THE *PINUS PATULA* PLANTATION … A NURSERY FOR NATURAL FOREST SEEDLINGS

[1]C. J. Geldenhuys and [2]C. Delvaux
[1]Forestwood & Department of Forest & Wood Science, University of Stellenbosch
[2]Department of Plant Production, Laboratory for Tropical and Subtropical Agronomy and Ethnobotany, University of Gent, Belgium

Abstract

Even if the timber plantation presents many negative ecological impacts, it can catalyze regeneration of natural forest biodiversity and consequently it could be used as a management tool to rehabilitate degraded forest. In the CPWild study on Bark for Traditional Medicine, no seedlings, saplings or pole-sized trees of the key bark-harvested species could be found in the forest, but were found in the neighbouring *Pinus patula* plantation. This study had two objectives: 1) to formulate the hypothesis that the diversity and abundance of forest tree regeneration under a plantation stand adjacent to the Nzimankulu forest (Eastern Cape, South Africa) is enough to help to rehabilitate the natural forest; and 2) to establish different experimental systems for the planting of these seedlings - in gaps inside the forest, on the forest margin and near the rural village. Of the eleven target species, two species (*Cussonia spicata* and *Rhus chirindensis*) were found only in the plantation, three species (*Rapanea melanophloeos*, *Ocotea bullata* and *Kiggelaria africana*) were most found in the plantation and three species (*Zanthoxylum davyi*, *Prunus africana* and *Celtis africana*) grew preferentially in the plantation but also in the forest.

1. Introduction

Commercial timber plantations provide an important timber and fibre resource that the natural forests cannot provide. However, some people see them as green deserts that degrade natural biodiversity. Other people recognize that they may be pioneer tree species, but because they are introduced species they should be removed outside of production systems. But what about if they are allies that facilitate good forest regrowth and could be managed towards recovery of natural forest? Then there is also the issue of creating alternative resources for the other species used for various products but which are in short supply in the natural forests. But where would we find the seedlings easy and cheaply for the rural environment? If we use seed collected elsewhere or buy seedlings, would that be representative of the local genetic pool or would it introduce other genetic stock from elsewhere in the geographic range of the indigenous target species? Could the plantations be used for such purposes?

Natural forests provide a wide range of potential timber and non-timber products, other potential uses, and various direct and indirect benefits (McKenzie, 1988). Provision for alternatives is critical for sustainable management when the natural resource base is inadequate to provide in the user needs. For example, sustainable harvesting levels of *Rumohra adiantiformis* fern leaves from the Southern Cape forest (Geldenhuys & Van der Merwe, 1998; Geldenhuys, 1994a) were too low to satisfy the market demand for the cut-flower industry, both nationally and internationally. Cultivation of more productive resources outside the forests (timber plantation under storey and shade-cloth nurseries) to satisfy the demand contributed to conservation of many small forest patches on farmland, and to general social and economic benefits in the areas surrounding the forests (Geldenhuys, 1994a; Kok, 2004).

The survey of bark-stripped species in 13 forests in the Umzimkulu District (Geldenhuys, 2004) showed no seedlings, saplings or small trees <15 cm DBH of the main bark-harvested species *Ocotea bullata*. *Prunus africana* seedlings occurred only underneath the canopy trees, and saplings were very rarely found in large gaps. Seedlings and saplings of *Rapanea melanophloeos* found in the forest were stunted plants. The intensity of bark harvesting from these forests (Geldenhuys, 2004), and its impact on the forest and mortality of the harvested trees made it necessary to look at the development of alternative resources in and around the degraded forests to reduce the pressure on the degrading forests and to facilitate participation of bark harvesters in developing the alternatives.

Observations in the pine stand adjacent to the entrance to the Nzimankulu forest indicated that several forest species were present in the under storey, several of which had been browsed. A very brief study was made of the area with the following objectives in mind:

i. To assess the density and species composition of seedlings of natural forest tree species in the plantation under storey to test the hypothesis that the diversity and abundance of tree

regeneration of natural forest species under the plantation stand will be sufficient to help to rehabilitate the natural forest.

ii. To establish one fenced and one unfenced plot in the plantation to assess the effect of grazing/browsing by cattle and antelope (bushbuck) on the survival and height growth of tree seedlings of natural forest species;

iii. To collect seedlings of natural forest tree species from the plantation for planting in different systems (forest gaps, forest margins, and a home garden in Cancele Village).

iv. To assess the survival and height growth of the marked seedlings inside the fenced and unfenced plots, and transplanted seedlings in forest gaps, forest margin and community home garden.

2. Study area

The study area at the entrance to Nzimankulu forest (Figure 1) is located at approximately 30º20.3'S, 29º51.4'E and 1300 m above mean sea level (a.s.l.), in the Umzimkulu District of the Eastern Cape. The forest is situated on the southeastern slopes below the Nzimankulu peak (1528 m a.s.l.). The forest grows on soils derived from shales, mudstones and sandstones of the Ecca Group and dolerites of the Beaufort Group (Cawe, 1986). The mean annual rainfall is >1000 mm, with the wet period October - March, and dry period June - July (Cawe, 1986). The forest used to occur as an island within the grasslands (a typical fire refuge site according to Geldenhuys, 1994b). It now forms the southern boundary of the Straalhoek Plantation, a commercial timber plantation managed by Singisi Forest Products.

The *Pinus patula* stand (compartment B19) adjacent to the forest in the study area was planted at a spacing of 2.7 m x 2.7 m in 1981 (21 years old at time of study). Its stand density was 500 stems per ha. In the fenced plot the stand density is 600 stems/ha with mean DBH 30.1 cm, and in the unfenced plot the stem density is 325 stems/ha, with mean DBH 33.5 cm.

The study area was mapped as indicated in Figure 1. Only one tree of *Prunus africana*, partly debarked, was found, as indicated. Several dead/dying trees of *Ocotea bullata* are present in the forest shown on the map, with many dead debarked trees of *Rapanea melanophloeos* in the forest margin.

