other woodland (Umtchibi) and scrub (Sinanga) populations are more disturbed than Dopi, but considerably less than the species *Terminalia sericea*, *Burkea africana* and *Ochna pulchra*.

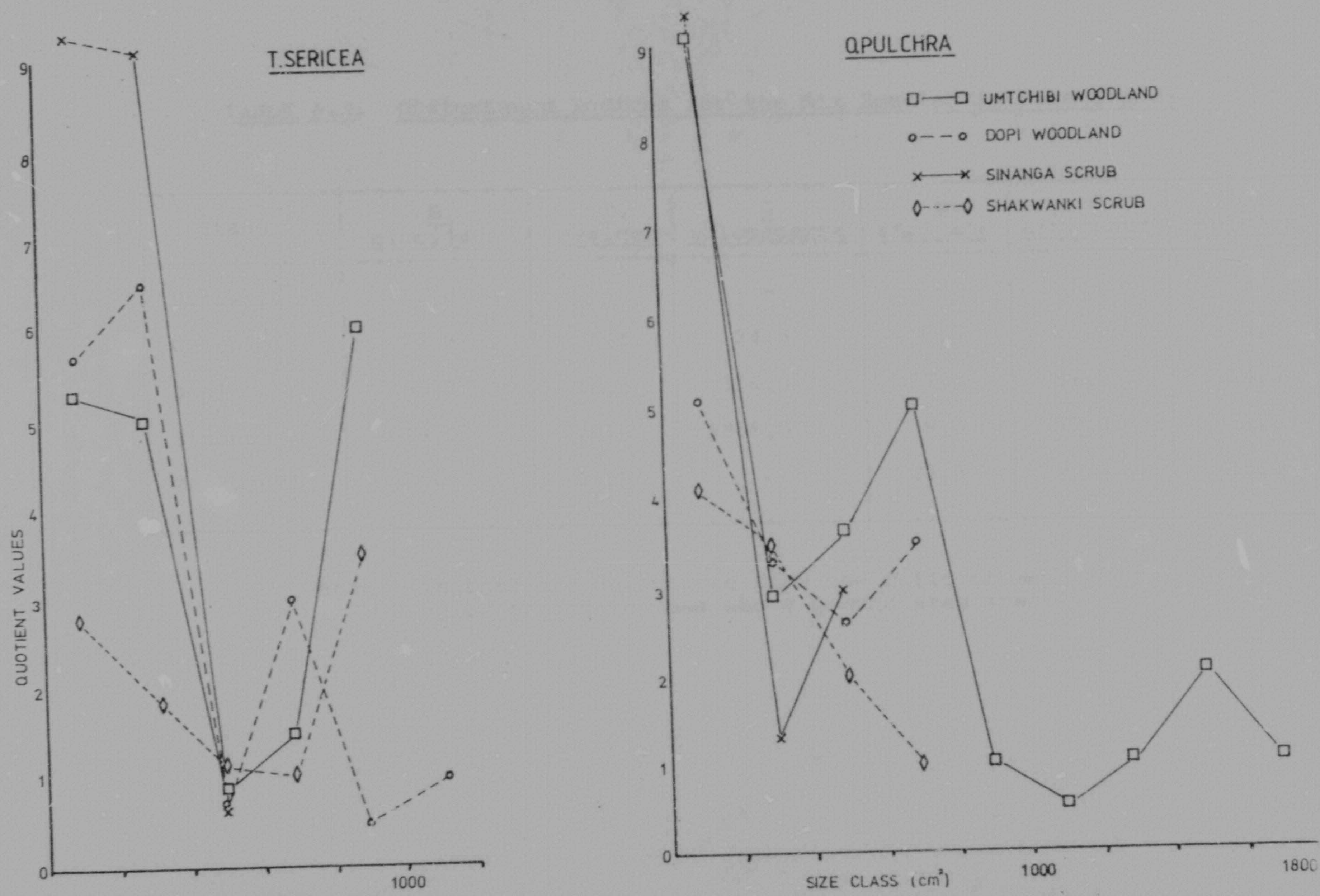
Burkea africana (Fig. 4.6 (b)) and *Ochna pulchra* (Fig. 4.6 (d)). Both these species show a high degree of disturbance, with very high quotient values in the first size class 0-200cm^2. In the one scrub plot at Shakwanki, *O. pulchra* displays a negative trend implying an expanding population.

4.3.1.4 Disturbance Index

In an undisturbed state, the ratio of above to below ground area would be approximately 1:1. The ratios could therefore be used as indices of disturbance, since a high ratio or index is indicative of a coppiced state. Table 4.3 lists the indices of the six species in the five vegetation stands. The indices were calculated from the ratio of mean below ground area to mean above ground stem area. The lowest indices are found in *B. plurijuga* in the least disturbed Mitswiri woodland. The highest index is shown by *G. coleosperma* in the Sinanga scrub, while *B. plurijuga* and *E. africanum* have the highest indices in the Dopi woodland. *T. sericea*, *B. africana* and *O. pulchra* generally show lower indices. These latter three species do not always form massive underground rootstocks, and can regenerate from root suckers.

4.3.2 Growth Rates

Growth rates were calculated in cm per year for the period April 1980 to June 1982. Although biannual measurements were made, there was a great deal of individual fluctuation due to variation in site conditions, so only the final set of readings were used. When the growth rates, in cm



<u>Fig. 4.6(d)</u> Quotients for successive 2000cm^2 size classes for two woodland and two scrub stands of <u>Terminalia</u> <u>sericea</u> and <u>Ochna</u> <u>pulchra</u>.

