to be performed, the difference between the absolutes of a species slope coefficient value and that of the mean slope for all the species within the same size class increment group was considered to be a good approximation of the harvesting potential of that species if the slope of the species is more negative than that of the mean of the size class increment group. In addition, the mean linear regression slope coefficient trend line was forced through the same X-axis intercept as that of the regression for a species in order to express the difference between the absolutes of the two slope coefficients as a constant value across the whole range of size classes for a species. This value, expressed as a percentage then represented the part of the total crop that can be harvested in a particular size class from the total number of trees present and was termed the preliminary harvesting rate.

Table 1. Stem circumference range for the seedling, subcanopy and canopy tree stages based on stem circumference size class increments used to classify the trees of TGR, northern Maputaland, KwaZulu-Natal, South Africa.

Stem circumference size class increment (mm) (Gaugris 2004)	Stem circumferences range		
	Seedling (mm)	Subcanopy tree (mm)	Canopy tree (mm)
25	0-100	>100-250	>250
50	0-150	>150-600	>600
100	0-400	>400-1000	>1000

The range of stem size classes favoured by the people for building purposes was identified by Gaugris (2004). For each of these size classes the total number of individuals of harvestable size per ha was estimated for each of the five plant communities in TCA. This calculation was performed by using the stem size class that has the lowest density of trees per ha in any stage of the SCD curve so that a gap in a size class set the limit for all other size classes. From the density of woody plants per ha, an estimated number of trees that can be harvested was calculated for the restricted harvestable area defined by Gaugris (2004). 200 ha in the Tall Sand Forest, Short Sand Forest was not harvestable, 42 ha in Closed Woodland, 145 ha in Open Woodland, Sparse Woodland was considered not-harvestable after the species grain classification.

The time required for any one size class to grow into the next size class was evaluated by using the mean stem circumference growth rate per year as established by Gaugris (2004). When the stem circumference mean growth rate of a species was unknown, the mean stem circumference growth rate of the all sampled Sand Forest or Woodland species was used instead (Gaugris 2004).

The sustainable harvesting quota per species was obtained by first applying the preliminary harvesting rate to the estimated number of trees found in the harvestable areas. This number was then further reduced by dividing it through the time required to grow from any one size class to the next. The sustainable harvesting rate of the harvestable species was obtained by dividing the sustainable harvestable quota for the harvestable area through the estimated total number of trees in the selected size classes of the vegetation community of TCA.

To establish whether the results of the present study are realistic. The sustainable harvesting quota was also calculated by using the method of Shackleton (1993) and the results were compared. This author evaluated a sustainable level of utilization for fuel wood harvesting in both a communal grazing area and a protected area of the eastern Lowveld in South Africa. He established a level of sustainable harvest by using the estimate of Rutherford (1978) of 4 – 5% of the transecting crop, which is roughly equivalent to the annual production. Shackleton (1993) further refined this value to 3% of the transecting crop after elimination of undesirable wood. The sustainable harvesting quota of TCA was calculated by using the 3% value established by Shackleton (1993). This study did not refer to a particular restricted harvestable area. Therefore, the method was applied to the total transecting crop first, and then to that in the restricted harvestable area. The results of the two methods were compared by means of paired two samples for means (t)-tests for community level results, and by (χ^2) contingency tables for the species results.

Results and Discussion

Identifying tree species for harvesting

Obiri *et al*. (2002) and Lawes & Obiri (2003) suggest that only fine-grained species should be used for sustainable harvesting and this was also applied here. The diagrammatical representation of the suitable species for sustainable harvesting suggests that only six species are suitable in the Tall Sand Forest community (Figure 1) and only *Hymenocardia ulmoides* Oliv. and *Ptaeroxylon obliquum* Radlk. in the Short Sand Forest community (Figure 2). Due to the small area size of the community (77 ha), Gaugris (2004) rejected the Short Sand Forest community for harvesting. In the present study, the lack of a large pool of fine-grained species also suggests that the Short Sand Forest community should be left alone.

Based on the lower limit of canopy density applied for Woodlands, only four species can be harvested in the Closed Woodland community (Figure 3), and four in the Open Woodland community (Figure 4). No species may be harvested in the Sparse Woodland community (Figure 5).

Establishing the sustainable tree harvesting quota

Because *B. huillensis* is such an important species for building construction (Gaugris 2004), it was included in the group of harvestable species, but provisions were made to conservatively halve its harvesting quota. The results for the sustainable harvesting quota per year is only 74 individual trees (Table 2) for *B. huillensis*. *Dialium schlechteri* Harms is another species with a low sustainable harvesting quota, with 76 trees that may be harvested per year. The other species have a higher sustainable harvesting quota ranging from 178 individuals for *Haplocoelum gallaense* (Engl.) Radlk. to 5019 individuals for *Drypetes arguta* (Müll. Arg.) Hutch. Regrettably, the latter species is not so desirable as a building wood. If all individual species harvesting quotas are summed, the total harvesting quota per year is 8358 trees. However, if only desirable species are harvested, then the total harvesting quota per year is reduced to 3262 individual trees (Table 2).

