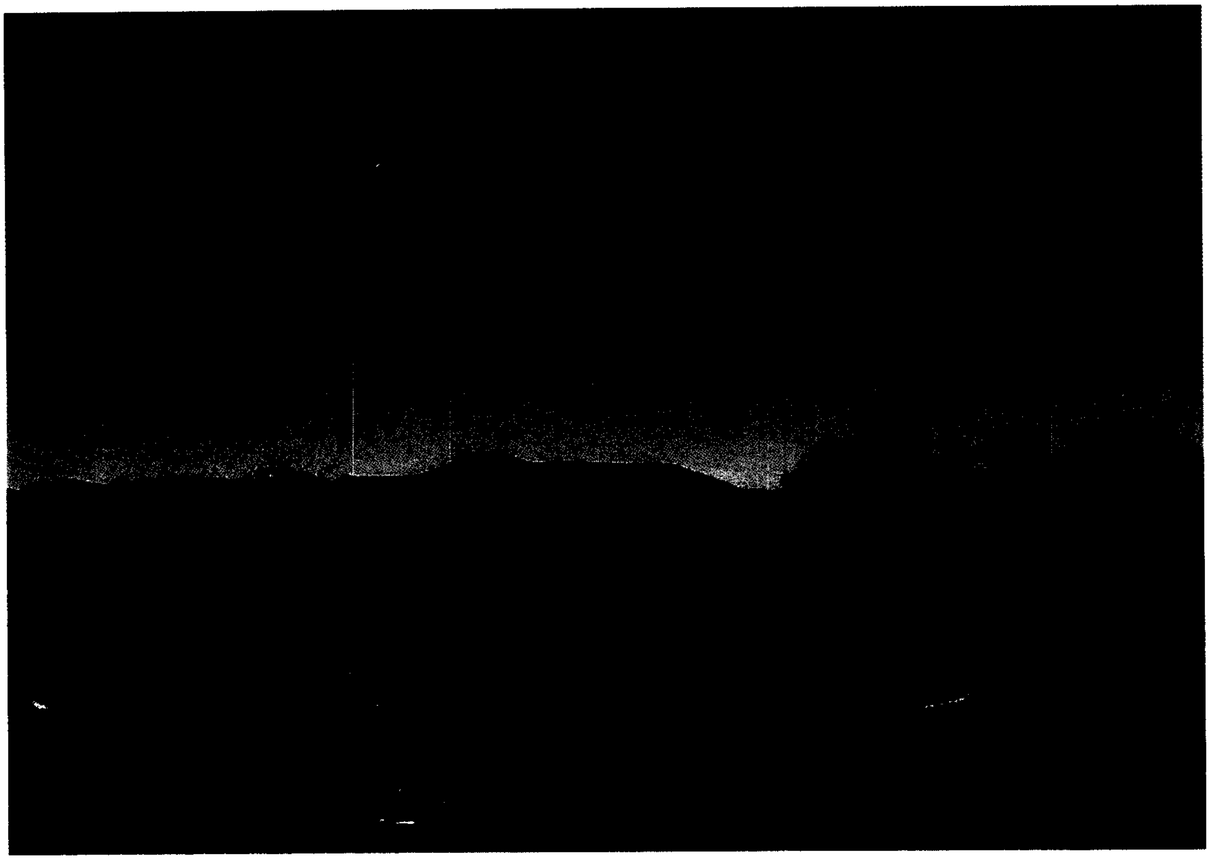
The spatial distribution of tree species across the Kuiseb river channel in relation to watercourse.



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ABSTRACT

At least seven of perennial plants occur in the Kuiseb River system, in the Namib Desert: *Acacia erioloba, Acanthosicyos horridus, Faidherbia albida, Euclea pseudebenus, Ficus sycomorus, Tamarix usneoides* and *Salvadora persica.* Their number, vitality, and spatial distribution (including position relative to the main channel of the river) were measured to allow comparison between transects surveyed at Gobabeb and Swartbank

The profile patterns were different between the two-study sites, within transects perpendicular to the river. The average percent canopy cover of tree species and distance length of their microhabitat were determined in transect laid at Gobabeb.The vitality and canopy width of specific tree by species at Gobabeb were compared to the data gathered in 2002 of vegetation mapping done by Grieve & Hensel. Long-term studies are recommended to provide an insight into this ecosystem and will better if all tree species within those two sites are marked for the future reference in terms of monitoring changes.

The *Acacia erioloba* was the dominant at both study sites, *Acacia erioloba* were also closer to the river channel at Swartbank while *Ficus sycomorus* and *Faidherbia albida* were closer to the river channel at Gobabeb. The tree species were showing better vitality at Gobabeb than Swartbank. There canopy cover and vitality of specific trees observed between 2002 and 2005 were more variables as there fluctuations from species to tree species. Generally there was a difference in tree species distribution at Gobabeb and Swartbank.

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1. INTRODUCTION

The Namib Desert, with its unusual geomorphology and climatology and its associated unique fauna and flora, has been a focus for biological research since the turn of the century (Seely, 1990).

The Kuiseb River is one of several rivers, flowing westward from the central plateau of Namibia through the Namib Desert into the southern Atlantic Ocean (Seely *et al*, 1981). It is approximately 440 km in length and its catchment area is 14700 km^2 (Seely *et al*, 1981). It is also a critical source of water for development in western Namibia, especially the town of Walvis Bay and Rőssing Uranium Mine (Jacobson, Jacobson & Seely, 1995). Its groundwater source is used by commercial farmers in the upper catchment and communal farmers–the Topnaar community–along the lower catchment (Kasaona, 2003). Floods are the primary source of water and nutrients that keep the riparian forest of the western ephemeral rivers alive and functioning (Huntley, 1985). The riparian oasis supported by the Kuiseb divides the gravel plain and the Namib sand dune sea. The maintenance of the vegetation is, however, not only essential to the Kuiseb River ecosystem as a whole but also possibly acts as barrier which checks the northwards movement of the Namib dune-sea (Theron, Van Rooyen & Van Rooyen, 1979). To what extent the withdrawal of water will influence the vegetation along the river is still an open question.

The Kuiseb is also an important source of pasture for livestock belonging to the Topnaar community. The Topnaar are the inhabitants along the Kuiseb River west towards Walvis Bay and their presence along the Kuiseb River can be traced back to the 14th century (Van den Eyden, 1992). They raise livestock, mainly goats and donkeys, and also harvest *Acanthosicyos horridus* melons as a source of water and food (Van den Eyden, 1992).