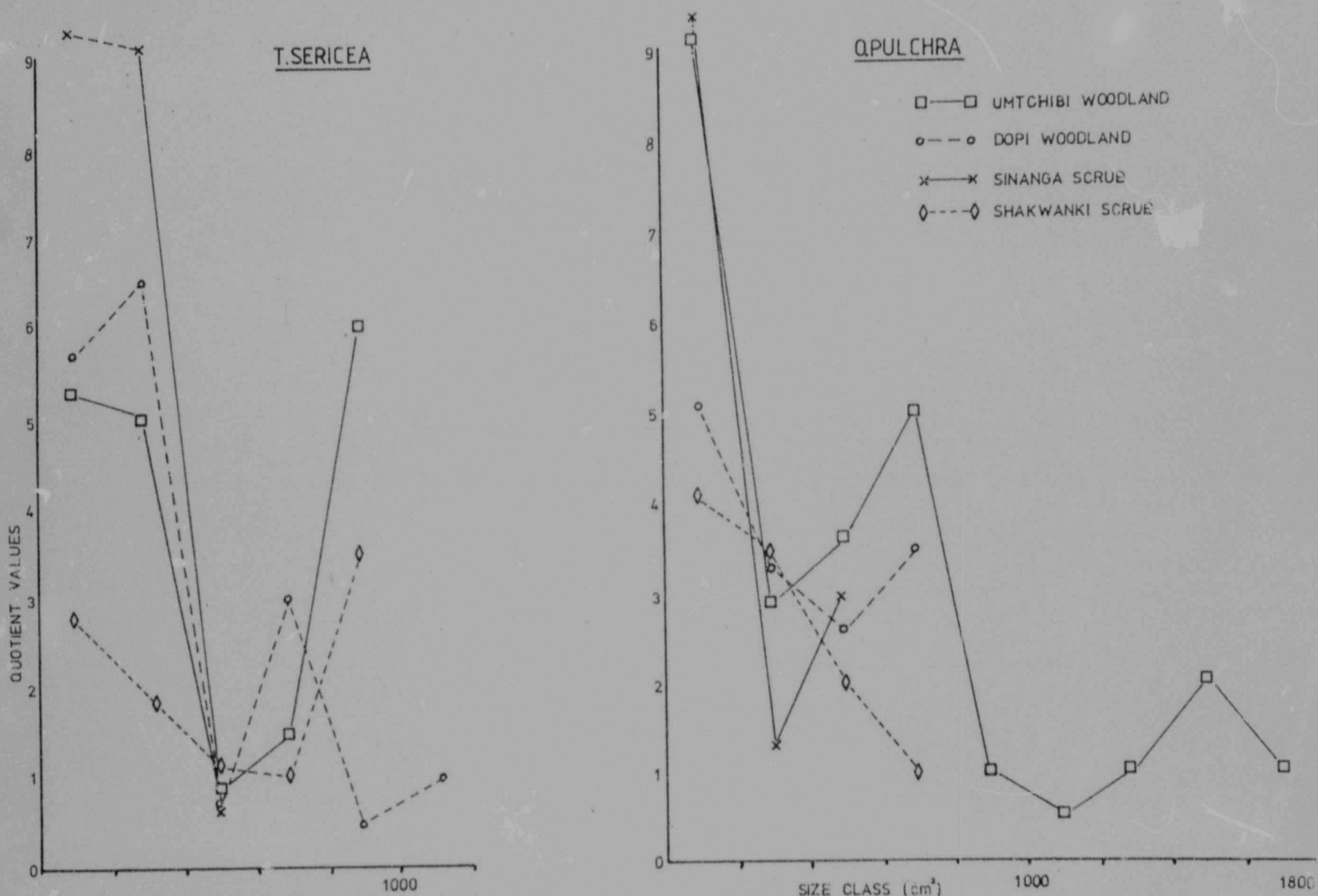


Fig. 4.6(d) Quotients for successive 2000cm^2 size classes for two woodland and two scrub stands of *Terminalia sericea* and *Ochna pulchra*.

TABLE [illegible]. Disturbance Indices for the Six Species in Five Stands

Stand	B. plurijuga	T. sericea	G. coleosperma	B. africana	E. africanum	O. pulchra
Mitswiri	2,8	-	-	-	-	-
Umtchibi	22,5	5,5	34,5	3,5	16,0	6,0
Dopi	58,3	14,3	316,0	17,8	67,5	14,8
Sinanga	19,0	4,0	3858,0	9,0	59,0	7,0
Shakwanki	-	15,0	-	23,0	-	15,0

Note: Indices are calculated from the ratio of mean below ground to mean above ground stem area.

of circumference, were plotted against size, curves could only be distinguished in the smaller size range of B. plurijuga, G. coleosperma, B. africana and E. africanum. T. sericea and O. pulchra showed such a high variability that no definite lines were apparent (see Fig. 4.7). The life stages seedling, shrub, sapling/young tree, mature and senescing tree are marked on the graph for B. plurijuga (see Section 6.1.1.). These divisions were made after extensive field observations. B. plurijuga, G. coleosperma, B. africana and E. africanum all show slow aerial growth in the seedling stage while the root systems are establishing. This is followed by rapid growth in the sapling phase as competition for light increases. Once maturity is reached, and seed production maximised, there is a slowing down of growth. The high variability shown in all the graphs is important as it probably indicates that there is no meaningful average growth rate. Each individual, due to its unique position and site conditions has its own growth rate. The growth rate data from the Forestry Commission are shown in Table 4.4. and on the graphs (Fig. 4.7). The category 'establishment' corresponds roughly to my seedling and shrub phases in B. plurijuga. For B. plurijuga and G. coleosperma, the Forestry results show much lower peaks of growth in the young tree phase, otherwise the two sets of data are quite comparable. Maximum growth rate of B. plurijuga according to my data is 1,4cm y^{-1}, and approximately 0,7cm y^{-1} with Forestry data.

G. coleosperma has a maximum of 3,5cm y^{-1} and 0,7cm y^{-1} respectively. Much of the G. coleosperma measured were coppiced stems and therefore could be expected to have an altered growth rate.