In his method, Shackleton (1993) did not allow for a special conservation area where no harvesting takes place. By using the estimated total number of trees per species as established for the whole area of Tall Sand Forest, the results obtained with the fixed 3% harvesting rate (Table 3) of Shackleton allows for a significantly larger harvesting quota of individual trees (26440 trees) than what is suggested in the present study (8350 trees) ($t = 3.95$, $df = 6$, $P < 0.01$). However, if the number of individuals per species for the harvest-restricted areas is used and a fixed 3% harvesting rate applied, then the results are similar to those suggested in the present study ($t = 1.00$, $df = 6$, $P > 0.05$). But, when using a chi square contingency table to compare the results for the individual Tall Sand Forest species a significant difference is clearly visible ($\chi^2 = 4519.28$, $df = 6$, $P < 0.01$) between the numbers of individual trees available for harvest using the present study's methodology and that of Shackleton (1993).

When looking at the results for the Woodland vegetation (Table 4), the frequency of occurrence of *Euclea natalensis* A. DC. in the Open Woodland is < 0.5, and the species is therefore not suitable for harvesting. However, for information purposes the species is retained in the tables. For the Closed Woodland, *Strychnos madagascariensis* Poir. is the species with most trees available for harvesting in both Open and Closed Woodland communities (Table 4). The total harvesting quota is 1105 trees for the Closed Woodland community and 1115 individual trees for the Open Woodland community.

When the same statistical tests are applied to the Woodlands species of both communities, a significant difference can be seen between Shackleton's (1993) method (results on Table 5) for the number of individuals per species for the whole area and the present study's methodology (Closed woodland: $t = 2.41$, $df = 3$, $P < 0.05$; Open woodland: $t = 2.38$, $df = 3$, $P < 0.05$). However, there is

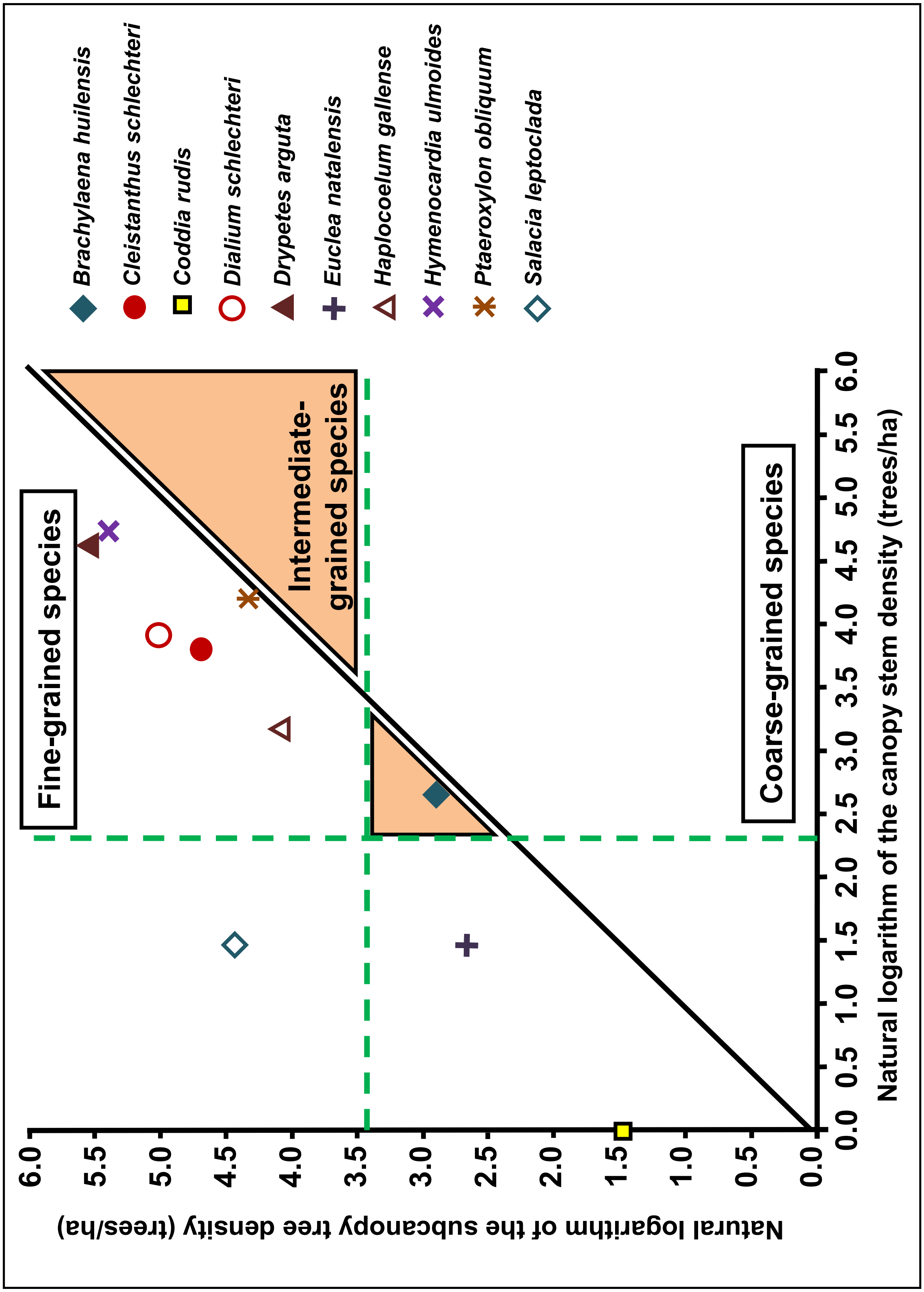

Figure 1. Theoretical representation of the grain of tree species in the Tall Sand Forest community of TCA, northern Maputaland, KwaZulu-Natal, South Africa. The dashed lines represent the sustainable harvesting limits of the respective subcanopy and canopy tree densities (adapted from Obiri *et al.* 2002)