3. Methods

3.1 Inventory of seedlings

Seedlings were recorded on seedling sample plots of 2 m x 5 m (= 10 m²) distributed as shown in figure 1. Survey lines were demarcated 10 m apart into the plantation stand to the north and south of the road (at 90º from the center line). Seedling sample plots were laid out, starting at 10 m away from the zero point on the road, to the north of the road. A new plot was started every 10 m, i.e. 10 m, 20 m, 30 m, etc. until no more seedlings were found. To the south of the road, a first plot was started 20 m to the south of the road and the survey line was ended where the slope changed, with forest down the slope. South of the road, the location of the seedling sample plots was noted as plantation stand, natural forest or the transition between plantation and forest. On each seedling sample plot, the species and height (in cm) were recorded for each seedling found. Seedlings of *Ocotea bullata*, when observed outside of the sample plots along the survey line, were recorded.

A pilot survey was started north of the road in March 2002. It focused on seven species (*Celtis africana, Kiggelaria africana, Ocotea bullata, Prunus africana, Rapanea melanophloeos, Xymalos monospora* and *Zanthoxyllum davyi*), but other species were noted when present. The survey south of the road was done in June/July 2002 and included 12 species (adding *Allophylus dregeana, Cussonia spicata, Ilex mitis, Rhus chirindensis, Rothmannia capensis)*.

Figure 1. Layout of seedling sample plots and seedling growth plots (fenced and unfenced) inside the *Pinus patula* plantation stand and natural forest, adjacent to the Nzimankulu forest, and planted groups (with and without protection) in the clearing between Nzimankulu forest and the pine stand.

3.2 Fenced and unfenced plots

Two plots of 20 m x 20 m each were demarcated as shown in Figure 1. The plot north of the road was fenced with diamond-mesh wire to 1.2 m above the ground, with three strands of barbed wire on top. The plot south of the road was demarcated with four corner poles but left unfenced. All seedlings of natural forest species found in each of the two plots were marked with a plastic tag, with the first four bits of information recorded on the tag. The following information was recorded for each marked seedling: 1: Species; 2: Seedling height, cm; 3: Serial number; 4: Recording date; 5: Number of total leaves; 6: Number of leaves already eaten. All information was recorded into a database on a handheld computer. The seedlings were numbered in a sequence along 2-3 m wide strips, as indicated in Figure 2.

3.3 Planting of seedlings in different sites

Seedlings were lifted with a spade from the *P. patula* stand for planting in three different sites, with some soil around the roots, placed in a plastic bucket together with other plants, and transferred to the planting site. Seedlings were planted in a small hole made with the spade, and the soil was firmed around the roots. Approximately 250 ml of water was added to each plant immediately after planting. Each planted seedling was marked with a plastic tag, with the following information written on the tag: 1: Species; 2: Seedling number; 3: Seedling height, cm; 4: Planting date. All information was recorded into a database on a handheld computer.

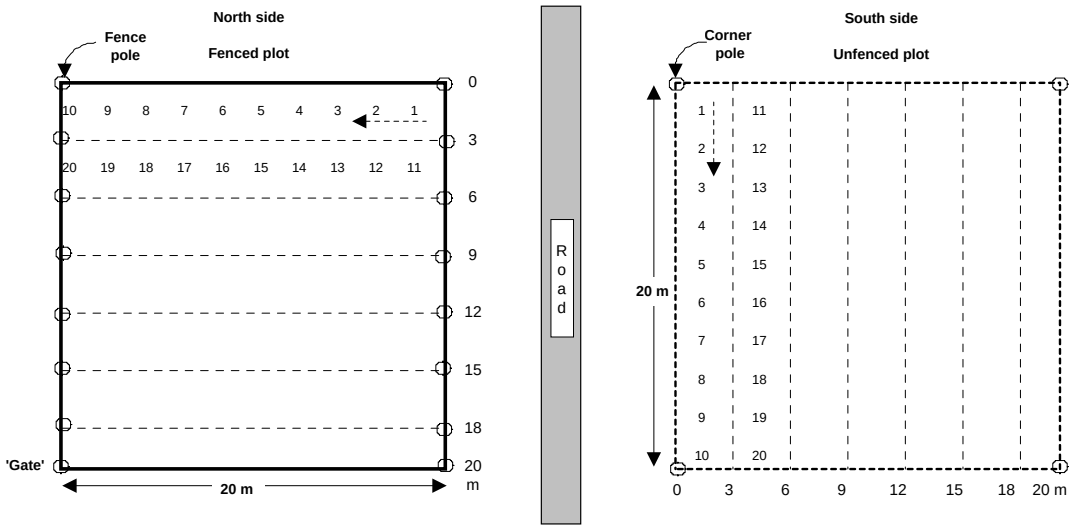

Figure 2. Layout of the fenced and unfenced plots, and indication of sampling strips and direction of marking seedlings.

The three sites were:

3.1.1 Forest margin

In the forest margin site (Figure 1) a tall stand of the invader plant *Solanum mauritianum* was cleared by cutting the trees, treating the stumps and piling the branches on one side of the clearing. Twenty-six groups of seedlings were planted; 20 protected and six left unprotected. Each planted group consisted of six plants, i.e. one per species. In the protected groups, planting of *Ocotea bullata, Prunus africana* and *Rapanea melanophloeos* was obligatory, and in the unprotected groups, planting of *Prunus africana* and *Rapanea melanophloeos* was obligatory (not enough *O. bullata* seedlings). The other species were selected at random from the available plants. Protection against browsing by antelope and/or cattle was done by stacking the dead branches of *Solanum mauritianum* over the seedlings. In each protected group, the seedlings were planted about 1.5 m apart: one in the middle and five in a circle. In each unprotected group the seedlings were not planted in a circle but under an available fern plant to protect it against the sun.