The main aim of the study was to increase awareness and understanding of the functioning of the ephemeral river system and thus to improve the conservation of biodiversity. The study was also necessary, as it will contribute to the international Floodwater Recharge of Alluvial Aquifer in Dryland Environments (WADE) project by characterising the project's study site near the Gobabeb Training and Research Centre. The WADE project is conducted world wide in arid environments similar to the Kuiseb River, in countries like Spain, Israel, and South Africa. The findings of this paper will also contribute to long-term ecological research at Gobabeb.

2. Study sites

a) Gobabeb

The name Gobabeb comes from the Damara-Nama word meaning 'place of fig tree', referring to *Ficus sycomorus.* (Kham. pers. comm. 2005). The Centre, (23° 33.889, E015° 02.411') located in the basin of the Kuiseb River (Makuti, 2004), aims to further understanding of the desert environment (Tjikurunda, 2002).

The centre lies at the point were three key ecosystems of the Namib - the - dune sea, the ephemeral Kuiseb River and gravel plains-converge (Huntley, 1985). This confluence of three ecosystems supports an amazing abundance of life, including many endemic species of fauna and flora, including *Welwitschia mirabilis* and *Acanthosicyos horridus* (Jacobson, Jacobson & Seely, 1995).

The Centre also lies on the boundary between the western fog belt and the inland rainfall areas (Lancaster, 1989). The median annual rainfall precipitation at Gobabeb is 12 mm rainfall and 36 litres m^{-2} fog (Henschel *et al*, 2000). The vegetation obtains most of its water needs from the floods in the Kuiseb (Makuti, 2004). Floods in the Kuiseb River usually pass Gobabeb every year for an average of 16 days, although consecutive years of no flow were recorded in the early 1980's and the longest recorded flow, in 1974, lasted 102 days (Henschel *et al,* 2000). The absolute maximum temperature recorded at Gobabeb was 42, 3 UNITS: °C or "deg C" and the absolute minimum temperature 2, 1 UNITS. March is usually hottest month with mean temperature of 24, 8 UNITS whereas July is the coldest with mean temperature of 18, 4 UNITS (Jacobson, Jacobson &Seely, 1995).

The site at Gobabeb is situated within Gobabeb's long-term tree mapping project study area across the Kuiseb River.

b) Swartbank

Swartbank (S23° 19 351 E014° 45 986) is also situated in the ephemeral Kuiseb River. Although the main study site was Gobabeb, the Swartbank site was added so that there could be a comparison of the spatial distribution of tree species along the main river channel between these two sites. The two sites are different in terms of the groundwater level and ground water usage (Makuti, 2004). These differences may influence tree species distribution in relation to the main channel.

Swartbank is about 45 km west of Gobabeb on the main road (D 1983). The study site is about three kilometers south of the first Namwater reservoir close to the main road. There is a high water extraction in this area compared to Gobabeb, as there are about four active water extraction points in the vicinity of the study area (Makuti, 2004). At Gobabeb there is only one active water point. The vegetation in this area is dominated by *Acacia erioloba*, *Erograstis spinosa* and *Faidherbia albida*, which occur as solitary individuals compare to Gobabeb, where they are mainly in clusters.

3. PROJECT OBJECTIVES

Two of the project objectives - to determine relationship between tree species and soil composition, vegetation changes based on remote sensing - could not be achieved due to time and problems with the methodology.

1. To identify tree species and assess their vitality along the transects in the Kuiseb River course near Gobabeb.
2. To determine patterns of tree species distribution and position from the main watercourse.
3. To determine vegetation changes based on previous studies and remote sensing.
4. To determine the canopy cover of tree species and the length occupied by their microhabitats.

4. PERSONAL OBJECTIVES

1. To learn more from scientists working at Gobabeb.
2. To learn more about the influence of the floods in the arid environment.
3. To contribute to work packages of Floodwater Recharge of Alluvial Aquifer in Dry land Environment (WADE) project by doing a site characterisation.
4. To gain more experience in conducting research and writing scientific reports.
5. To contribute to Gobabeb operational activities through out in-service period.
6. To enhance my capacity in data analysis

5. METHODS AND MATERIALS

5.1. To identify tree species and assess their vitality along transects in the Kuiseb River course near Gobabeb.

Ten transects were laid at Gobabeb in the river, covering a distance of approximately 1.5 kilometers (see Appendix 2). The transects started downriver from the pipeline across the river at the station and ended at the upper WADE borehole. The transects were 10 m wide with a variable length, were depending on the river course (see Appendix 2). All tree species within each transect were counted and their vitality was assessed. The vitality assessment included health status and productivity, specifically looking at flowering and pods. The vitality assessments used were adopted from the study of vegetation mapping done by Grieve & Hensel (2002). The scores were between 0 and 5, half scores were not used: 0 = complete dead tree, 1 = few live tips, 2 = several live branches, 3 = half live half dead, 4 = few dead branches and 5 = all alive. For the flowers were 0 = none and 1 = present and fruits score were 0 = none, 1-50 = few, 51 –100 = common and 101- above = more. The statistical analysis programme SPSS was used for the data analysis.

5. 2. To determine patterns of tree species distribution and position from the main watercourse.

Using the dumpy level and tape measure a profile of the river was surveyed. To give a better idea of the tree distribution across the Kuiseb River, vegetation map for the Kuiseb River at Gobabeb were made (Appendix 1) and profile pattern were drawn (Appendix 3).The vegetation map (Appendix 4) of the Kuiseb River reaviling tree species patterns common to all riparian forest near Gobabeb were attached a copy from (Jacobson, Jacobson & Seely, 1995). GIS programme were used to make the vegetation map. The position of tree species were measured in relation to the main watercourse along transects at Gobabeb. The statistical analysis programme SPSS was used for the data analysis.

5.3. To determine vegetation changes based on previous studies.

Data gathered were compared to previous data of the project research 'Vegetation mapping of the Kuiseb River at Gobabeb' which was done by Grieve and Hensel (2002) in the Kuiseb River near Gobabeb. The main focuses were to identify changes on the tree by species by looking at the canopy width and vitality in 2002 and 2005 of marked individual trees falling in the current study transects. The same vitality assessment mentioned above in the first objectives was used.

5.4. To determine the canopy cover of tree species and the length occupied by each microhabitat along the transects.

A dumpy level and metric tape were used to measure linear distances occupied by (1) canopy width of each species of tree encountered in the transect, (2) base silt bank (referred to an area on the left and right bank of the river), (3) tree stumps, (4) the Kuiseb river course, (5) bed rock and (6) old channel islands (referred to the riparian forest area followed after the right bank of the river). All the linear distances measured from all these above-mentioned variables in each transect were added together **divided by** distance occupied by transects **multiplied by** one hundred to get the percentage of canopy covered by all tree species and microhabitats along the transects. This was done to estimate the canopy cover of tree species and the length occupied by each microhabitat along transect laid in the Kuiseb River at Gobabeb.