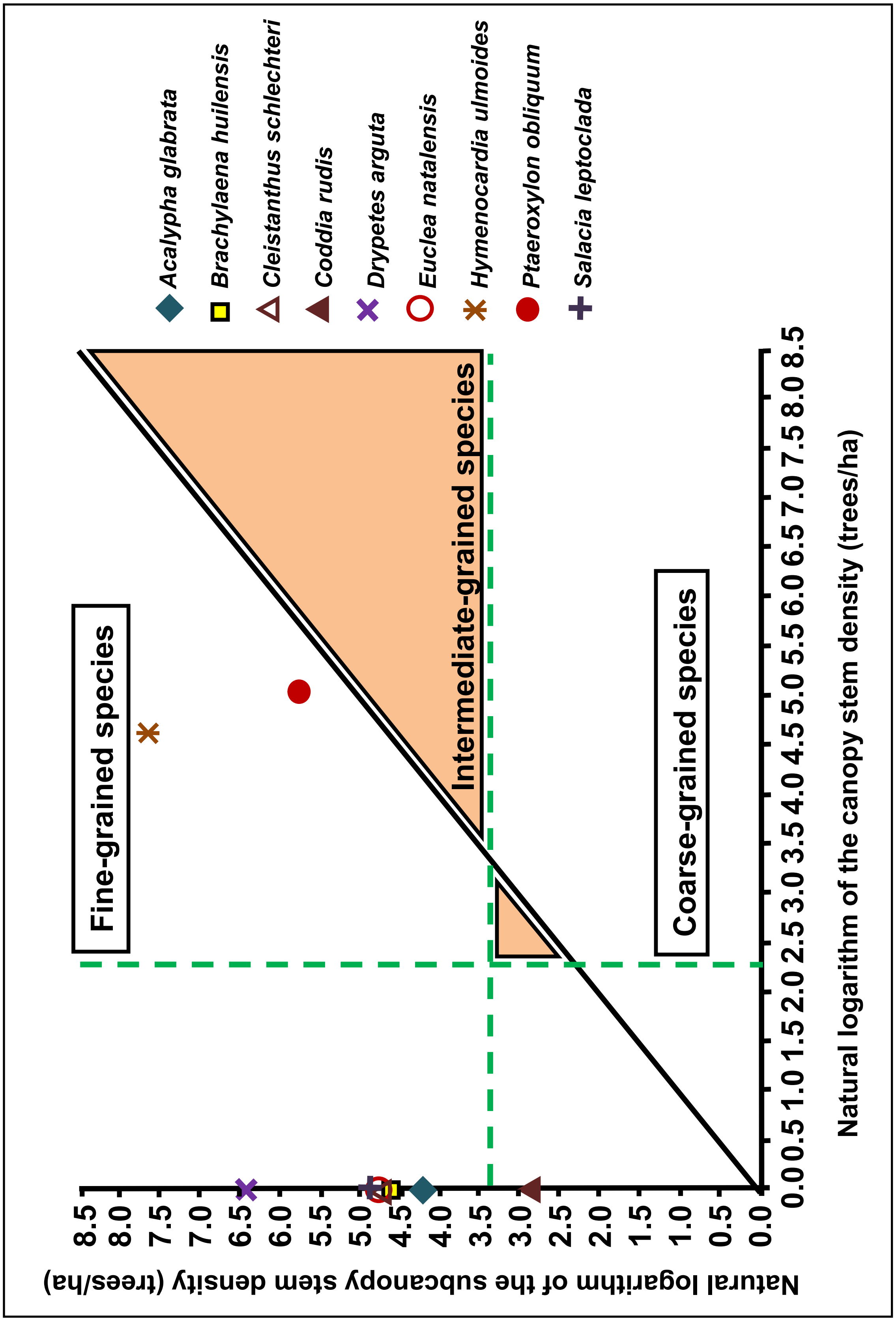

Figure 2. Theoretical representation of the grain of tree species in the Short Sand Forest community of TCA, northern Maputaland, KwaZulu-Natal, South Africa. The dashed lines represent the sustainable harvesting limits of the respective subcanopy and canopy tree densities (adapted from Obiri et al. 2002)