3.1.2 Forest gaps

Five forest gaps were selected for planting seedlings to facilitate gap recovery. The first large gap was caused by the illegal felling of a large *P. africana* tree about 250 m down the road from the forest margin. Sixteen *P. africana* plants between 20 cm and 75 cm high were collected from the secondary plantation road (Figure 1) and planted on 12 March 2002 in groups of two seedlings: one with protection (branch) and the other without protection. On 4 April 2002 only one of the planted seedlings appeared wilted, and the others appeared healthy. On 15 April 2002, some of the seedlings were defoliated (some by insects, but others possibly by rodents or by antelope).

3.1.3 Primary Health Care Centre

On their request, traditional healers from the Cancele Village were assisted to plant seedlings inside the fence around their Primary Health Care Centre (clinic) (Figure 3). A total of 92 seedlings of 12 forest tree species (*Allophylus dregeana, Celtis africana, Cussonia spicata/sphaerocephala, Ilex mitis, Kiggelaria africana, Ocotea bullata, Prunus africana, Rapanea melanophloeos, Rhus chirindensis, Rothmannia capensis, Xymalos monospora* and *Zanthoxylum davyi*) were collected from the studied *P. patula* stand during April 2002 for this planting. The village is located on the north western side of Nzimankulu Mountain, close to Adam forest. The clinic is located on a south-westerly slope, with the surrounding area covered in grassland. The area around the clinic was fenced to protect the vegetable gardens of local inhabitants against domestic livestock. The time of planting was not good for the survival of the seedlings, i.e. at the start of the dry season, and strong, hot bergwinds. A survey on 6 July 2002 showed that many of the seedlings

appeared dead. Some of the dead seedlings were replaced in July 2002, either with the same species, or with other species, such as *Elaeodendron croceum* and *Ptaeroxylon obliquum*, all collected from the Adam forest area near a cut plantation. During this replanting, the seedlings were protected against the sun and wind by planting a fern leaf next to the seedling.

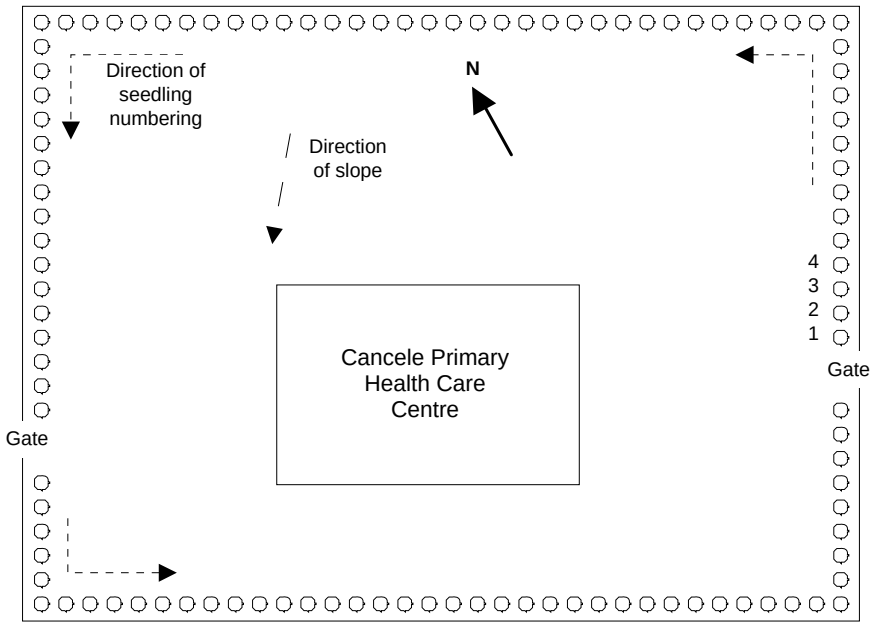

Figure 3. Location of planted seedlings around Cancele Primary Health Care Centre, and direction of numbering of the seedlings.

3.3 Remeasurement of seedlings

An adaptive management research approach was followed. It provided for comparison between treatments, but also for demonstration to local resource managers of the potential to follow the practices investigated. Remeasurement of all marked seedlings was scheduled first at the start of the rainy season, then two months later, and then every six months for three remeasurements, and then once a year after that in June (middle of the dormant period). We realized that this pilot study may not provide for detailed statistical analyses and extrapolation of results.

4. Results

4.1 General comments

Only results from the seedling surveys are presented below. Several happenings impacted on the use of results from the planting studies.

i. The local forest management team required forest seedlings of forest species for planting in the forest gaps and, without knowledge of the Project team, collected the tagged seedlings, first from the unfenced plot and then halfway through the fenced plot.

ii. The planted groups on the forest margin were totally overgrown by creepers. With the low-packed bugweed (*Solanum mauritianum*) branches, the creepers became entangled within the branches. This made it very difficult to find the seedlings within the short time available to follow up on their survival and early growth.

iii. A devastating fire, driven by a bergwind, swept through the adjacent Straalhoek plantation during July 2003. It burnt through the studied *P. patula* stand and totally cleared the understorey vegetation, without killing the pine trees. This caused a dense pine needle layer covering the ground layer and impeded forest seedling recovery. This fire also burnt through the Cancele Village clinic area, although some of these plants resprouted afterwards.

4.2 Inventory of natural forest seedlings in plantation

4.2.1 Species richness and seedling density

Twenty-four seedling sample plots (240 m²) were recorded in the plantation north of the road, 47 plots (470 m²) in the plantation south of the road and 31 plots (310 m²) in the natural forest or transition between the forest and plantation (Figure 1). A total of 614 seedlings were recorded on these plots, i.e. 6020 seedlings/ha in the sampled area. Table 1 shows the density of these seedlings by species in 10 cm wide height classes. Figure 4 shows the number of seedlings of each species per sampled plot. There were 6250 natural forest seedlings/ha in the stand north of the road (CV=91.1%, where CV= coefficient of variation or 100*SE/mean), 6383 seedlings/ha in the plantation south of the road (CV=89.0%), and 5290 seedlings/ha in the patch of natural forest (CV=71.6%). The different species show major differences in total seedling density (Table 1). *Rapanea melanophloeos* is the most common species with 2382 seedlings/ha, followed by *Zanthoxylum davyi* (961 seedlings/ha), *Prunus africana* (598 seedlings/ha), *Allophylus dregeanus* (588 seedlings/ha) and *Celtis africana* (569 seedlings/ha). *Ocotea bullata* has the lowest density (78 seedlings/ha), but occurred with relatively high density in some clusters (line 2, plots N5 and N6 in Figure 4). In this cluster there were at least 12 *O. bullata* seedlings inside and adjacent to the survey line. A total of 20 seedlings of *O. bullata* were recorded in the plantation north of the road.