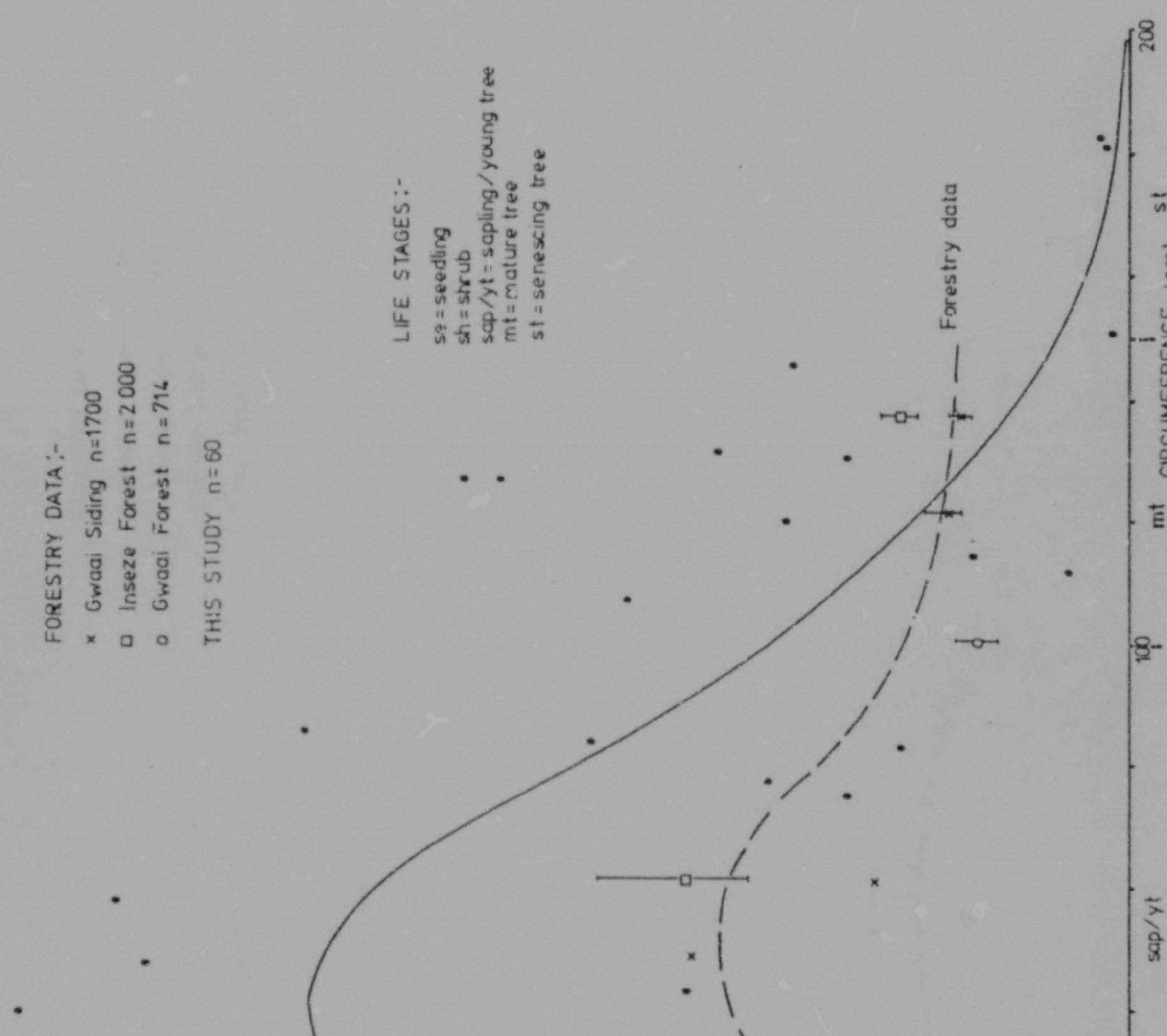


Fig. 4.7(a) Growth of Baikiaea plurijuga using data from this study and Forestry Commission data. The curves only indicate the general trend of the data.

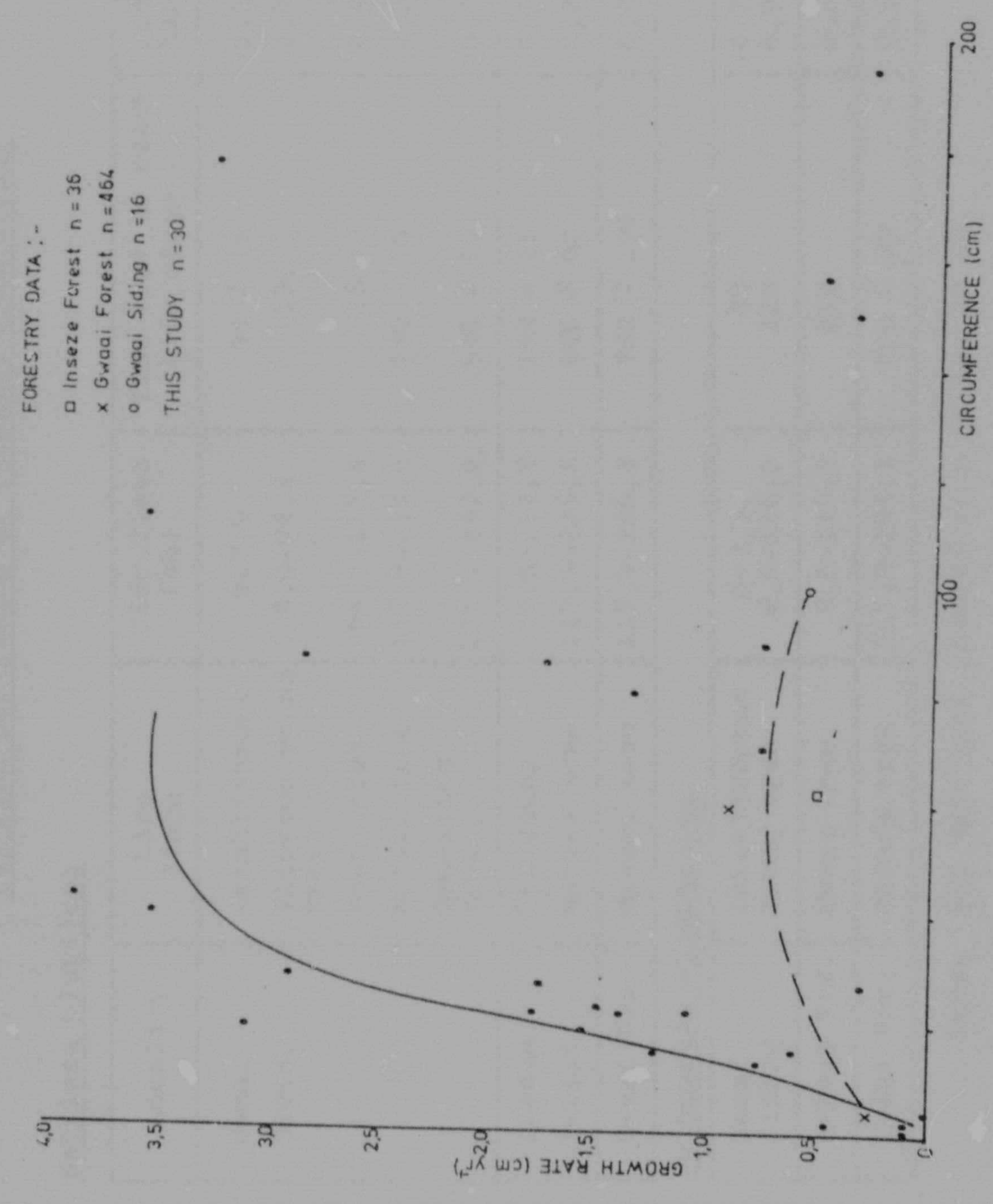


Fig. 4.7(b) Growth of *Guibourtia coleosperma* using data from this study and Forestry Commission data. The curves only indicate the general trend of the data.