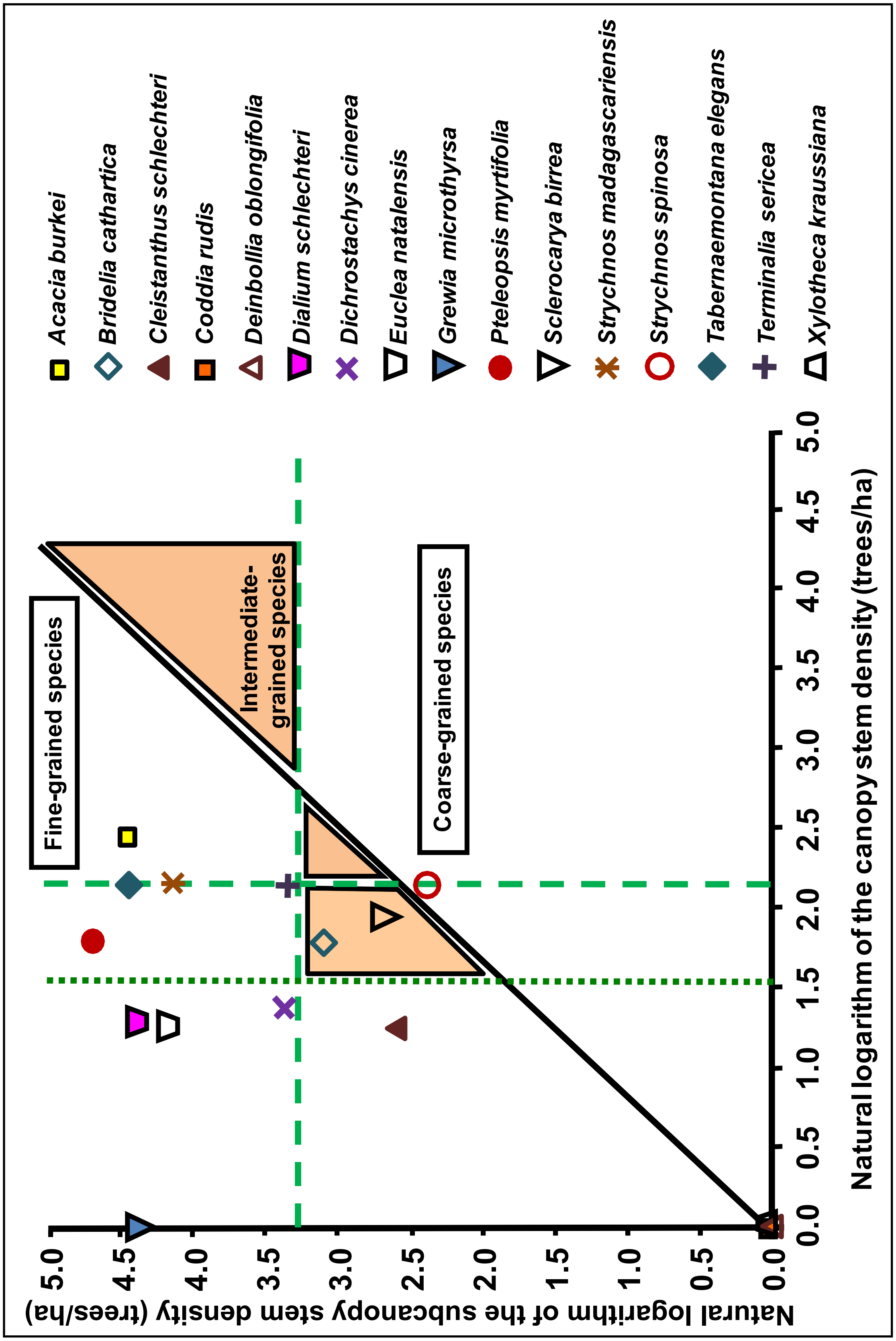

Figure 3. Theoretical representation of the grain of tree species in the Closed Woodland community of TCA, northern Maputaland, KwaZulu-Natal, South Africa. The dashed lines represent the sustainable harvesting limits of the respective subcanopy and canopy tree densities (adapted from Obiri et al. 2002). The vertical dotted line represents the revised and lower sustainable harvesting limit of the canopy tree density for the woodlands of TGR utilised in the present study.