The diagram for all seedlings combined (Figure 4) shows that the seedlings are not evenly distributed through the sampled stand (also shown by the high CV values). There are clusters of seedling sample plots with higher seedling numbers and others with fewer to zero seedlings. In the area north and northeast of the sampled area north of the road and east of the sampled area south of the road there are zero to very sparsely distributed seedlings. There is also a zone around the forest with sparse seedling density. This sparse zone is particularly obvious in the diagrams of *Allophylus dregeanus, Celtis africana* and *Zanthoxylum davyi* (Figure 4).

Species showed differences in seedling density between the three sampled areas (Table 1, Figure 4). All eleven sampled species occurred in the plantation, but *Cussonia spicata* and *Rhus chirindensis* were not recorded from the forest (*Allophylus dregeanus, Cussonia spicata, Rhus chirindensis* and *Rothmannia capensis* were not sampled north of the road).

- *Rapanea melanopholoeos* (228 of 243 seedlings), *Kiggelaria africana* (17 of 19 seedlings) and *Ocotea bullata* (8 of 9 seedlings) are almost exclusively found in the plantation.
- *Zanthoxylum davyi* (75 of 98 seedlings), *Prunus africana* (46 of 61 seedlings) and *Celtis africana* (37 of 58 seedlings) are recorded preferentially in the plantation but are also found inside the forest and transition zone).
- *Allophyllus dregeana* (42 of 60 seedlings), *Rothmannia capensis* (27 of 32 seedlings) and *Xymalos monospora* (18 of 20 seedlings) are more often found in the forest than in the plantation.

4.2.2 Seedling height

The mean height of all seedlings recorded in the survey was 40.8 cm (SE=25.5 cm) (Table 1). The mean height in the plantation north of the road was 30.1 cm (SE=24.5 cm), in the plantation south of the road it was 49.6 cm (SE=23.7 cm) and in the forest it was 34.3 cm (SE=24.1 cm). The mean height and SE of the mean height of seedlings of each of the 11 species in the three localities are shown in Table 2. The mean height of plants in the plantation south of the road was always higher than the plants in the forest, which were higher than the plants in the plantation north of the road – except for *Zanthoxylum davyi*.

The peaks in the frequency distribution of seedling height vary between the different sites (Table 1). For example, *Prunus africana* had no seedlings smaller than 10 cm, but the peak of the distribution is in the 21-30 cm class in the plantation south of the road, but in the 11-20 cm class in the plantation north of the road, and in the forest. *Rapanea melanophloeos* has a high peak in plants 10 cm and smaller in the plantation to the north, and peaks in the 21-30 cm class in the other two sites. Similar differences can be seen with *Kiggelaria africana* and *Zanthoxylum davyi*.

Table 1. Density of forest tree seedlings (seedlings/ha) by plant height classes and species in a *Pinus patula* stand of 21 years adjacent to the Nzimankulu forest. The site symbols have the following meaning: F = Forest; Ps = Plantation stand to the south side of the road; Pn = Plantation stand to the left north side of the road. The * indicates that the particular species was not sampled in the particular site

Species	Site	Seedling height, upper limit of class, cm											Total
		10	20	30	40	50	60	70	80	90	100	100+	
Allophylus dregeanus	F	161.3	612.9	290.3	32.3	64.5	32.3	32.3	-	-	32.3	96.8	1354.8
	Ps	-	63.8	-	21.3	42.6	42.6	21.3	42.6	42.6	21.3	85.1	383.0
	Pn*												*
Cussonia spicata	F	-	-	-	-	-	-	-	-	-	-	-	-
	Ps	-	21.3	-	-	-	21.3	-	-	-	-	-	42.6
	Pn*												*
Kiggelaria africana	F	-	32.3	32.3	-	-	-	-	-	-	-	-	64.5
	Ps	-	-	63.8	21.3	21.3	21.3	-	-	-	-	-	127.7
	Pn	208.3	166.7	41.7	-	-	41.7	-	-	-	-	-	458.3
Ocotea bullata	F	32.3	-	-	-	-	-	-	-	-	-	-	32.3
	Ps	-	-	-	-	-	-	-	-	-	-	-	-
	Pn	333.3	-	-	-	-	-	-	-	-	-	-	333.3
Prunus africana	F	-	225.8	193.5	64.5	-	-	-	-	-	-	-	483.9
	Ps	-	63.8	276.6	191.5	42.6	106.4	-	21.3	21.3	-	21.3	744.7
	Pn	-	375.0	83.3	-	-	-	-	-	-	-	-	458.3
Rapanea melanophloeos	F	-	32.3	193.5	96.8	64.5	-	32.3	32.3	-	-	32.3	483.9
	Ps	42.6	383.0	638.3	510.6	531.9	446.8	212.8	404.3	85.1	63.8	85.1	3404.3
	Pn	1250.0	875.0	250.0	83.3	250.0	41.7	-	-	-	-	41.7	2791.7
Rhus chirindensis	F	-	-	-	-	-	-	-	-	-	-	-	-
	Ps	-	-	-	-	21.3	-	-	21.3	-	21.3	-	63.8
	Pn*												*
Rothmannia capensis	F	322.6	258.1	161.3	64.5	-	-	32.3	32.3	-	-	-	871.0
	Ps	-	42.6	42.6	-	-	-	-	-	21.3	-	-	106.4
	Pn*												*
Xymalos monospora	F	64.5	322.6	161.3	32.3	32.3	-	-	-	-	-	-	612.9
	Ps	21.3	42.6	63.8	21.3	-	-	-	-	-	-	-	148.9
	Pn	41.7	41.7	41.7	41.7	-	-	-	-	-	-	-	166.7
Zanthoxylum davyi	F	-	-	64.5	129.0	161.3	161.3	32.3	32.3	32.3	-	129.0	741.9
	Ps	-	-	191.5	170.2	127.7	127.7	21.3	63.8	85.1	-	21.3	808.5
	Pn	125.0	83.3	83.3	250.0	375.0	250.0	41.7	125.0	41.7	125.0	-	1500.0