TABLE 4.4. Growth Rates of Five of the Main Species Determined over a Period of 30-50 Years in Areas near Hwange National Park (by kind permission of Forestry Commission)

1. Baikiaea plurijuga

Locality	Life Stage	Circ.Class (cm)	Time (yr) to reach life stage	Growth rate ($cm\ yr^{-1}$) & Range	cal.from data
Gwaai Siding	Establishment	0-7,9	35 ± 15	0,23	Range 0,16-0,40
	Vigorous young tree	8,0-94,2	120	0,72	-
	Young tree	94,3-117,8	260	0,42	-
	Mature tree	117,9-235,6	750 ± 75	0,30	Range 0,28-0,34
	Senescing tree	235,7-267,0	910 ± 50	0,28	Range 0,27-0,30
Inseze Forest	Vig.young	8,0-117,8	150 ± 25	0,73	Range 0,63-0,88
	Mature tree	117,9-235,6	600 ± 50	0,38	Range 0,35-0,41
Gwaai For.	Mature tree	117,9-196,3	750 ± 100	0,25	Range 0,22-0,29

2. Guibourtia Coleosperma

Gwaai Siding	Establishment	0-7,9	30	0,26	-
	Young tree	8,0-110,0	110	0,93	-
Inseze For.	Young tree	8,0-117,8	210	0,52	-
Gwaai For.	Mature tree	117,9-196,3	330 ± 20	0,57	Range 0,54-0,61

Note: All data were changed from inches to cm.

TABLE 4.4. Growth Rates of Five of the Main Species Determined over a Period of 30-50 Years in Areas near Hwange National Park (by kind permission of Forestry Commission)

1. Baikiaea plurijuga

Locality	Life Stage	Circ.Class (cm)	Time (yr) to reach life stage	Growth rate (cm yr^{-1}) &	Range cal.from data
Gwaai Siding	Establishment	0-7,9	35 ± 15	0,23	Range 0,16-0,40
	Vigorous young tree	8,0-94,2	120	0,72	-
	Young tree	94,3-117,8	260	0,42	-
	Mature tree	117,9-235,6	750 ± 75	0,30	Range 0,28-0,34
	Senescing tree	235,7-267,0	910 ± 50	0,28	Range 0,27-0,30
Inseze Forest	Vig.young	8,0-117,8	150 ± 25	0,73	Range 0,63-0,88
	Mature tree	117,9-235,6	600 ± 50	0,38	Range 0,35-0,41
Gwaai For.	Mature tree	117,9-196,3	750 ± 100	0,25	Range 0,22-0,29

2. Guibourtia Coleosperma

Locality	Life Stage	Circ.Class (cm)	Time (yr) to reach life stage	Growth rate (cm yr^{-1}) &	Range cal.from data
Gwaai Siding	Establishment	0-7,9	30	0,26	-
	Young tree	8,0-110,0	110	0,93	-
Inseze For.	Young tree	8,0-117,8	210	0,52	-
Gwaai For.	Mature tree	117,9-196,3	330 ± 20	0,57	Range 0,54-0,61

Note: All data were changed from inches to cm.

TABLE 4.4. (contd.) Growth Rates of Five of the Main Species Determined over a Period of 30-50 Years in Areas Near Hwange National Park (by kind permission of Forestry Commission)

3. Terminalia sericea

Locality	Life Stage	Circ.Class (cm)	Time (yr) to reach life stage	Growth Range	Rate (cm yr^{-1}) & calc. from data
Forest Hill	Establishment	0-7,9	10 ± 5	0,79	Range 0,53-1,58
Inseze For.	Mature tree	20,0-58,9	35	1,46	-

4. Burkea africana

Inseze For.	Establishment	0-7,9	10 ± 5	0,79	Range 0,53-1,58
	Mature tree	40,0-110,0	50	2,04	-

5. Erythrophleum africanum

Inreze	Establishment	0-7,9	5	1,58	
Forest	Mature tree	30,0-78,5	55	1,28	

Note: All data were changed from inches to cm.

The *B. africana* results appear to correlate quite well with those of Forestry, with a maximum growth rate of 2,5cm y^{-1}. The two sets of data show markedly different rates for *E. africanum* in the seedling or establishment phase. This may be due to low sampling (ten seedlings) on my part, or to the fact that the Inseze Forest is a more suitable habitat for *E. africanum*. It was very difficult to find seedlings of this species in the study area. The growth curves of *T. sericea* and *O. pulchra* were hardly discernible (Fig. 4.7). Very few large or senescing trees of either species could be found, again suggesting that neither are in ideal habitats (see 4.3.1.). *T. sericea* has a maximum growth rate of approximately 1,5cm y^{-1}. The extremely variable results for *O. pulchra* may be a consequence of its peeling bark.

Fig. 4.8 illustrates the relative growth rates of coppiced trees. Only the data from *G. coleosperma* and *B. plurijuga* appear to follow any definite lines. *G. coleosperma* coppice grows rapidly in the 20-40cm size, and slows as the stems become larger. No data were available for small *B. plurijuga* coppice, but growth in the larger stems shows a decline from the 40cm to 110cm size class.

