LAND DEGRADATION IN THE PRO-NAMIB

Edited by David Ward

A project funded by U.S. A.I.D. and S.I.D.A.

wheat were common which, when added to income from pastoral activities, provided the African community with economic independence.

This bright picture has been blurred in recent years. Today the inhabitants live in extreme poverty. Only a small fraction of the wheat field is planted. This could largely be caused by the building of the Von Bach Dam upstream on the Swakop river at Okahandja in the 1960's about 100km from Otjimbingwe as well as the construction of Swakoppoort Dam upstream about 50km upstream from Otjimbingwe. These dams reduce runoff of water in the river during summer floods in the mesic catchment areas, resulting in water becoming less available to the residents of Otjimbingwe.

Local herds have declined dramatically in size over the last fifteen years. The majority of the inhabitants, including the young and supposedly economically-active, depend in one form or another on old-age pensions or government hand-outs. Social evils such as alcoholism, drug use and crime (mainly theft) are common in the area (Fuller 1993). Ethnic tensions are still prevalent between the majority Damara section and the minority Herero section and are a constant feature of contemporary life.

Sustained high population growth rates, the influx of people (about 50 % of the population has immigrated into the area since 1981) and their livestock as well as the small area of land are the major causes for the continued hardship and poverty among the people of the Otjimbingwe Reserve.

MATERIALS AND METHODS

Study area

The Otjimbingwe reserve lies 200km northwest of Windhoek on an undulating plain on the banks of the Swakop river. The reserve is completely surrounded by fenced commercial farms. The major rock type is Donkerhuk granite. The soils are sandy and are vegetated with *Acacia tortilis*, *Acacia reficiens*, *Boscia albitrunca and Schotia afra*. *Faidherbia albida* is the dominant tree on the banks of the Swakop river. We compared the ecology of Otjimbingwe with the neighbouring Tsaobis farm (21 000 ha; stocking rate 378 ha/LSU) which has similar geology and vegetation types. We also compared the soils of Otjimbingwe and Tsaobis with those of Donkerhuk farm, some 30 km distant on the same soil and with a similar vegetation type. Donkerhuk farm differed from the other two sites in that it had some grass at the time of the study (December 1996)(see *Methods* below).

Grass height

The Levi bridge (or point-frequency frame) is made from aluminium and is 1m high and 1m long, has ten guide holes bored perpendicular through the two horizontal fixed bars (Mueller-Dombois and Ellenburg, 1974). A steel rod of the same length as the legs is slid through the holes which are equally spaced, 10cm apart, along the linear frame.

The Levi bridge is placed with its legs over the vegetation to be measured and the pins are lowered vertically one after the other. Wherever the pin touches the vegetation the

Percentage organic carbon = ((Initial weight - Final weight)/Initial weight) * 100.

Sociological study

We separately interviewed 28 mostly elderly residents of the town (selected randomly) and interviewed personally. All respondents were asked the same questions (Appendix 1). The reason for this choice of interviewees was to get reliable long-term information from them concerning changes in the ecology of the area.

RESULTS

Browse Line

There were significant differences among sites in browse line height (F=17.68, P=0.000, error d.f. =27)(Fig. 3). The mean ± S.E. height of the browse line of the close site (1.135±0.122 m) vs. the site far from town (0.491± 0.122 m) was highly significantly different (Tukey test: P=0.003). There was also a significant difference between sites far from town vs. in town (1.505± 0.122 m) (Tukey test: P=0.000, d.f. =27) while the comparison close vs. in town was not significant (Tukey test: P=0.100, d.f. =27).

There was no significance difference in tree size distribution close to and far from town (Kolmogorov-Smirnov test: D_{max} =0.188, P=0.895, d.f. = 98)(Fig. 4). Although this showed no significant difference overall, there were more small trees far from town and more big trees close to town.

The mean ± S.E. of the distance between trees close to town (15.15 ± 1.134 m) was highly significantly different from far from town (5.65 ±0.403 m)(t =8.20, P=0.000, d.f. = 98)(Fig. 5).

Grass height

In spite of the higher stocking densities at Otjimbingwe, there was no significant difference in grass height in Otjimbingwe and Tsaobis (F=1.86, P=0.154, error d.f.=36). All sites were similarly denuded of grass in December 1996.

Mean ± S.E. grass height at Otjimbingwe close (1.060 ± 0.456 cm) and far (0.030 ± 0.021 cm) was not significantly different (t =8.20, P=0.128, d.f. =18). The same applied to the comparison of Tsaobis close (0.420 ± 0.182 cm) and far (0.150 ± 0.073 cm) (t =1.373 ; p =0.187 d.f. =18).

Soil carbon

The mean ± S.E. % organic carbon content at Otjimbingwe (1.148±0.10 %) was significantly higher than that of the commercial farms (0.701 ± 0.05 %) (t =3.946, P=0.000, d.f. =27.5)(Fig. 6).

(d) Cutting grasses for goats to feed on and collect Ana (*Faidherbia albida*) pods 3.6%

(e) Receiving (free-of-charge) or renting grazing fields from commercial farmers 3.6%

(f) Depending on government food hand-outs. 57.1%.

The low percentage of people moving out of Otjimbingwe in response to drought is congruent with the data provided by Fuller (1993), which show that even in the first half of the century the population did not respond to rainfall fluctuations (Fig. 7).

During drought, 60.7% of the respondents sold their animals during drought, 35.7% said their animals simply died, while 3.6% moved to better areas with their animals. With regard to whether they keep extra animals for outsiders during good rainy seasons, 78.6% said yes, while 21.4% said no, suggesting that the animals maintain a high grazing pressure even in good years.