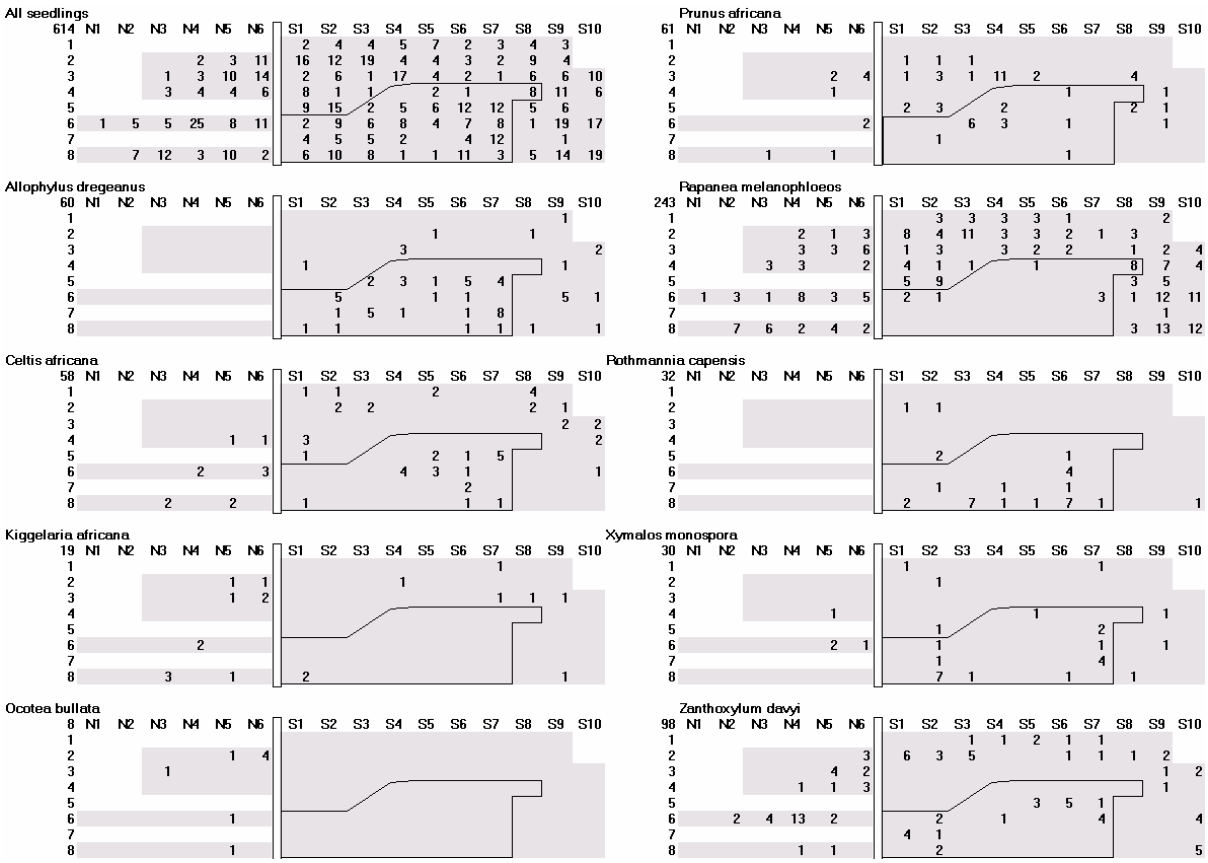

Figure 4. Number of seedlings per seedling sample plot (10 m²), for each of the natural forest tree species, in the *Pinus patula* plantation and natural forest (blocked out) adjacent to Nzimankulu forest (see Figure 1 for details of sampling layout). The total number of seedlings recorded per species is shown in the upper left cell below the species name. The sampled area is shaded.

Table 2. Mean height (cm), number of seedlings (n) and sample standard error of mean (SE) for the natural forest seedlings by species, recorded in the *Pinus patula* plantation and forest patch adjacent to Nzimankulu forest

Species	Forest			Plantation (south)			Plantation (north)		
	Mean (cm)	n	SE	Mean (cm)	n	SE	Mean (cm)	n	SE
Allophylus dregeanus	**33.3**	42	27.5	**70.6**	18	32.3	**-**	0	-
Celtis africana	**26.2**	21	8.6	**42.7**	26	16.9	**36.4**	11	32.6
Cussonia spicata	**-**	0	-	**40.0**	2	28.3	**-**	0	-
Kiggelaria africana	**25.0**	2	7.1	**40.0**	6	12.6	**20.0**	11	14.8
Ocotea bullata	**10.0**	1	-	**-**	0	-	**10.0**	8	0.0
Prunus africana	**26.7**	15	7.2	**42.6**	35	19.9	**21.8**	11	4.0
Rapanea melanophloeos	**45.3**	15	24.2	**50.4**	160	23.2	**21.7**	68	17.0
Rhus chirindensis	**-**	0	-	**76.7**	3	25.2	**-**	0	-
Rothmannia capensis	**23.7**	27	17.6	**38.0**	5	29.5	**-**	0	-
Xymalos monospora	**24.2**	19	9.6	**25.7**	7	9.8	**25.0**	4	12.9
Zanthoxylum davyi	**63.0**	23	26.2	**53.4**	38	21.8	**54.1**	37	26.4