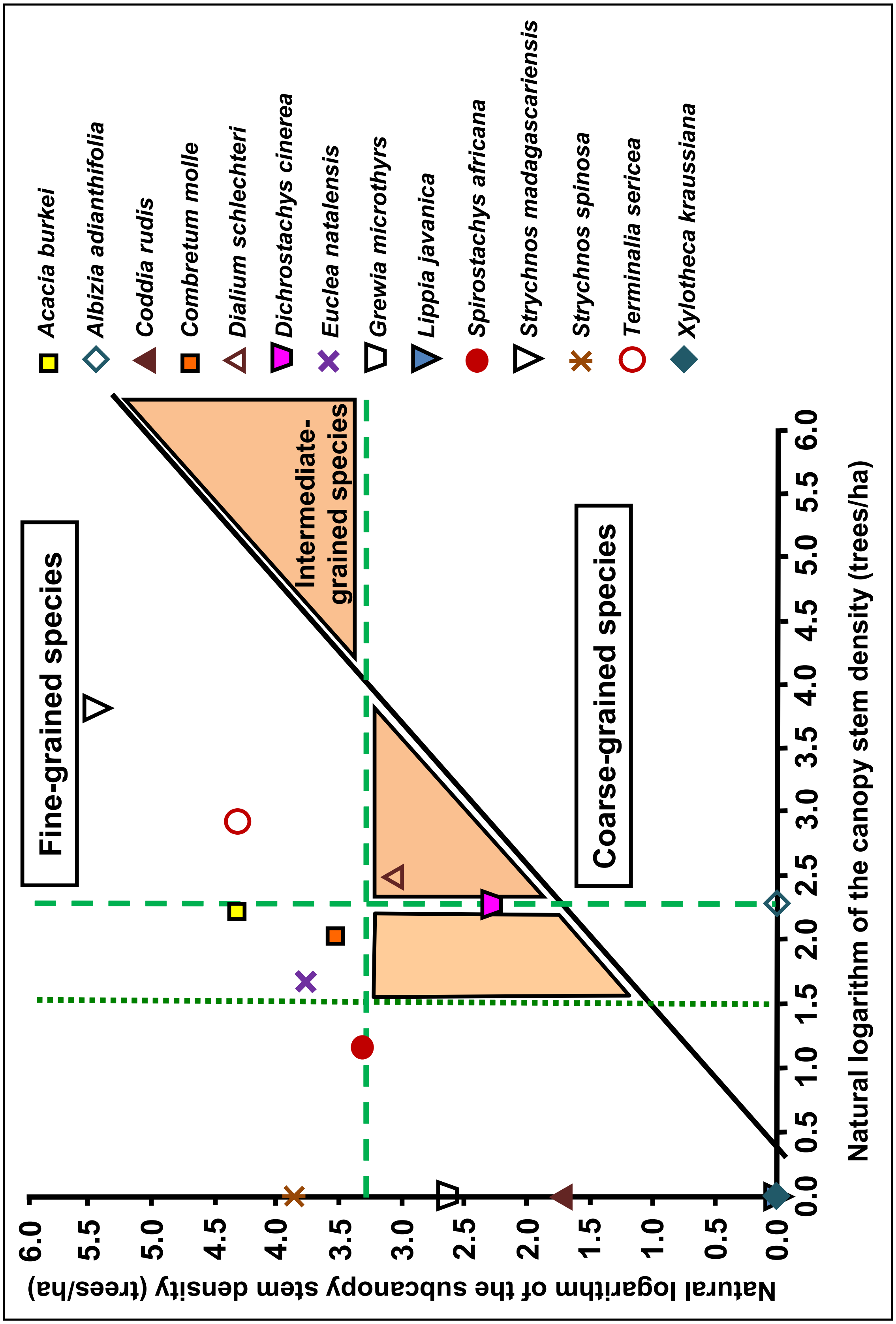

Figure 4. Theoretical representation of the grain of tree species in the Open Woodland community of TCA, northern Maputaland, KwaZulu-Natal, South Africa. The dashed lines represent the sustainable harvesting limits of the respective subcanopy and canopy tree densities (adapted from Obiri et al. 2002). The vertical dotted line represents the revised and lower sustainable harvesting limit of canopy tree density for the woodlands of TGR utilised in the present study.