4.3.3 Mortality

The percentage dead trees per 10cm (circumference) size class are depicted in Fig. 4.9. *B. plurijuga* has a slight peak of dead trees in the 70cm and 120cm sizes. No dead trees with stems less than 30cm were found. *G. coleosperma* has over 40% of the dead trees in the 20cm circumference class with the remainder occupying only 2-6% the larger sizes. *B. africana* resembles *B. plurijuga*, with a less marked peak of 12% dead trees in the 20-40cm class. *T. sericea*, *E. africanum* and *O. pulchra* have the same distribution patterns of dead trees :

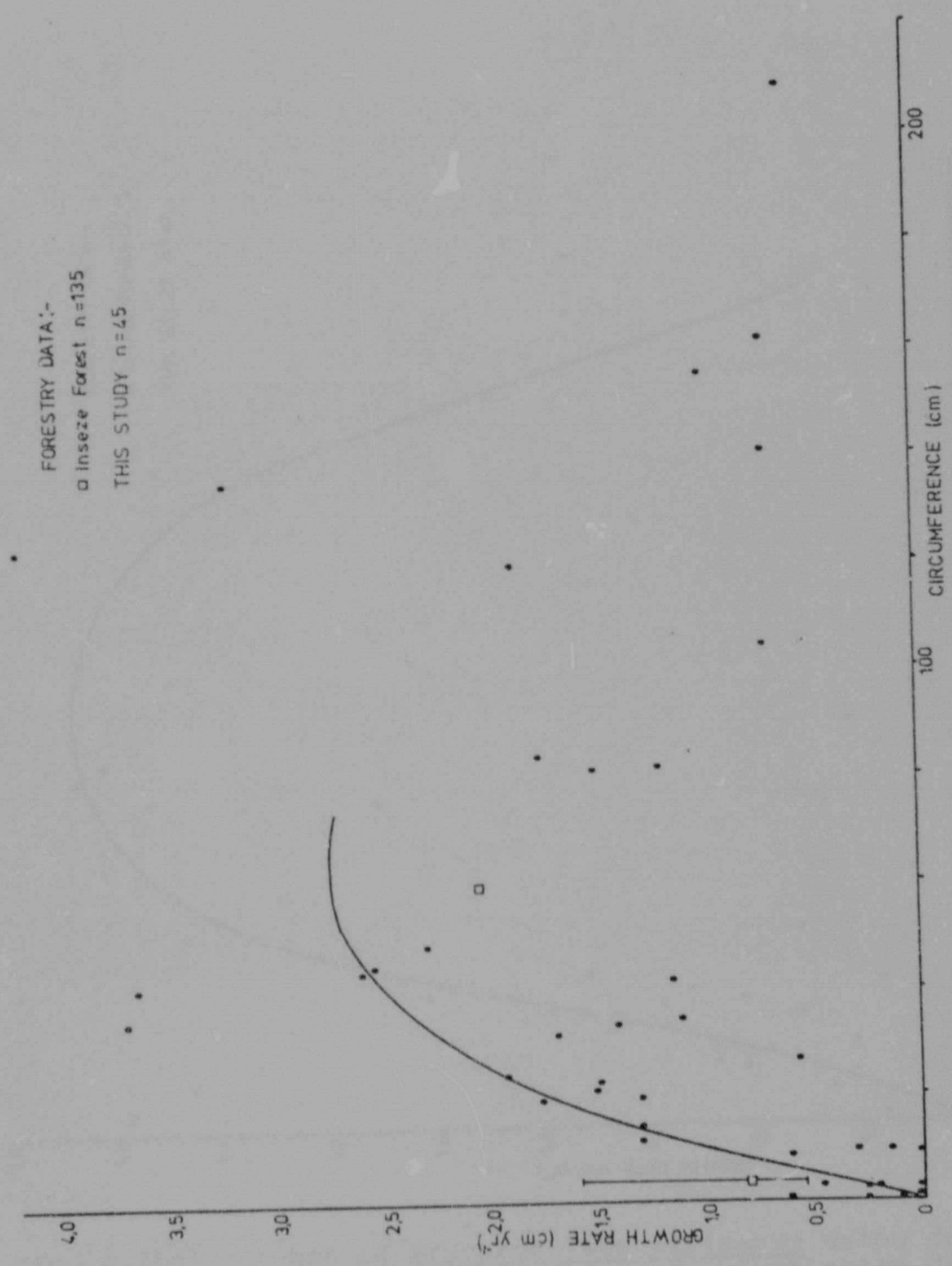


Fig. 4.7(c) Growth of *Burkea africana* using data from this study and Forestry Commission data. The curves only indicate the general trend of the data.