4.3 Fenced and Unfenced plots

The fenced plot in the plantation north of the road had 459 forest seedlings/400 m² (11 475 seedlings/ha), and the unfenced plot in the plantation south of the road had 302 seedlings/400 m² (7 550 seedlings/ha) (Tables 3 & 4). The most abundant species were *Rapanea melanophloes* (more abundant in the unfenced plot) and *Zanthoxylum davyi* (more abundant in the fenced plot). These two species also have the widest range in height classes. *Celtis africana* also includes stems across the range of height classes. Both *Prunus africana* and *Ocotea bullata* had more seedlings in the fenced than unfenced plot. Seedlings in the fenced plot were smaller than in the unfenced plot, as in the inventory, except for *Kiggelaria africana* and *Zanthoxylum davyi* (Table 3 & 4). The seedlings of *Cussonia spicata, Kiggelaria africana, Ocotea bullata, Rothmannia capensis* and *Xymalos monospora* were generally less than 40 cm high. The fenced plot included one seedling of *Ilex mitis* of 15 cm height.

Table 3. Natural forest tree seedling density (per 400 m²), mean height and sample standard error (SE) of the mean height in the fenced and unfenced plots in the *Pinus patula* stand adjacent to Nzimankulu forest

Species	Fenced			Unfenced		
	Density	Height (cm)		Density	Height (cm)	
		Mean	SE		Mean	SE
Allophylus dregeanus	16	24.4	14.5	7	35.1	26.3
Celtis africana	51	28.6	22.2	30	40.9	26.5
Cussonia spicata	18	18.5	11.0	14	21.0	7.2
Kiggelaria africana	23	25.7	17.7	20	22.2	10.1
Ocotea bullata	11	15.5	9.0	4	14.5	5.1
Prunus africana	41	23.8	12.0	20	26.5	11.9
Rapanea melanophloeos	116	30.0	26.4	133	35.8	19.6
Rhus chirindensis	5	49.8	27.8	1	64.0	-
Rothmannia capensis	7	18.7	11.4	6	14.7	10.0
Xymalos monospora	34	9.1	6.5	1	39.0	-
Zanthoxylum davyi	137	48.0	29.3	66	43.3	19.9

Table 4. Height class distribution of seedlings of natural forest species in the fenced and unfenced plots in the *Pinus patula* stand adjacent to the Umzimkulu forest, expressed in stems/ha

Species	Protection	Seedling height, cm (upper limit of 10 cm wide class)										
		10	20	30	40	50	60	70	80	90	100	110
Allophylus dregeanus	Fenced	25	150	150	25	-	50	-	-	-	-	-
	Unfenced	25	25	50	25	25	-	-	-	25	-	-
Celtis africana	Fenced	100	475	375	25	100	75	25	50	25	-	25
	Unfenced	-	100	250	125	50	100	50	25	-	-	50
Cussonia spicata	Fenced	50	325	25	25	-	25	-	-	-	-	-
	Unfenced	-	175	150	25	-	-	-	-	-	-	-
Kiggelaria africana	Fenced	50	200	150	125	25	-	-	-	-	25	-
	Unfenced	25	225	175	25	50	-	-	-	-	-	-
Ocotea bullata	Fenced	50	175	25	25	-	-	-	-	-	-	-
	Unfenced	-	75	25	-	-	-	-	-	-	-	-
Prunus africana	Fenced	25	425	400	100	25	25	25	-	-	-	-
	Unfenced	-	175	200	50	50	25	-	-	-	-	-
Rapanea melanophloeos	Fenced	275	975	750	325	175	200	25	75	50	-	50
	Unfenced	125	625	800	800	325	350	100	125	25	25	25
Rhus chirindensis	Fenced	-	-	25	25	50	-	-	-	-	25	-
	Unfenced	-	-	-	-	-	-	25	-	-	-	-
Rothmannia capensis	Fenced	25	100	-	50	-	-	-	-	-	-	-
	Unfenced	50	75	-	25	-	-	-	-	-	-	-
Xymalos monospora	Fenced	625	200	-	-	25	-	-	-	-	-	-
	Unfenced	-	-	-	25	-	-	-	-	-	-	-
Zanthoxylum davyi	Fenced	250	425	425	400	475	425	300	275	100	175	175
	Unfenced	50	125	300	275	300	250	175	125	25	25	-
TOTAL	Fenced	1475	3450	2325	1125	875	800	375	400	175	225	250
	Unfenced	275	1600	1950	1375	800	725	350	275	75	50	75

5. Discussion

5.1 Successful regeneration of forest species under pine stands

It is often considered that timber plantations are detrimental to the natural forest. However, this study supported several other studies, indicating that forest species establish in the understorey of pine and other planted tree stands adjacent to the forest (Geldenhuys, 1996, 1997; Parrotta *et al.*, 1997). In this study, density of natural forest seedlings, representing 12 forest species, varied between 5290 seedlings/ha in the forest patch to 6383 seedlings/ha in the plantation stand, to 7 550 seedlings/ha in the unfenced and 11 475 seedlings/ha in the fenced plot. The more common species were *Rapanea melanophloeos* (most common species), *Zanthoxylum davyi*, *Prunus africana*, *Allophylus dregeanus* and *Celtis africana*. Other less common species were *Cussonia spicata, Ilex mitis, Kiggelaria africana, Ocotea bullata* (lowest density), *Rhus chirindensis, Rothmannia capensis* and *Xymalos monospora*.

The species were present at considerable distances away from the forest margin, and potential parent trees in the forest margin. For example, *Prunus africana* seedlings were present at 110 m away from the only parent tree. Seedlings of *Ocotea bullata* were present in transect 8, i.e. 100 m away from the forest margin, with some dying debarked *O. bullata* trees inside the forest margin. Some *O. bullata* seedlings occurred northeast of the fenced plot, i.e. at least 130 m away from the forest margin. All the species are bird-dispersed. There is also a tendency for the seedlings to be clustered close to the stems of pine trees (perches for birds), but this was not investigated.