6. RESULTS AND DISCUSSIONS

6 .1 To identify tree species and assess their vitality along the transects in the Kuiseb River course near Gobabeb and Swartbank.

There was a difference between the tree species at Gobabeb compared to Swartbank although *Acanthosicyos horridus* was only visible at Swartbank. The *Ficus sycomorus* (a single individual) was only counted at Gobabeb, growing in the edge of the main river channel. Although more *Acacia erioloba* were counted along the transect at Swartbank than Gobabeb, the tree species were more abundant at Gobabeb than at Swartbank (Table 1). This could be due to high extraction of aquifer at Swartbank than Gobabeb: as the river course is narrower at Swartbank than Gobabeb, there could be less aquifer recharge than at Gobabeb.

Table 1: Tree species count at two study sites namely Gobabeb and Swartbank

	Study Sites			
	Gobabeb		Swartbank	
Tree species	**Percent**	**Number**	**Percent**	**Number**
Acacia erioloba	53.08%	86	79%	120
Acanthosicyos horridus	0.00%	0	9.90%	15
Euclea pseudebenus	4.90%	8	1.30%	2
Faidherbia albida	23.40%	38	7.90%	12
Ficus sycomorus	0.61%	1	0 %	0
Salvadora persica	8.02%	13	1.30%	2
Tamarix usneoides	9. 87 %	16	0%	0
Total trees	**100**	**162**	**100**	**151**

The trees at Gobabeb showed better vitality than those at Swartbank. The trees at Gobabeb fell mostly into the "all alive" and "few dead branches" categories (Figure 1), whereas at Swartbank trees fell mostly into "few dead branches" and "half live half dead" (figure 2). Most unhealthy trees at Swartbank were mainly old example *Acacia erioloba.* This difference in vitality could be attributed to high extraction of underground water at Swartbank (Makuti, 2005).

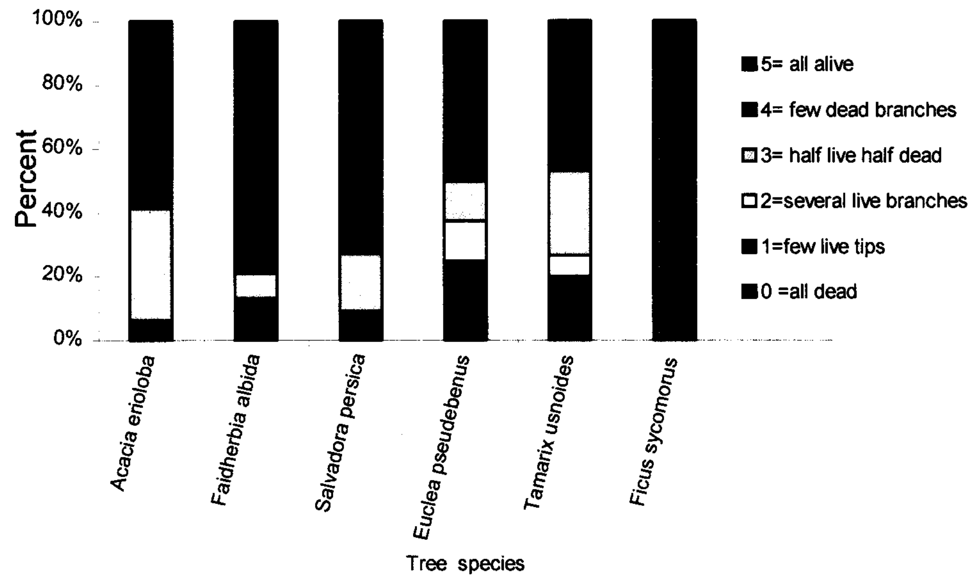

Figure 1: Assessment of tree species vitality at Gobabeb using a rating from 0 to 5. *Acacia erioloba* (n=86), *Faidherbia albida* (n=38), *Salvadora persica* (n=13), *Euclea pseudebenus* (n=8), *Tamarix usnoides* (n=16) and *Ficus sycomorus* (n=1).

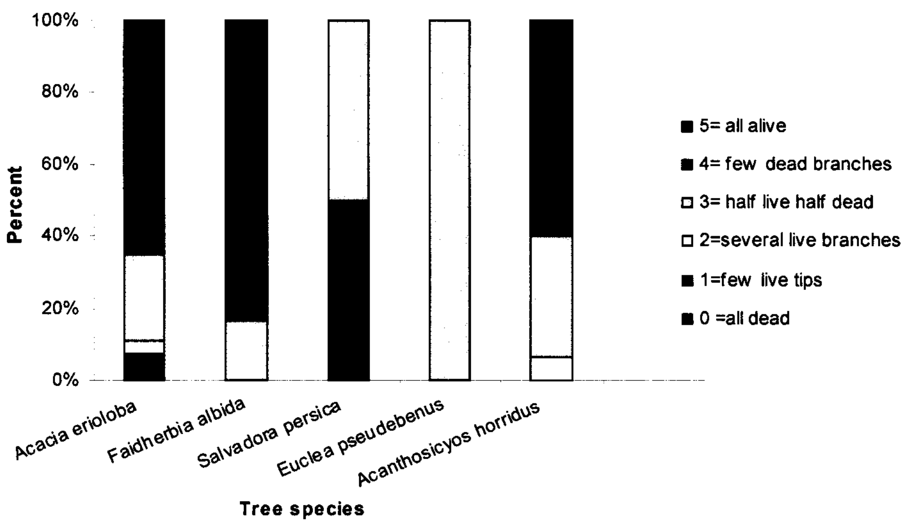

Figure 2: Assessment of tree species vitality at Swartbank by using a rating from 0 to 5.

Acacia erioloba (n=120), *Faidherbia albida* (n=12), *Salvadora persica* (n=2), *Euclea pseudebenus* (n=2) and *Acanthosicyos horridus* (n=15).

8.2. Patterns of tree species distribution and position from the main watercourse

There were different patterns in the transects laid at Gobabeb (Appendix1&2 The patterns of tree species elevation point above the surface were changing from point to point and between each transect profile. These patterns diffences in elevation and width of main river course may affect tree distribution in the sense that available moisture might constantly change from place to place. The patterns of tree species distribution and position were differed along the transects profile at Gobabeb for example. *Ficus sycomorus* and *Faidherbia albida* concentrated seemed to be closer to the main watercourse microhabitats, whereas *Acacia erioloba* and *Salvadora persica* were far from the watercourse microhabitats (figure 3). At Swartbank, *Acacia erioloba* were closer than *Faidherbia albida* (figure 4). This could be easily influenced by their abundant distribution in dry ephemeral (Curtis & Mannheimer, 2005). The health status of the trees were also different as moving further away from the main watercourse at both study sites (see Appendix 2 &3).