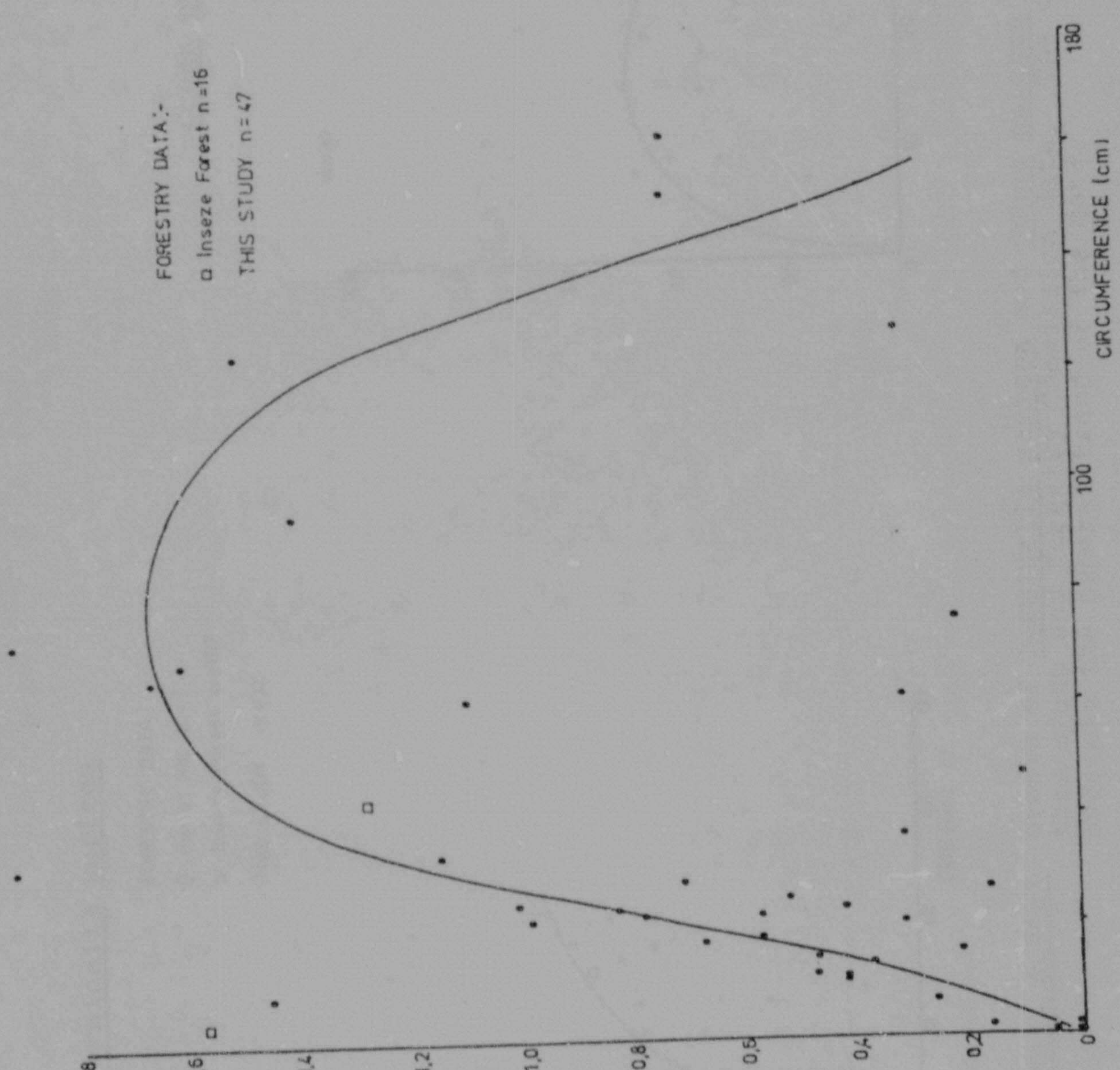
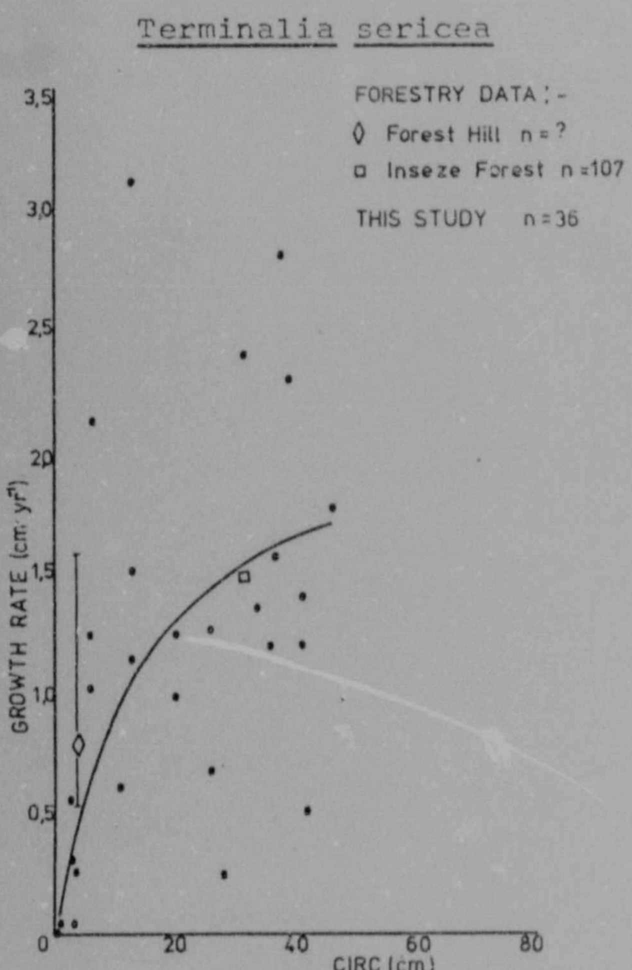


Fig. 4.7(d) Growth of *Erythrophleum africanum* using data from this study and Forestry Commission data. The curves only indicate the general trend of the data.



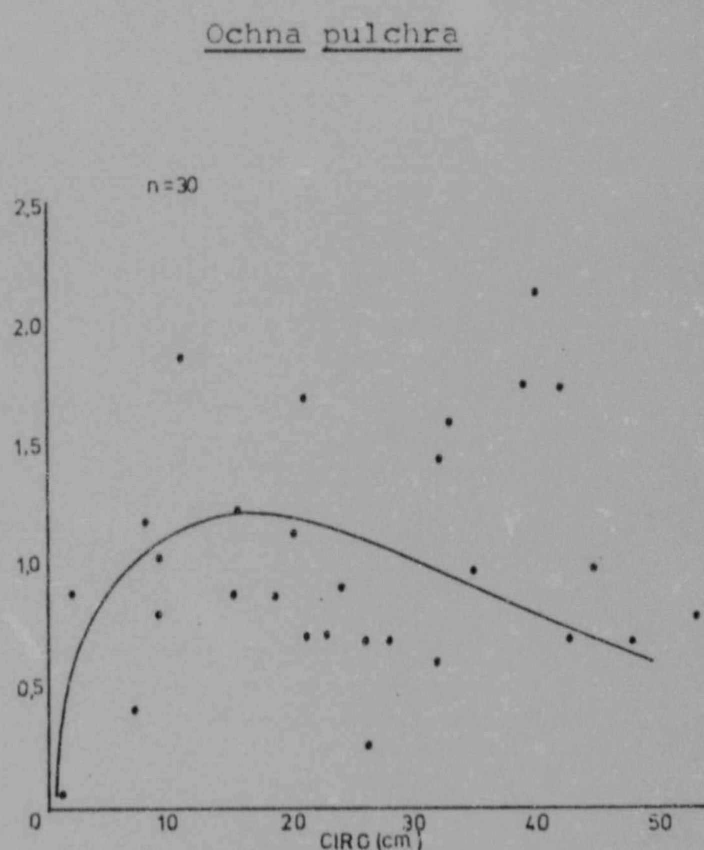


Fig. 4.7(c) Growth of Terminalia sericea and Ochna pulchra using data from this study and Forestry Commission data. The curves only indicate the general trend of the data.