The mean height of plants in the plantation south of the road (49.6 cm) was always higher than the plants in the forest (34.3 cm), which was higher than the plants in the plantation north of the road (30.1 cm) – except for *Zanthoxylum davyi*. It is possible that the plantation stand south of the road is older or more advanced in stand development, or that it is closer to the surrounding forest. The northern part of the plantation was also separated from the forest by a secondary road and a stand of bugweed (forest margin site in Figure 1). Geldenhuys (1997) has shown that the older stands have seedlings of greater diversity and height than the younger stands. The seedlings in the forest are of a different suite, and their ages may be totally different from those in the plantation.

The seedlings in the plantation stands show a wide range in heights. The smaller seedlings are recent germinations, and show that there is continuous recruitment of seedlings. The seedlings of *Ocotea bullata* are very young and of similar age. It may suggest an irregular seed production by trees in the forest.

The plantation stands have stronger plants of forest species than the forest. Seedlings of *P. africana* are sometimes found underneath the parent trees in the forest, but they are never taller than 15 to 20 cm, and generally appear etiolated. The seedlings in the plantation were strong plants.

Less than 5 seedlings of *Ocotea bullata* have been found inside the forest under the canopy, two near the *P. africana* tree indicated in Figure 1, and only one surviving. The seedlings recorded in the plantation understorey all appeared healthy and strong. Their numbers and quality suggest that plantation stands adjacent to the natural forest may serve as a nursery for the collection of forest species for planting in suitable sites for development of alternative resources. Alternatively, some plantation stands could be thinned to facilitate the height growth of the established forest species in the plantation understorey. Several experiments were initiated to study the response of forest seedlings in the plantation:

- The expectation was that the fenced and unfenced plots would show the effects of grazing/browsing by cattle and/or antelope on the survival and height growth of the established seedlings. However, fencing is not a practical, cheap option for protection of seedlings if this practice is considered for use by bark harvesters. The majority of groups of planted seedlings in the cleared area on the forest margin were protected using branches from the cleared invader plant *Solanum mauritianum*. Again, the expectation was that the protected and unprotected plots/planted groups would demonstrate how practical these measures are. Unfortunately the devastating fire prevented this comparison. We suggest that it would have been better not to fell the stand of bugweed before planting the groups of forest seedlings, because the standing trees would provide shade to prevent the proliferation of creepers, and could have been ring-barked at a later stage to die standing while still casting shade.

- The purpose of planting useful forest tree species in the Cancele Village was to show that this could be done, and by doing this, the people could develop their own, more productive resources for small business and thereby reduce the pressure on the forest. However, the timing of the plantings was not the best (the dry period with exposure to the hot, dry bergwinds). Despite the watering of plants from time to time, many of the seedlings died. Unfortunately, the fire also damaged these plantings, although some of the seedlings survived through resprouting.

The fire pathway, i.e. burning through grassland and plantation stands but not entering the forest (supporting the views of Geldenhuys, 1994b), showed that such plantings should not be done inside the fire zone, unless the planted area is protected against fire.

The plantings used relatively many seedlings. The seedlings could not be found in the forest nor could be grown from seed (because no seed was available during the study period). The presence of the seedlings in the plantation stand offered an opportunity to transplant relatively strong plants into the different experimental sites at very low cost. Unfortunately the follow-up work (seedling height growth and survival) could not be continued due to the stated reasons.

5.2 Options for alternative resources

Results from this study present several options for the development of alternative resources through planting of seedlings of the target tree species (in high demand) in different systems:

i. Planting seedlings in gaps inside the forest and on the forest margin, to facilitate consolidation of forest or recovery of degraded forest.

ii. Planting seedlings in partially thinned plantation stands on the forest margin, or through facilitation of the development of existing regeneration of the selected species inside the plantation stands. An international research effort showed that tree plantations act as successional catalysts for native forest regeneration on degraded land (Parrotta *et al.,* 1997; Geldenhuys, 1997). Several of the bark-harvested species, including *Ocotea bullata*, were observed to establish underneath the pine stands adjacent to natural forests in the Umtata area (Geldenhuys, 2000), and under *Acacia melanoxylon* stands in the Southern Cape forests (Geldenhuys, 1996).

iii. Planting seedlings along unplanted riparian zones inside the plantation forestry estate, and near the villages of rural communities living near the forest. In these areas the plantings could be developed into coppice systems from which the leaves could be harvested like in tea plantations (and not the bark). Drewes *et al.* (2006) showed that the active chemical compounds in the bark associated with anti-inflammatory action were also present in the leaves. Leaves of another bark-harvested species in high demand, *Warburgia salutaris*, are already produced through this method (Mander *et al.*, 2006).

Planting stock could be obtained by different means:

i. Transfer of seedlings from seedling banks under the forest canopy (where they cannot become established) to gaps inside the forest and on the forest margin. In Newlands forest in the Cape Peninsula (Geldenhuys & Du Toit, 2002) and in the Southern Cape forests many seedlings of *Ocotea bullata* were present below the canopy of parent trees in the forest. In the Umzimkulu forests seedling banks of *Prunus africana* were sometimes present below the canopy of parent trees, but they cannot establish under the forest canopy and will eventually die. This approach ensures that seedlings of the local genetic pool can be obtained and transplanted at very low costs.

ii. Natural regeneration of the preferred species under plantation stands on the forest margin, as discussed above.

iii. Propagation of seedlings from seed collected from trees in the nearby forest. The reality was that between March 2000 and April 2002 no seed could be found on trees of the three target species, *O. bullata, P. africana* and *R. melanophloeos*, in the Umzimkulu forests.

iv. Mass production of planting stock in the medium term through vegetative propagation techniques. This option was considered outside the scope of the present study, i.e. to develop low technology and cost-effective practices for the rural environment.