The patterns of tree species distribution and position at Swartbank were similar to each other but were different to the one at Gobabeb. At Swartbank the riverbed was wide with small visible channels that were assumed to be the main watercourse (Appendix 3). This could influence the tree species distribution across the river as it might be that the narrower the channel the smaller the underground water resource and that this affects the distribution of different tree species. This was the case at Swartbank, where transect patterns were dominated by *Acacia erioloba* and *Acanthosicyos horridus*, unlike at Gobabeb. This difference in spatial distribution of tree species could also be attributed to the differences in the water table at the two study sites.

At Gobabeb there were differences in distances from the main river course between tree species. *Ficus sycomorus* was the closest growing right in the main watercourse, followed by *Faidherbia albida* at less than 50 meters an average (figure 3). *Acacia erioloba* had a long-range distribution from main river watercourse compared to other species. This could be attributed to its tolerance of a wide variety of environmental condition (Curtis & Mannheimer, 2005). However, while *Faidherbia albida*, *Salvadora persica* and *Tamarix usneoides* were mainly growing less than 100 m from the main water course, there were few individual of these trees which were position far away from the channel. This may have been caused by good aquifer recharge in 2002 or it could be due to nearby underground water sources.

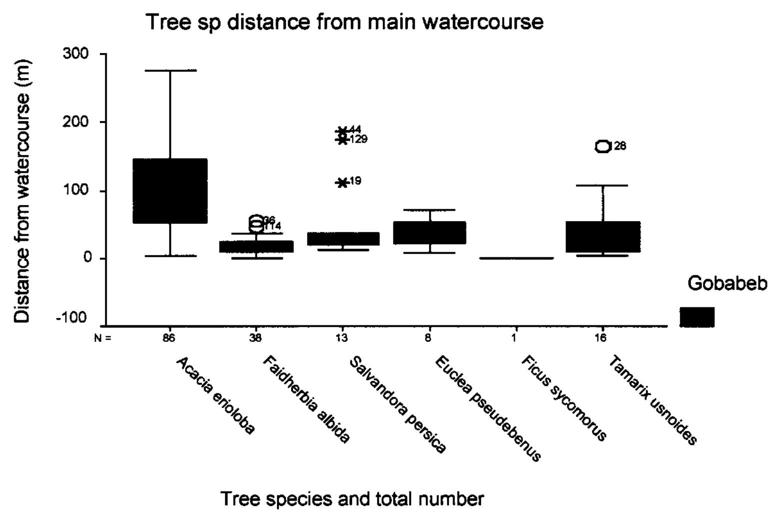

Figure 3: Patterns of tree species distribution at Gobabeb.

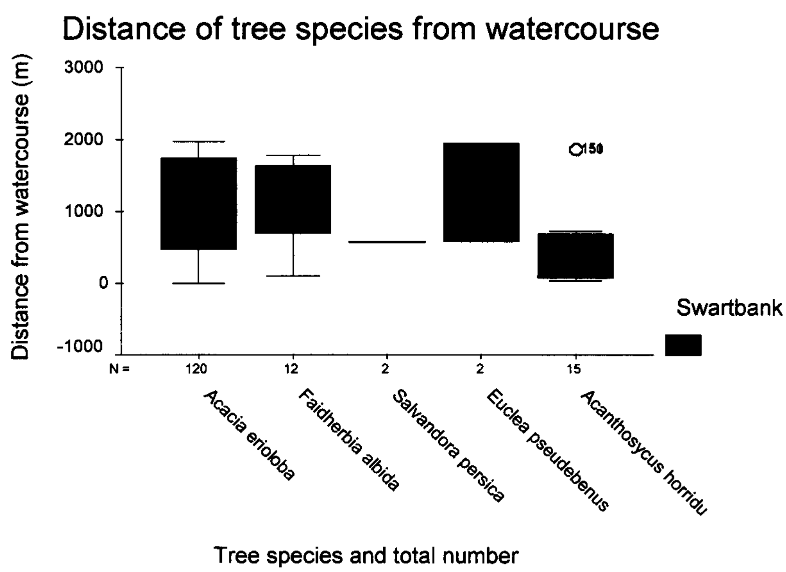

Figure 4: Patterns of tree species distribution at Swartbank.

8.3. Vegetation changes based on canopy cover and vitality between 2002 and 2005

There was no significant difference between the tree species canopy cover of 2002 and 2005 (Paired t–test, P = 0.130). The sample sizes were too small so therefore could also have the effect of making the result not to be highly reliable. However, Figure 5 seems to show that certain tree species, such as *Euclea pseudebenus* and *Tamarix usnoides* appear to have a dramatic declining in canopy width while *Faidherbia albida* were steady. This could be influenced by differences in the physiological activities from tree species to species, for example growth rate and adaptation to available moisture content of underground water.

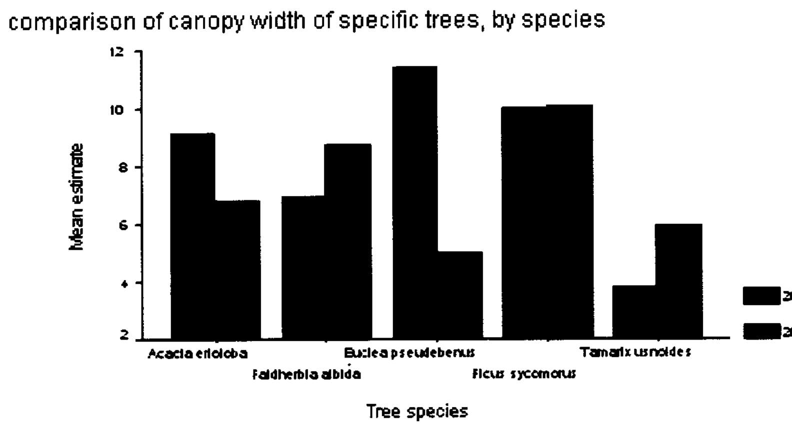

Figure 5: Comparison of mean canopy width of specific trees (n=41), *Acacia erioloba* (n=27), *Faidherbia albida* (n=9), *Euclea pseudebenus* (n=1), *Ficus sycomorus* (n=1) and *Tamarix usnoides* (n=4) observed at Gobabeb in 2002 and 2005.

The health status of the tree species showed a significant difference (Sign t-test, P = 0.003). As figure 6 shows, there is a difference in tree species, between *Acacia erioloba, Euclea pseudebenus* and *Ficus sycomorus* showed a massive drop in vitality, as oppose to another tree species that did not see a drop. This could be due to fewer water supplies in 2005 as there was no huge flood than the one of 2002. *Faidherbia albida*, on the other hand, remained at a steady health, which could be supported by their closeness to the main river watercourse (Figure 4).