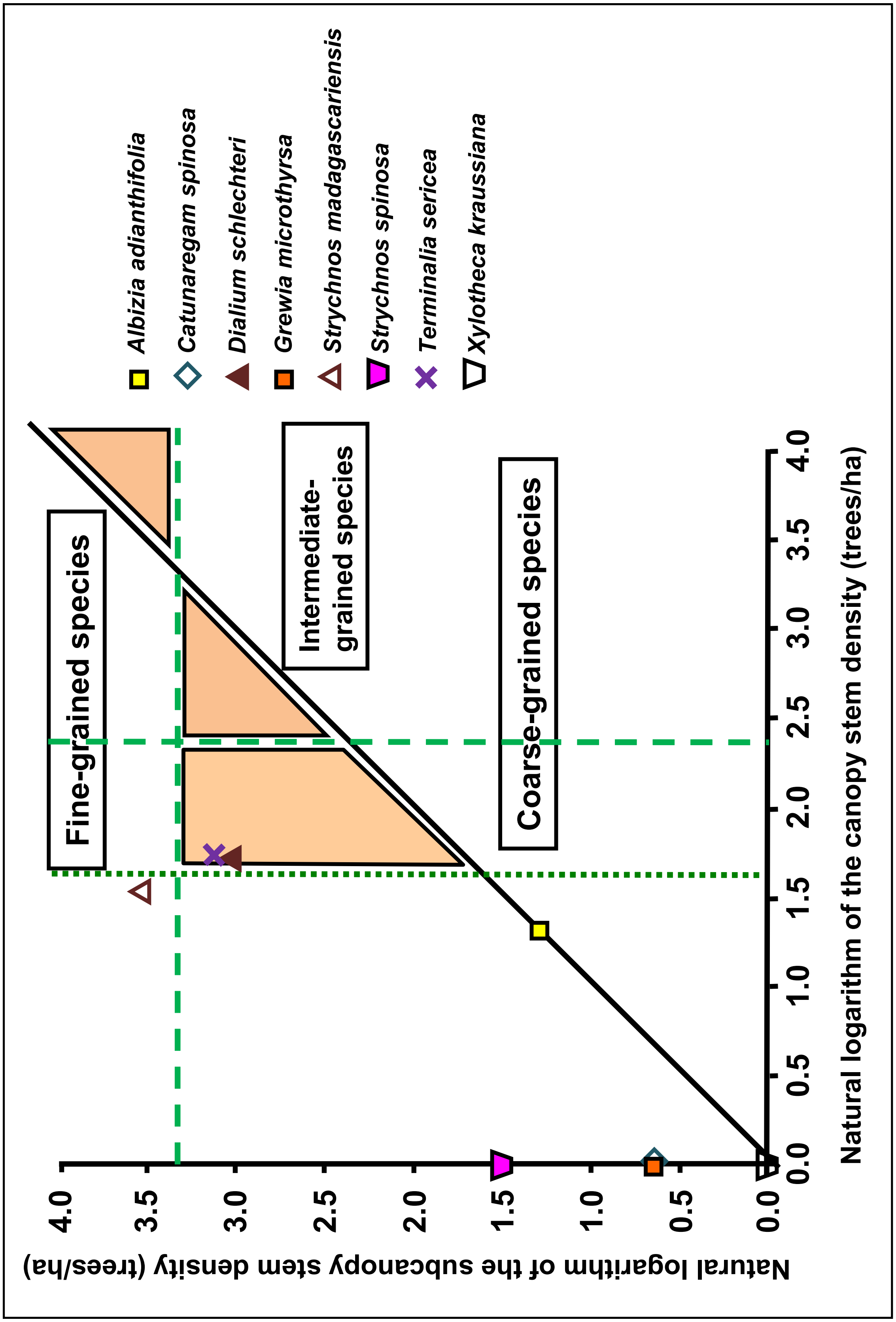

Figure 5. Theoretical representation of the grain of tree species in the Sparse Woodland community of TCA, northern Maputaland, KwaZulu-Natal, South Africa. The dashed lines represent the sustainable harvesting limits at the respective subcanopy and canopy tree densities (adapted from Obiri et al. 2002). The vertical dotted line represents the revised and lower sustainable harvesting limit of canopy tree density for the woodlands of TGR utilised in the present study.

Table 2. Determination of the sustainable harvesting quota per year for the harvestable tree species in the Tall and Forest community of TGR, northern Maputaland, KwaZulu-Natal, South Africa.

Tree Species	**Species desirability for construction (Gaugris 2004)**	**Species frequency**	**Stem circumference size class increment (mm)**	**Size classes included (mm)**	**Linear regression slope**	**Absolute of LrS**	**Difference between |LrS| and |mLrS|**	**Preliminary harvesting rate per year (%)**
			(SCI)	**(SC)**	**(LrS)**	**(|LrS|)**	**(Qu = |LrS| - |mLrS|)**	**(PHr = Qu/|LrS|)**
Cleistanthus schlechteri	High	0.83	100	0-300	-1.32	1.32	0.85	64.20
Dialium schlechteri	Low	1.00	50	100-300	-0.98	0.98	0.15	15.42
Haplocoelum gallense	High	0.75	50	100-300	-1.08	1.08	0.25	23.25
*Brachylaena huillensis**	Highest	0.66	25	100-275	-0.96	0.96	0.22	23.19
Drypetes arguta	Low	0.83	25	100-275	-1.33	1.33	0.59	44.56
Hymenocardia ulmoides	High	0.91	25	100-275	-0.87	0.87	0.13	15.24
Ptaeroxylon obliqum	High	0.83	25	100-275	-0.87	0.87	0.13	15.24
Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 100mm SCI					-0.47	0.47		
Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 50mm SCI					-0.83	0.83		
Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 25mm SCI					-0.74	0.74		

* In an attempt to balance conservation and human needs, this non-harvestable species was included because it is the most desirable for building construction (Gaugris 2004). However, its harvesting quota per year was halved (SHq = (PHq/Rsc)/2).

Table 2. continued.

Tree Species	Preliminary harvesting rate per year (%)	Estimated of the total number of trees in the selected size classes of the Tall Sand Forest		Preliminary harvest quota (number of trees)	Circumference growth rate (mm/year)	Time required to replace one size class (years)	Sustainable harvesting quota per year (number of trees)	Sustainable harvesting rate per year (%)
		Total area (ha)	Harvested Area (200 ha)					
	(PHr)	(T)	(N)	(PHq=NxPHr)	(Gr)	(Rsc = SCI/Gr)	(SHq = PHq/ Rsc)	(SHr = SHq/T)
Cleistanthus schlechteri	64.20	103307	21333	13697	6.80	15	931	0.90
Dialium schlechteri	15.42	100078	20667	3187	1.20	42	76	0.08
Haplocoelum gallense	23.25	45197	9333	2170	4.10	12	178	0.39
*Brachylaena huillensis**	23.19	25827	5333	1237	3.00	8	74	0.29
Drypetes arguta	44.56	284093	58667	26140	4.80	5	5019	1.77
Hymenocardia ulmoides	15.24	251810	52000	7926	5.40	5	1712	0.68
Ptaeroxylon obliqum	15.24	71023	14667	2236	4.10	6	367	0.52
					Total		8358	
					Total highly desirable species		3262	

* In an attempt to balance conservation and human needs, this non-harvestable species was included because it is the most desirable for building construction (Gaugris 2004). However, its harvesting quota per year was halved (SHq = (PHq/Rsc)/2).

Table 3. Determination of the sustainable harvesting quota per year for the total standing crop of the Tall Sand Forest community of TGR, northern Maputaland, KwaZulu-Natal, South Africa, based on Shackleton's (1993) fixed 3% harvesting rate.

Tree Species	Species desirability for construction (Gaugris 2004)	Estimated number of trees in the selected size classes in the TSF		Sustainable harvesting quota per year based on the fixed 3% sustainable harvesting rate	
		Total area (ha)	Harvestable area (200 ha)	Total area (ha)	Harvestable area (200 ha)
Cleistanthus schlechteri	High	103307	21333	3099	610
Dialium schlechteri	Low	100078	20667	3002	620
Haplocoelum gallense	High	45197	9333	1356	280
*Brachylaera huillensis**	Highest	25827	5333	387	80
Drypetes arguta	Low	284093	58667	8523	1760
Hymenocardia ulmoides	High	251810	52000	7554	1560
Ptaeroxylon obliquum	High	71023	14667	2131	440
		Total		26440	5460
		Total highly desirable species		14528	3000

* In an attempt to balance conservation and human needs, this non-harvestable species was included because it is the most desirable for building construction (Gaugris 2004). However, its harvesting quota per year was halved (1.5% harvesting rate).