6. Recommendations

It is recommended that these initial studies be expanded, particularly planting in gaps, on the forest margin and in the settlements. This will add considerable information to improve our understanding of the ecology of the species in terms of their light requirements, tolerance of low water levels during the dry season, and recovery from browsing.

In the interim, the plantation stands adjacent to natural forest could be used as sources for plants for planting alternative resources, and also in the communities, considering the following rules and guidelines:

- The permission of the local forester in charge of the relevant plantation should be obtained.
- Seedlings should only be collected during the rainy season, or during cool, misty periods to improve the survival rate of the collected plants and minimize the fire danger.
- The collectors should move in small groups under guidance of a forestry official or a local knowledgeable person from the community.
- In general, only seedlings of 20 to 50 cm tall should be used. Taller plants are more difficult to lift, to transport, and will adapt with more difficulty.
- The collectors should not take more plants than necessary, or that can be planted in one day.
- When a plant is lifted and transported, its roots should not become exposed. Some soil should be kept around the roots by placing the seedlings into a plastic bucket, container or bag, and adding some water before transporting the seedlings.
- The seedlings should be planted in small, pitted planting holes, with the roots spread out and the soil firmed around the roots. The soil should be watered thoroughly without drowning the plant, and kept moist for at least two weeks if no rain occurs.
- If necessary, a small branch of a wattle or other similar plant should be planted on the sunny side to shade the seedling.
- If necessary, the seedlings should be protected against browsing by antelope and cattle, and protected against fire.

Planting of the medicinal plants should be encouraged in the communities such as at schools, in home gardens and even in production systems. It is important to maintain the enthusiasm and interest of community members in maintaining existing plantings and assistance with further plantings. It will however be important to find a local interested person to take initiative and responsibility for such activities in the community.

Acknowledgement

This study formed part of the study of ‘Bark for Medicinal Use’, within the Innovation Fund Project ‘Commercial Products from the Wild’ (see www.cpwild.co.za). The participation of Claire Delvaux was funded, in part, by the ‘Fonds voor Wetenschappelijk Onderzoek (FWO)’, Vlanderen, Belgium. We acknowledge Singisi Forest Products for their permission to carry out the study within their plantation and to collect seedlings from the plantation for planting at Cancele Village. The enthusiasm of the people of Cancele Village, and in particular the hospitality of the Mjoli family during the stay of Claire Delvaux in their house, are acknowledged with great appreciation. Zithobé Mbala, Zélulé Mjoli and Zelve Mjoli helped with the inventory, planting and measurement of the seedlings, and K T Mlambo, S Thembele, Msizi Mjoli and S Mbhele helped with making the fence.

References

CAWE, S.G. (1986). *A Quantitative and Qualitative Survey of the Inland Forests of Transkei.* University of Transkei, Umtata.

DREWES, S., HORN, M. & KHAN, F. (2006). The chemistry and pharmacology of medicinal plants. In: DIEDERICHS, N (ed.). *Commercialising Medicinal Plants: A Southern African Guide*. SUN Press, Stellenbosch. pp. 87-95.

GELDENHUYS CJ. (1994a). Review of studies of the fern *Rumohra adiantiformis* in the southern Cape forests: Implications for sustained management. Report FOR-DEA 758, Division of Forest Science and Technology, CSIR, Pretoria. 14 pp.

GELDENHUYS, C.J. (1994b). Bergwind fires and the location pattern of forest patches in the southern Cape landscape, South Africa. *Journal of Biogeography* 21: 49-62.

GELDENHUYS, C.J. (1996). The Blackwood Group System: its relevance for sustainable forest management in the southern Cape. *South African Forestry Journal* 177: 7-21.

GELDENHUYS, C.J. (1997). Native forest regeneration in pine and eucalypt plantations in Northern Province, South Africa. *Forest Ecology and Management* 99: 101-115.

GELDENHUYS, C.J. (2000). Ecological processes the basis for sustainable nature conservation. Guest Editorial, *Plantlife* 23, 2-4.

GELDENHUYS, C.J. (2004). Meeting the demand for *Ocotea bullata* bark: implications for the conservation of high-value and medicinal tree species. In: LAWES, M.J., EELEY, H.A.C, SHACKLETON, C.M. & GEACH, B.G.S. (eds.). *Indigenous Forests and Woodlands in South Africa. Policy, People and Practice*. University of KwaZulu-Natal Press, Scottsville, South Africa. pp. 517-550.

GELDENHUYS, C.J. & DU TOIT, L. (2002). Proposal for Medicinal Plant Garden Training Facility at Mount Pleasant, Cape Peninsula National Park. Unpublished report, CP Wild Consortium, University of Stellenbosch. 10 pp.

GELDENHUYS, C.J. & VAN DER MERWE, C.J. (1988). Population structure and growth of the fern *Rumohra adiantiformis* in relation to frond harvesting in the southern Cape forests. *South African Journal of Botany* 54: 351-362.

KOK, R. (2004). The seven-weeks fern (*Rumohra adiantiformis*): an economically viable forest product. In: LAWES, M.J., EELEY, H.A.C, SHACKLETON, C.M. & GEACH, B.G.S. (eds.). *Indigenous Forests and Woodlands in South Africa. Policy, People and Practice*. University of KwaZulu-Natal Press, Scottsville, South Africa. pp. 333-336.

MANDER, M., Steytler, N. & Diederichs, N. (2006). The economics of medicinal plant cultivation. In: DIEDERICHS, N (ed.). *Commercialising Medicinal Plants: A Southern African Guide*. SUN Press, Stellenbosch. pp. 41-52.

McKENZIE, B. (ed.). (1988). Guidelines for the sustained use of forests and forest products. Workshop Report, Forest Biome Project, FRD:CSIR, Pretoria.

PARROTTA, J.A., TURNBULL, J.W. & JONES, N. (1997). Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management* 99: 1-7.