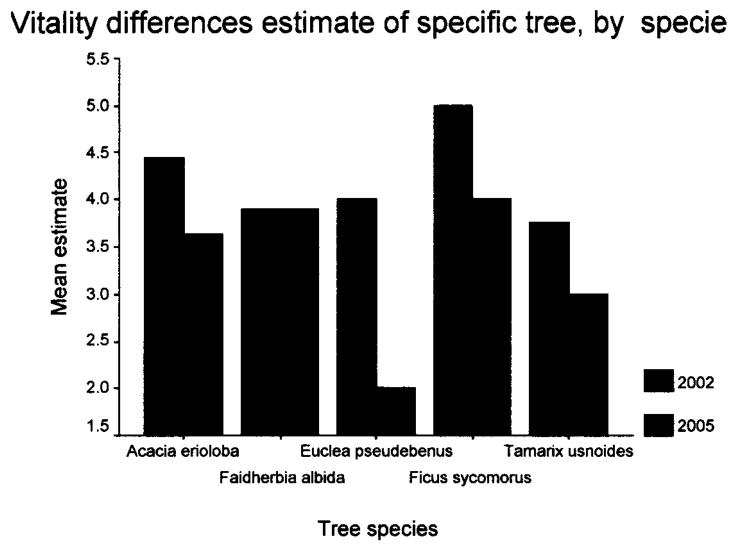

Figure 6: Show the vitality estimate of specific trees (n=41) observed in 2002 and 2005, by species. *Acacia erioloba* (n=27), *Faidherbia albida* (n=9), *Euclea pseudebenus* (n=1), *Ficus sycomorus* (n=1) and *Tamarix usnoides* (n=4).

The vitality of tree species was tested against the distance of tree species from edge of watercourse at Swartbank and Gobabeb. Table 2 shows that fruits and flowers have no significant correlation, while health status shows a significant negative correlation, but the fit is not perfect. This means that the further away from the edge of watercourse the lesser the health status of the tree species. This also supports the study expectations, as more poor health tree were expected to be far away from the watercourse. This could also indicate that the more moving further away from the channel the lesser the underground water source. However, the number of the samples taken could also be too small to prove the reliability of the data.

Table 2: Correlation of vitality tested against the distance of tree species from edge of watercourse at Swartbank (Spearman's rho 2-tailed were used).

Type of tested variables	r_s	P-value	N	Test result
Fruits	-128	.116	151	No significant relationship but there was a negative correlation
Flowers	-.131	.114	148	No significant relationship but there is a negative correlation
Health	-.233	.004	151	There is highly significant but negative correlation

In table 3, the number of fruits shows a significant negative correlation but the fit is not perfect. The flowers show highly significance positive correlation but still not perfect, but better fit. The health shows no significance. The fruit result means that the further away from the main watercourse the lesser the fruits. This could be caused by high browsing of vegetation by livestock, game and also harvesting of fruits by local communal farmers for their livestock during the drought period. It could have to do with water supply (being further away from watercourse means--> less water is available, leading to more stress and--> fewer fruits). The flower result means that the further away from the main water course the more flowers. This might be caused by difference in annual cycle in tree species flowering season and its peaks across the river due to differences in adaptations (Curtis & Mannheimer, 2005) For example *Faidherbia albida* flowers mostly between March and September while *Acacia erioloba* flower from August until May. (Curtis & Mannheimer, 2005). This could be due to less browsing of tree species far away than tree closer to the main water course than these closer.

Table 3: Showing correlation of vitality tested against the distance of tree species from edge of watercourse at Gobabeb (Spearman's rho 2 tailed were used).

Type of tested variables	r_s	P-value	N	Test result
Fruits	-.164	.041	156	There is a significant but negative correlation
Flowers	.388	.000	156	There is a significant but positive relationship
Health	-.016	.842	157	There is no significant association

8.4. Canopy cover of tree species and the length occupied by their microhabitats along the transect at Gobabeb.

The river course was covered by microhabitats 100% of which 53% is covered by old channel island and another 47% was covered by tree species and other microhabitats. This could be attributed to the fact that old island channel is the largest area from right bank and more tree were found here as they get more water on being between two channel. These microhabitat are very important in the sense that they are providing vegetations with nutrient, growth space, underground water and functioning of river ecosystem by preventing the northwards movement of Namib dune sea. The *Acacia erioloba* were showed better average canopy cover of 29 % compared to other tree species, which all had an average canopy cover of less than 20% for example *Faidherbia albida* were more closer to the main water course that is why could not show better canopy cover while *Acacia erioloba* were more scarted across the transect profile. Other tree species for example *Tamarix usnoeides* and *Salvandora persica* were not dominant that is why could not show better canopy cover (figure 7). The tree species were showing equally distributed across microhabitat except the main river course and *Acacia erioloba* were only tree species found in the dune base. (see Appendix 3).

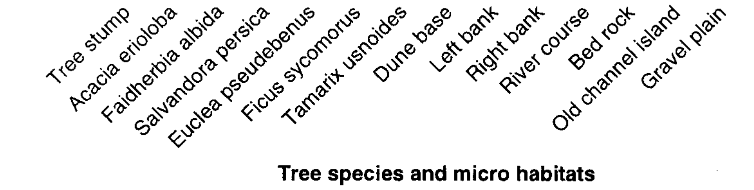

Figure 7: Show average percentage tree species canopy cover and the linear distances occupied by their microhabitats along transects at Gobabeb

9. CONCLUSION

There were more abundant type of tree species at Gobabeb than Swartbank. *Acacia erioloba* was the dominant species at both study sites, as they are very adaptive to dry conditions. The vitality of tree species was much better at Gobabeb than Swartbank. Most unhealthy trees at Swartbank were mainly old. The *Ficus sycomorus* and *Faidherbia albida* proved to be closer to the main watercourse than others at Gobabeb while *Acacia erioloba* and *Acanthosicyos horridus* were closer at Swartbank. The canopy width of specific trees between 2002 and 2005 were more variables, as there was a lot of fluctuation from tree species to tree species between 2002 and 2005. However, the health status of those specific trees was much better in 2002 compare to 2005. The *Acacia erioloba* were showing better canopy cover than other tree species in transects laid at Gobabeb, although the lengths occupied by old island channel were far higher than others (figure 7). There was a difference between the patterns of the cross section laid Gobabeb and the one of Swartbank

The general observation of the study is that there was the difference in spatial distribution of tree species across the Kuiseb River channel in relation to watercourse at Gobabeb and Swartbank.