Table 4. Determination of the sustainable harvesting quota per year for the harvestable tree species in the Closed and Open Woodland communities of TGR, northern Maputaland, KwaZulu-Natal, South Africa.

<table>
<tr><th rowspan="2">Woodland communnity type</th><th rowspan="2">Tree species</th><th rowspan="2">Species desirability for con-struction (Gaugris 2004)</th><th rowspan="2">Species fre-quency</th><th>Stem circum-ference size class increment (mm)</th><th>Size classes included (mm)</th><th>Linear regression slope</th><th>Absolute of LrS</th><th>Difference between |LrS| and |mLrS|</th><th>Pre-liminary harvesting rate per year (%)</th></tr>
<tr><th>(SCI)</th><th>(SC)</th><th>(LrS)</th><th>(|LrS|)</th><th>(Qu = |LrS| - |mLrS|)</th><th>(PHr = Qu/|LrS|)</th></tr>
<tr><td>Closed</td><td>Pteleopsis myrtifolia</td><td>Low</td><td>0.60</td><td>25</td><td>100-275</td><td>-1.73</td><td>1.73</td><td>0.85</td><td>49.17</td></tr>
<tr><td>Closed</td><td>Tabernaemontana elegans</td><td>Low</td><td>0.80</td><td>50</td><td>100-300</td><td>-1.36</td><td>1.36</td><td>0.43</td><td>31.80</td></tr>
<tr><td>Closed</td><td>Acacia burkei</td><td>Medium</td><td>1.00</td><td>100</td><td>0-300</td><td>-1.53</td><td>1.53</td><td>0.36</td><td>23.61</td></tr>
<tr><td>Closed</td><td>Strychnos madagascariensis</td><td>Low</td><td>1.00</td><td>100</td><td>0-300</td><td>-1.89</td><td>1.89</td><td>0.72</td><td>38.16</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td colspan="6">Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 100mm SCI</td><td>-0.88</td><td>0.88</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="6">Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 50mm SCI</td><td>-0.93</td><td>0.93</td></tr>
<tr><td colspan="6">Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 25mm SCI</td><td>-1.17</td><td>1.17</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Open</td><td>Euclea natalensis*</td><td>Low</td><td>0.44</td><td>50</td><td>100-300</td><td>-1.05</td><td>1.05</td><td>0.08</td><td>7.62</td></tr>
<tr><td>Open</td><td>Acacia burkei</td><td>Medium</td><td>0.78</td><td>100</td><td>0-300</td><td>-1.30</td><td>1.30</td><td>0.17</td><td>12.97</td></tr>
<tr><td>Open</td><td>Strychnos madagascariensis</td><td>Low</td><td>1.00</td><td>100</td><td>0-300</td><td>-1.41</td><td>1.41</td><td>0.28</td><td>19.76</td></tr>
<tr><td>Open</td><td>Terminalia sericea</td><td>Medium</td><td>0.78</td><td>100</td><td>0-300</td><td>-1.46</td><td>1.46</td><td>0.33</td><td>22.50</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td colspan="6">Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 100mm SCI</td><td>-1.06</td><td>1.06</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="6">Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 50mm SCI</td><td>-0.97</td><td>0.97</td></tr>
<tr><td colspan="6">Mean of the linear regression slopes (mLrS) and absolute values (|mLrS|): 25mm SCI</td><td>-1.13</td><td>1.13</td></tr>
</table>

*Due to its low frequency value of < 0.50, this species may not be harvested (Lawes & Obiri 2003).

Table 4. continued.

Woodland community type	Tree species	Harvest-able area (ha)	Pre-liminary harvesting rate per year (%)	Estimated of the total number of trees in the selected size classes of the Tall Sand Forest		Pre-liminary harvest quota (number of trees)	Circum-ference growth rate (mm/ year)	Time required to replace one size class (years)	Sustainable harvesting quota per year (number of trees)
				Total area (ha)	Harvested Area (200 ha)				
		(Har)	(PHr)	(T)	(N)	(PHq = N x PHr)	(Gr)	(Rsc = SCI/Gr)	(SHq = PHq/Rsc)
Closed	*Pteleopsis myrtifolia*	42	49.17	50930	4620	2272	5.24	5	476
Closed	*Tabernaemontana elegans*	42	31.80	32410	2940	935	0.86	29	32
Closed	*Acacia burkei*	42	23.61	158578	14385	3395	1.71	58	58
Closed	*Strychnos madagascariensis*	42	38.16	230343	20895	7974	6.76	15	539
						Total Closed Woodland Community			1105
Open	*Euclea natalensis**	145	7.62	3640	1933	147	0.86	29	--
Open	*Acacia burkei*	145	12.97	81293	43175	8531	1.71	58	146
Open	*Strychnos madagascariensis*	145	19.76	91607	48652	13367	6.76	15	904
Open	*Terminalia sericea*	145	22.50	155307	82483	18564	0.35	286	65
						Total Open Woodland Community			1115

*Due to its low frequency value of < 0.50, this species may not be harvested (Lawes & Obiri 2003).

Table 5. Determination of the sustainable harvesting quota per year for the total standing crop of the Closed and Open communities of TGR, northern Maputaland, KwaZulu-Natal, South Africa, based on Shackleton's (1993) fixed 3% harvesting rate.