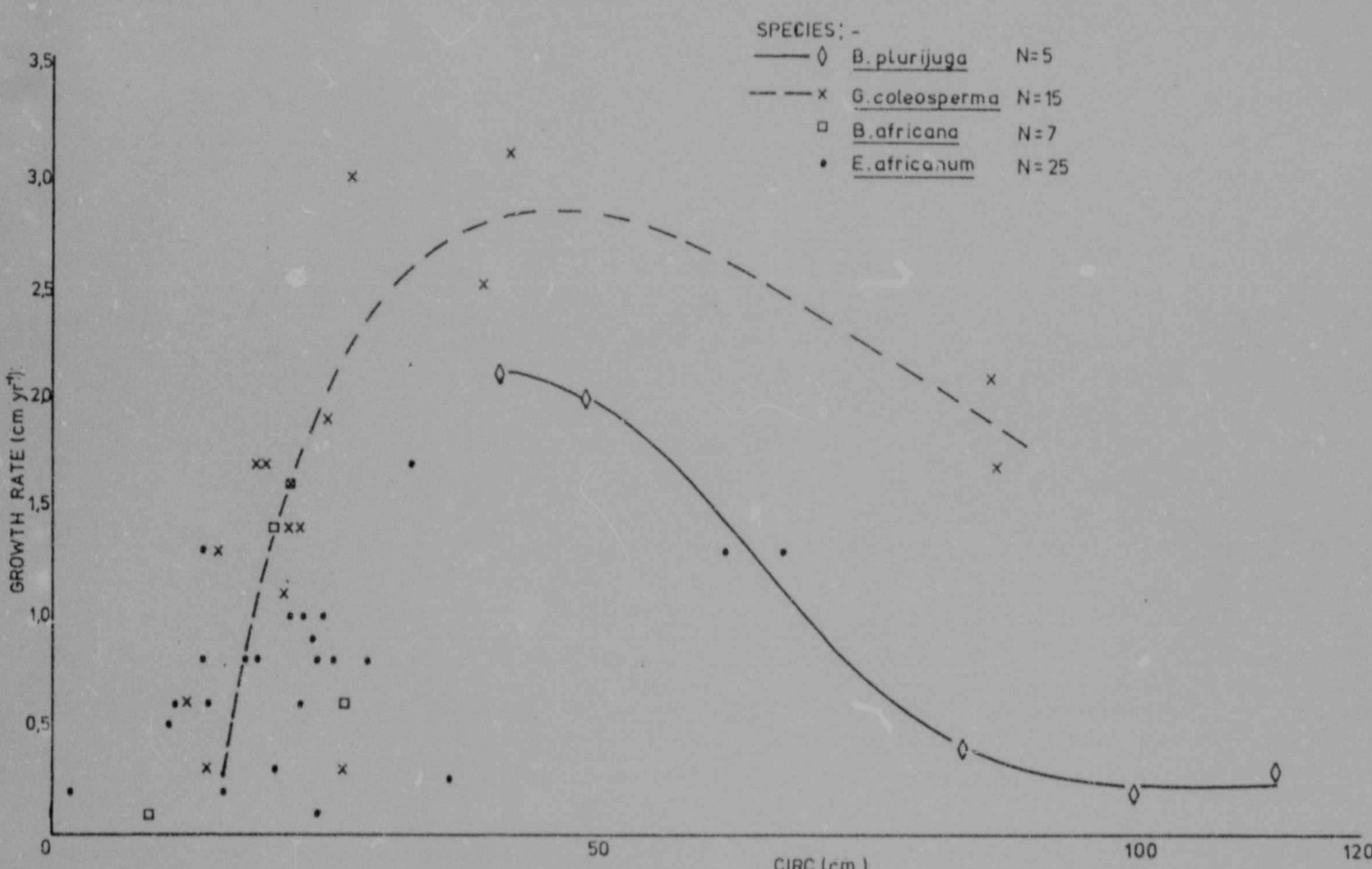


Fig. 4.8. Growth of coppiced individuals of Baikiaea plurijuga, Guibourtia coleosperma, Burkea africana and Erythrophleum africanum. See Section 4.3.2.