10. RECOMMENDATIONS

a) The study should be continued after every two years to examine changes in vegetation.
b) The tree at Swartbank should be marked with metal tag for easier observation and monitoring.
c) Settlements up river where there is little underground water extraction should be added to this vegetation monitoring.
d) Namwater should be informed about the findings of every report carried out in concern with survival of vegetation close the river watercourse.
e) The study should involve a questionnaire targeting the neighboring farmers to give their view about changes in species distribution towards the main watercourse.
f) Livestock and human influence to the tree species should also be study constantly.

11. ACKNOWLEDGEMENT

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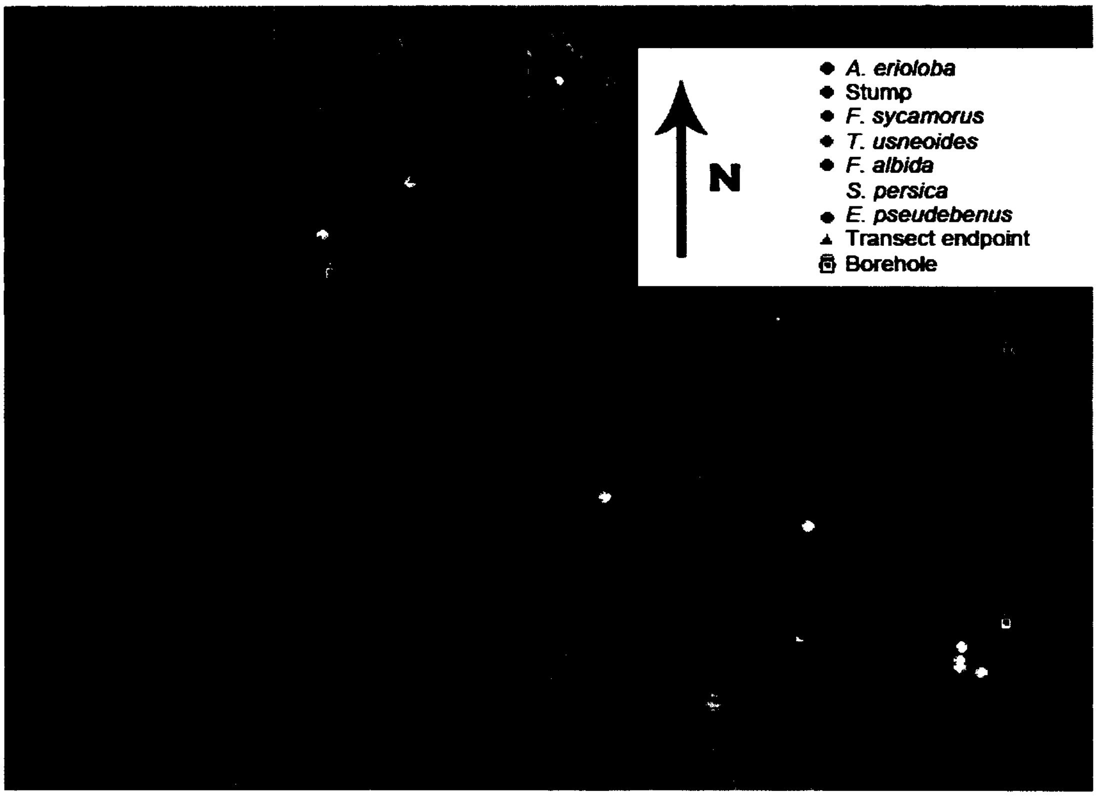
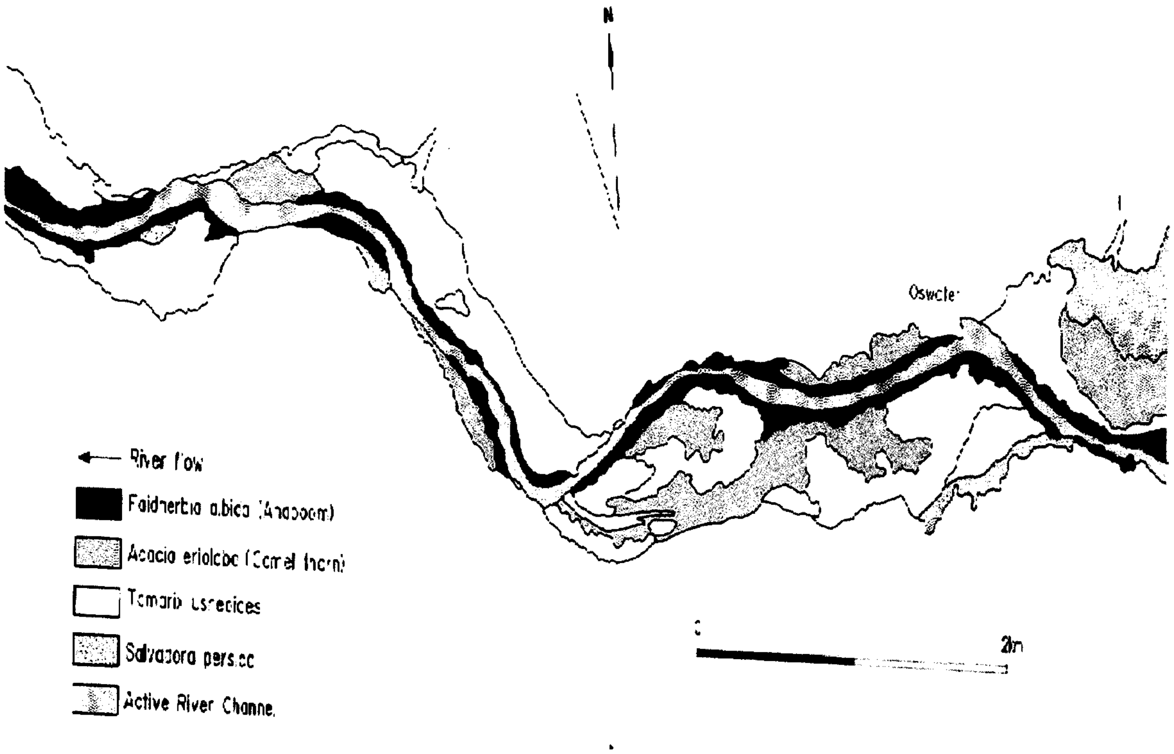
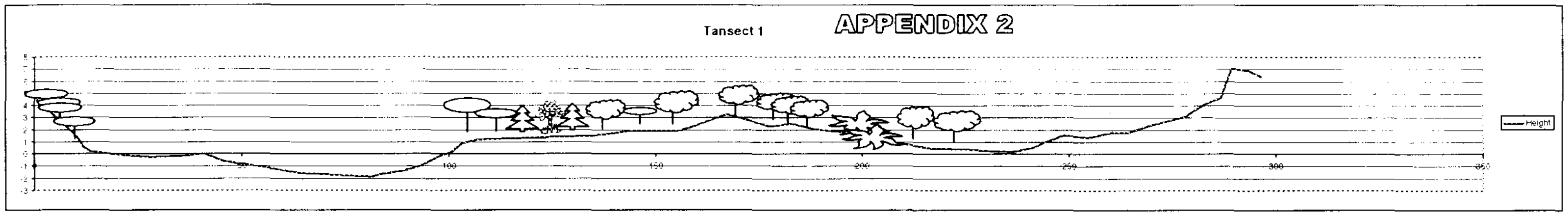
Appendix 1: Vegetation map of the Kuiseb River revealing distribution pattern away from the main river channel.