Woodland community type	Tree species	Harvestable area (ha)	Estimated number of trees in the selected size classes in the woodlands (ha)		Sustainable harvesting quota per year based on the fixed 3% sustainable harvest rate	
			Total area	Harvestable area	Total area	Harvestable area
Closed	*Pteleopsis myrtifolia*	42	50930	4620	1528	139
Closed	*Tabernaemontana elegans*	42	32410	2940	972	88
Closed	*Acacia burkei*	42	158578	14385	4757	431
Closed	*Strychnos madagascariensis*	42	230343	20895	6910	627
		Total Closed Woodland Community			14167	1285
Open	*Euclea natalensis**	145	3640	1933	--	--
Open	*Acacia burkei*	145	81293	43175	2439	1295
Open	*Strychnos madagascariensis*	145	91607	48652	2748	1460
Open	*Terminalia sericea*	145	155307	82483	4650	2475
		Total Open Woodland Community			9846	5229

*Due to its low frequency value of < 0.50, this species may not be harvested (Lawes & Obiri 2003).

no significant difference between the two methods when Shackleton's (1993) method is used for the restricted areas number of individuals (Closed woodland: t = 0.30, df = 3, P > 0.05; Open woodland: t = 2.05, df = 3, P > 0.05). By using a chi square contingency table to compare the results for the Closed Woodland species and Open Woodland species individually, a significant difference is clearly visible in both cases between the numbers of individual trees available for harvest using the present study's methodology and that of Shackleton (1993) (Closed Woodland: χ^2 = 491.18, df = 3, P < 0.01, Open Woodland: χ^2 = 1156.38, df = 3, P < 0.01).

Conclusion

The concept of grain of the species (Obiri *et al*. 2002, Lawes & Obiri 2003) revealed which species may be harvested in the Tall Sand Forest, Closed and Open Woodland communities of TCA. As suggested by Lawes and Obiri (2003), the graphic representation of the grain of a species is a useful tool to establish which species may be harvested and those that should not be. By using the species pre-selected by Gaugris (2004) and applying the method developed by Obiri *et al*. (2002), we were able to restrict the harvestable species further. Interestingly, the method of Obiri *et al*. (2002) was also successfully used for Woodland vegetation, which increases its usability.

The similarity between the results of the present methodology and that of Shackleton (1993) to establish the sustainable harvesting quota when applied to a restricted harvestable area is encouraging as it demonstrates that the present method obtains applicable and realistic results. By using the method presented in this article, in the Tall Sand Forest community the sustainable harvesting quota independent of the species is 34.7% higher than that obtained when using Shackleton's method, while it is 14.0% lower in the Closed Woodland community and 78.8% lower in the Open Woodland community. Furthermore, by using the present method the Short Sand Forest and Sparse Woodland communities were excluded from harvesting. It appears doubtful that the method from Shackleton (1993) would allow such restrictions as it has a much broader scope. The chi square tests show that results per species are different between the two methods, which suggests the present method's consideration of more ecological criteria should therefore be more exact.

Gaugris (2004) established the resource base abundance, the rate of use and the regeneration of the resource base (criteria considered to be mandatory by Lawes & Obiri 2003) in the Manqakulane community. The already conservative results obtained by combining a restricted harvest zone as suggested by Gaugris (2004) and the additional restrictive criteria of the present study suggest that the harvesting quotas calculated should not be detrimental to the species considered in the selected vegetation communities under the current utilization pressures in TCA. A species restricted harvest is therefore possible and suggested for TCA, based on the results of the present study.

While all species are indeed used for construction although with a marked difference in desirability (Gaugris 2004), some species, such as *Acacia burkei* Benth. and *S. madagascariensis* are preferably used as firewood. While *B. huillensis* was included in the calculations, the results strongly suggest that the species should not be harvested at all, which is why we suggest that this species should no longer be harvested. However, due to the popularity of the species for building construction (Gaugris 2004) the final decision should be left in the hands of the future ecological manager of the reserve in consultation with the steering committee of the Manqakulane community. As an alternative solution we suggest that an attempt to grow *B. huillensis* in a nursery should be conducted.

The method of Shackleton (1993) is simpler and faster than the methodology followed in the present study. We feel it may be useful in providing a preliminary indication of the sustainable harvesting quota. However, when sufficient data are available, then the method followed in the present study is suggested as it offers the most detailed and species-sensitive approach.

While the results of the methodology employed in the present study show interesting promises, there are inherent limitations to this study. The study area and sample size were small in comparison to the examples cited by Obiri *et al*. (2002) and Lawes & Obiri (2003). The results are based on a small and localized section of the vegetation of Maputaland. Any generalization of the present study's results would be dangerous and incorrect. However, due to the remarkable similarity between the vegetation of TEP and TCA (Gaugris *et al*. 2004), it is probable that the results for TCA can be applicable to TEP. In addition, due to the limited knowledge of the area, ecological variables such as species growth rates had to be generalized from available data for a few species, and recruitment rates were unknown. Despite these restrictions, the methodology followed in this study provided comparable, useful and conservative sustainable harvesting quotas and rates from data commonly available after vegetation studies. The interest of the present study therefore lies in the methodology, which is also easily replicable. We feel that the present methodology is useful for nature conservation authorities as it allows a rapid and conservative assessment of sustainable harvesting quotas and thus provide an argument to start negotiating with local rural communities.

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