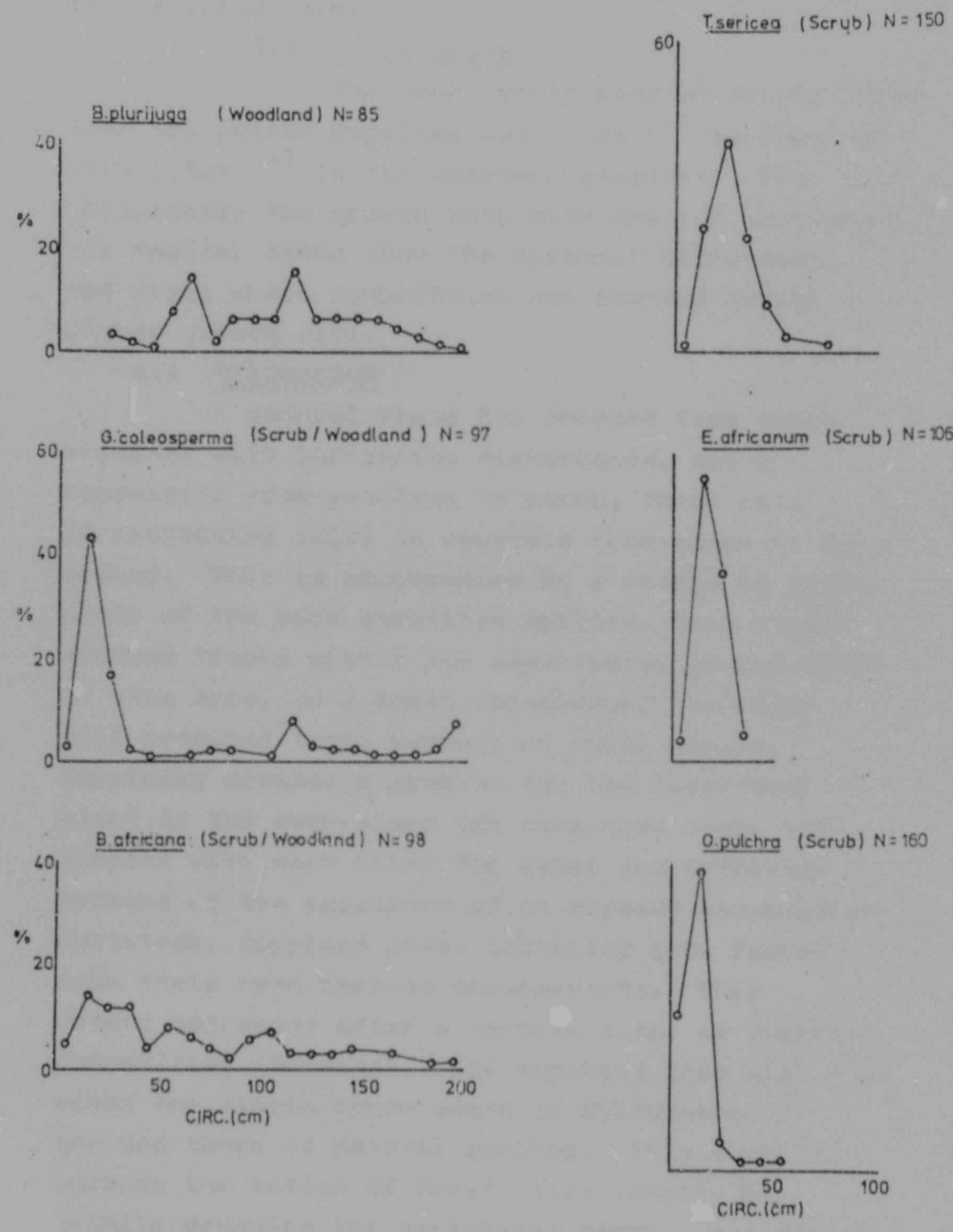


Fig. 4.9. Percentage of dead trees per 10cm circumference size class for the six species in six different sites.

40% or more in the 20-30cm size, decreasing to 2% in the larger trees.

4.3.4 Competition

The mean growth rate of single stems from the pruned coppices was 1,7cm y^{-1} as compared with 1,1cm y^{-1} in the unpruned coppices. Fig. 4.10 illustrates the growth rate with the two treatments. The smaller stems show the greatest difference, the stems where competition was removed having a higher growth rate.

4.4 DISCUSSION

A general trend has emerged from these results; with increasing disturbance, and a regression from woodland to scrub, there is a corresponding shift in emphasis from above to below ground. This is accompanied by a change in growth habit of the more sensitive species, from single stemmed trunks with a low above:below ground ratio in stem area, to a great underground rootstock that produces large numbers of small shoots. Coppicing creates a problem for the individual plant as the even-sized and even-aged stems all compete with each other for water and nutrients. Because of the existence of an already established rootstock, coppiced stems initially grow faster than their seed derived counterparts. This growth decreases after a certain size, as interstem competition increases. The coppiced tree will only reach the single trunk state if disturbance is low and there is natural pruning. This could be through the action of frost, fire (cool), or animals damaging the peripheral stems. The one or two central stems would grow more quickly and eventually suppress their neighbours through apical dominance.

Coppiced trees also pose a problem in population dynamic studies as it is difficult to decide what

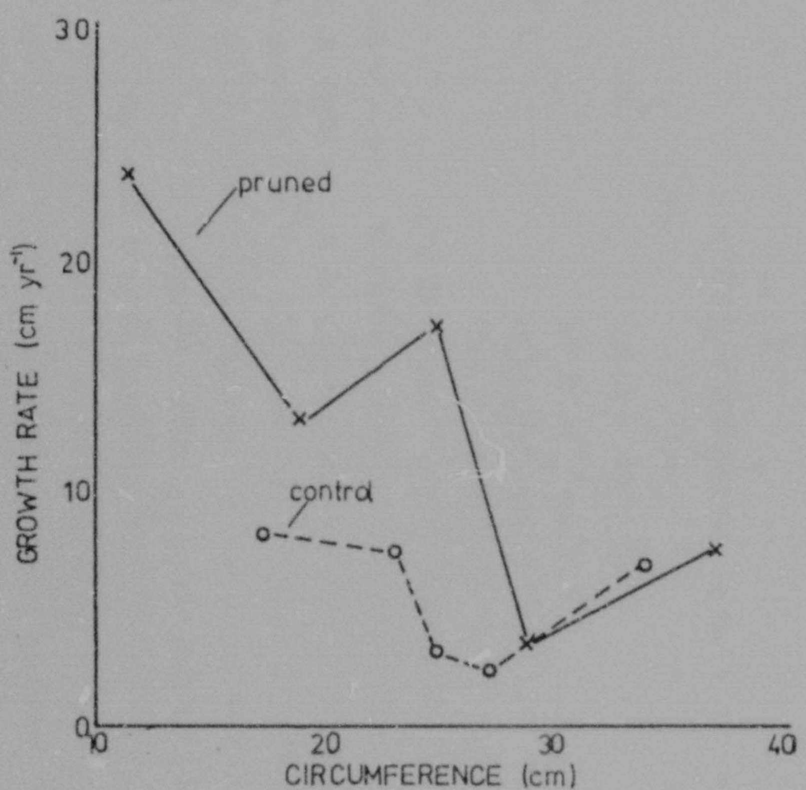


Fig. 4.10. A comparison between the growth of pruned and unpruned (control) coppiced stems of *Baikiaea plurijuga*.

constitutes an individual. To a browsing animal each above ground stem is an individual, whereas to the plant itself, the rootstock is the unique unit. This is further complicated in some species by the phenomenom of root-grafting, e.g. Pterocarpus angolensis (Knight, 1974) and root suckering, e.g. Ochna pulchra (Rutherford, 1982).

CHAPTER 5. DETERMINANTS OF VEGETATION CHANGE

5.1 INTRODUCTION

This chapter examines the factors influencing change in the vegetation with the primary objective of explaining the difference between the two physiognomic forms of Kalahari Sand vegetation, woodland and scrub.

The major factors influencing the composition and structure of the woody vegetation on the Kalahari Sands are:

1. Edaphic - soil texture, depth and moisture relations.
2. Frost damage.
3. Fire damage.
4. Herbivores - elephant damage in particular.
5. Logging activities.

5.1.1 Literature Review

5.1.1.1 Edaphic Factors

Soil Moisture

The literature (see 3.1 and 3.2) on Kalahari Sands emphasizes the importance of soil texture and moisture in influencing the vegetation. In a semi arid region such as Hwange, the irregularity of the rainfall accentuates the role of soil moisture. Water is held in the soil in two ways: in the pores between soil particles, and on the clay and organic particles.

In a sandy soil a decrease in water content has relatively little effect on root uptake, until the wilting point is reached. As most of the water is held at low water potential, a sandy soil releases almost all the rainfall, making it available for plant uptake (Hillel, 1971).

Root Systems

When water is applied to the surface of a dry soil it does not distribute evenly down the profile and only the surface is brought to field capacity. Further water applied to the system