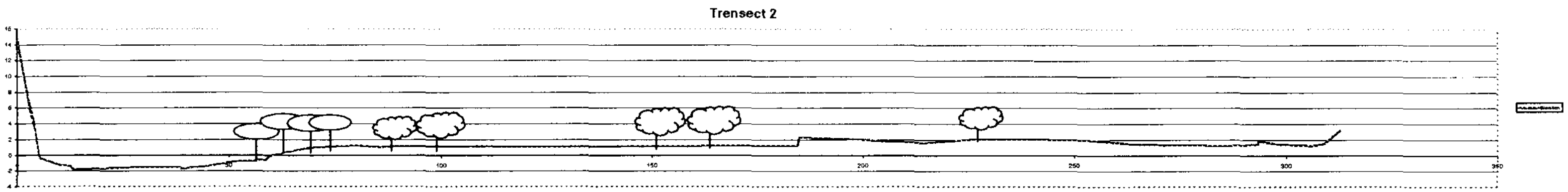


Appendix 4: Vegetation map of the Kuiseb River, revealing a pattern common to all riparian forests within the larger western. As can be seen, *F. albida* trees line the active river channel, flanked on the outside by more drought-tolerant species (Jacobson, Jacobson & Seely, 1995).

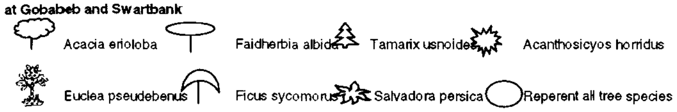


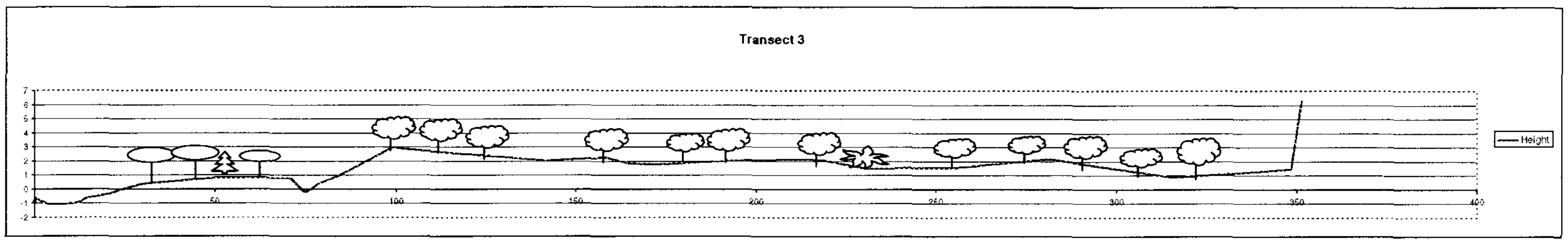
APPENDIX 2

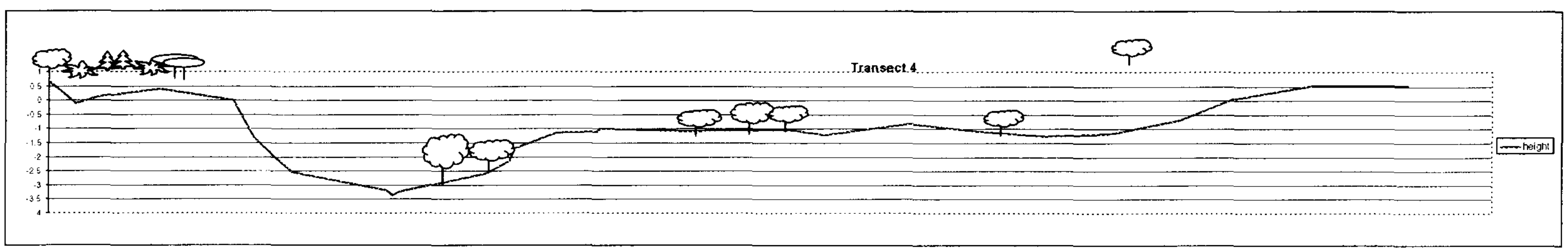


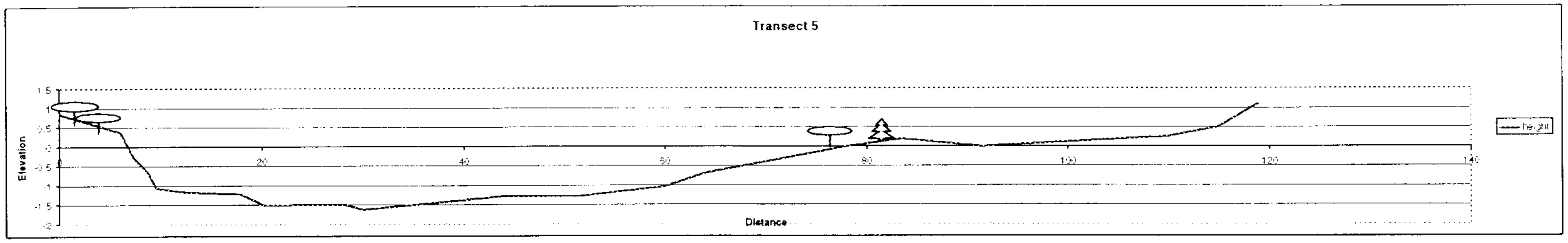


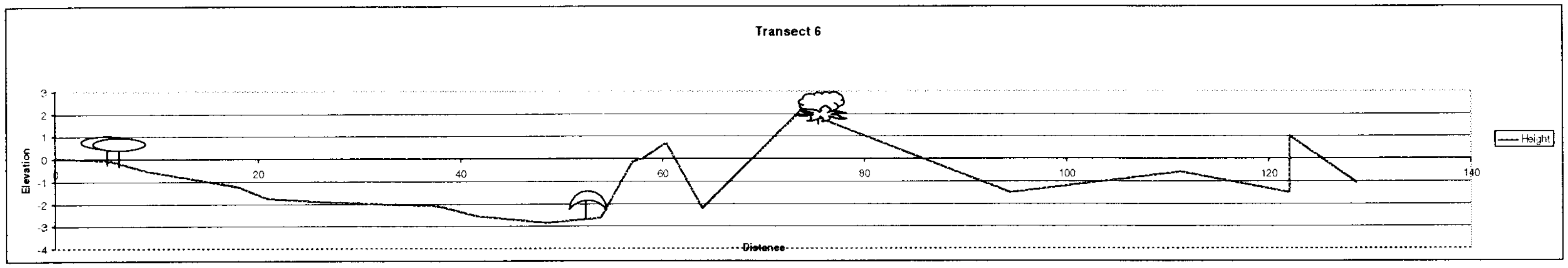
Legend displaying tree species found in the patterns of transect profile at Gobabeb and Swartbank

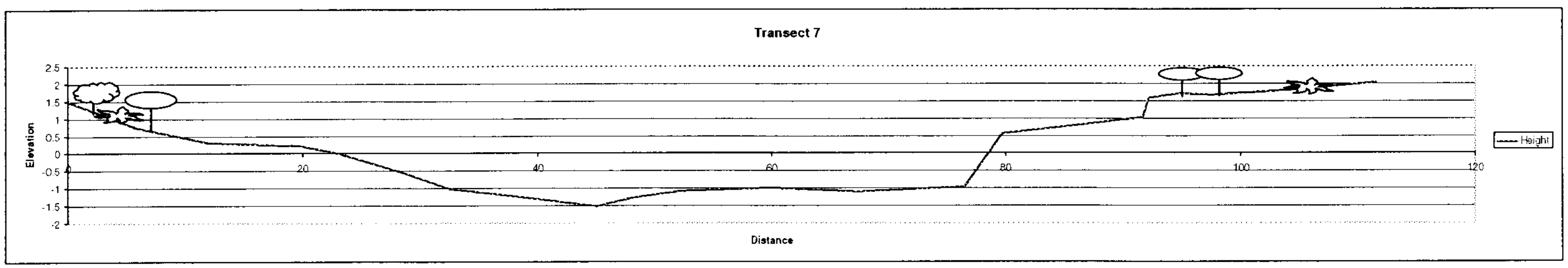


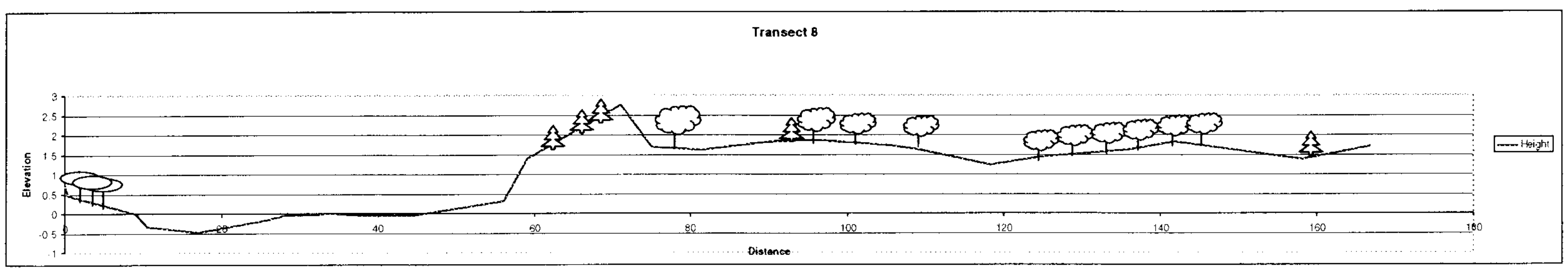


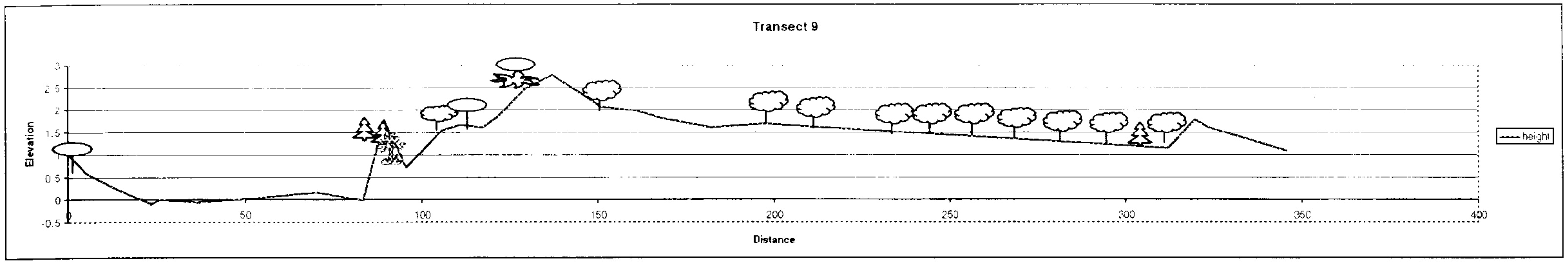


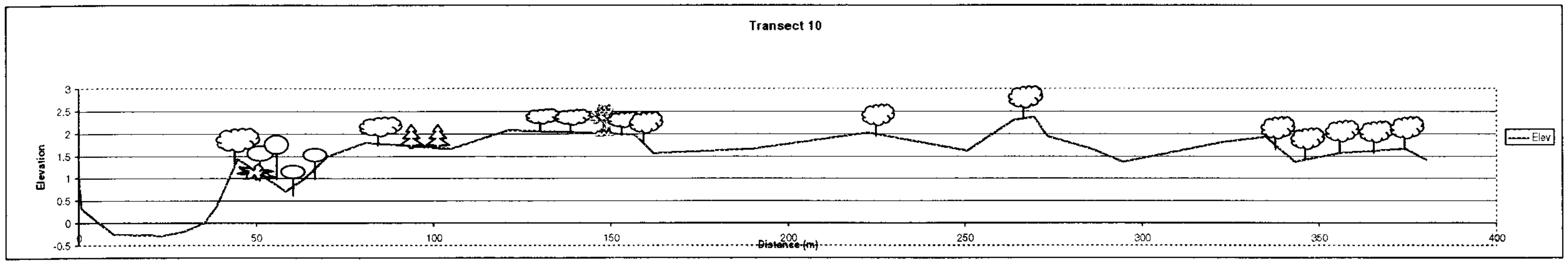

Transect 5
Elevation
Distance
He...ght


Transect 6
Elevation
Distance
Height


Transect 7
Elevation
Distance
Height


Transect 8
Elevation
Distance
Height


Transect 9
Elevation
Distance
height
3
2.5
2
1.5
0.5
0
-0.5
50
100
150
200
250
300
350
400


Transect 10
Elevation
Distance (m)
Elev
3
2.5
2
1.5
1
0.5
0
-0.5
0
50
100
150
200
250
300
350
400

AF PENDIX 3