All 100% of the respondents indicated that the Headman/community does not make any stocking decisions and that stocking decisions are an individual matter. This response is consistent with the data from Fuller (1993) that show that there is only a weak correlation between the number of large stock units in Otjimbingwe and rainfall (Fig. 8), i.e. animal numbers are not actively managed in response to environmental conditions.

DISCUSSION

The high human population density and low carrying capacity of the Otjimbingwe Reserve results in each farmer trying to stock as many livestock in the area in order to overcome the effects of drought and competition with other communal farmers. This results in the livestock having to compete for scarce natural vegetative cover, which in turn causes overgrazing in the 92 000 ha area. In the struggle for survival the livestock consume most of the palatable vegetative cover living in the area. In spite of the clear differences between the communal and commercial farms in this study in terms of human and livestock population densities, we found few differences in their long-term impacts on the environment.

Browse line

The browse line decreases as one moves from the town area to the outskirts. Thus one can conclude that more animals are found closer the town area than on the outskirts and that local overgrazing is occurring.

Tree size

It is immediately apparent that the area within 1 km of the town of Otjimbingwe suffers from greater wood removal than the surrounding countryside. Additionally, we observed that the trees decrease in average diameter as one moves from away from town. The absence of smaller trees closer to the town could be attributed to the fact that the Otjimbingwe residents cut them down for at least one of the following reasons:
(a) to feed their animals,
(b) to use them as a means of fuel,

Therefore, we strongly believe that once the Otjimbingwe reserve inhabitants reduce their livestock numbers and allow natural processes to continue at their own pace, the reserve could 'smile' again. This process of change may be difficult because of the low level of education of the people, numerous social problems, and high level of dependency on government hand-outs. It is clear that the sociological and ecological issues are intertwined, and that emphasis on improving the social situation (e.g. education) of the residents of Otjimbingwe is likely to ultimately lead to an improvement in their living conditions and the quality of the environment in which they live.

ACKNOWLEDGMENTS

We thank Ben Ngairorue and the staff of the Desert Ecological Research Unit (especially Inge Henschel and Vilho Mtuleni) for their assistance. We thank the community of Otjimbingwe and the farmers of Tsaobis for their assistance. This study was funded by a grant from U.S. Agency for International Development to David Ward, Uriel Safriel and Mary Seely and a grant from the Swedish International Development Agency (SIDA) to Mary Seely for the Summer Desertification Project.

REFERENCES

Archer, F.M., Hoffman, M.T. & Danckwerts, J.E. 1989. How economic are the farming units of Leliefontein, Namaqualand ? *Journal of the Grassland Society of southern Africa* 6: 211-215.

Foth, H.D. & Turk, L.M. 1972. *Fundamentals of soil science*. 5^{th} ed. Wiley, New York. 454 p.

Fuller, B.B. 1993. *Institutional appropriation and social change among agropastoralists in central Namibia*. Unpubl. PhD thesis, Boston University, Boston, Mass. 213 p.

Jacobson, P.J., Jacobson, K.M. & Seely, M.K. 1995. *Ephemeral rivers and their catchments: sustaining people and development in western Namibia*. DRFN, Windhoek, Namibia.

Muller D., - Dombois and Ellenberg H. 1974. *Aims And methods of vegetation ecology*

Mokwunye, U. 1996. *Nutrient depletion: Sub-Saharan Africa's greatest threat to economic development.* Presented at the STAP Expert workshop on Land Degradation, Dakar, Senegal, 18-20 September 1996.

Olsvig-Whittaker, L. & Morris, J.W. 1982. Comparisons of certain Nylsvley soils using a bioassay technique. *South African Journal of Botany* 4: 91-96.

Quan, J., Barton, D. & Conroy, C. 1994. *A preliminary assessment of the economic impact of desertification in Namibia*. Department of Environmental Affairs Research Discussion Paper No. 3, Windhoek, Namibia.

Seely, M.K. & Louw, G.N. 1980. First approximation of the effects of rainfall on the ecology and energetics of a Namib desert dune ecosystem. *Journal of Arid Environments* 3: 25-54.

Steyn, H.P. & du Pisani, E. 1984/1985. Grass-seeds, game and goats: an overview of Dama subsistence. *South West Africa Scientific Society Society Journal* 84/85: 37-47.

Table 1. Details of respondents: years of residence in Otjimbingwe, age (years) and number of years of education. Of the 28 respondents, 60.7 % were women and 39.5 % men.

	RESIDENCE	AGE	EDUCATION
Average	36.54	57.43	3.14
S.E	3.77	2.74	0.64
Maximum	80	80	9
Minimum	5	30	0
Median	33	56	2
n	28	28	28

Table 3. Opinion of respondents on changes in their environments over time.

CHANGES OVER TIME	INCREASED	DECREASED	SAME
DISTANCE TO GRAZING	100%		
AVAILABILITY OF WATER		100%	
AMOUNT OF FIREWOOD		100%	
WOOD COLLECTION TIME	100%		
AMOUNT OF RAIN		100%	
WILD ANIMALS		100%	
WILD PLANTS		100%	
HOUSEHOLD SIZES	100%		

Appendix 1

QUESTIONAIRE ON OTJIMBINGWE

Name:..................................
Sex:..............................

(1) Years of residence in area ....
(2) Age........
(3) Level of education

(4) Number of stock
Cattle..........
Goat.........
Sheep........
Donkey........
Other..........
(5) Have you changed your livestock over the years
(6) Do your animals walk further to graze today than before
Ans. Further : Shorter : No change
(7) Has the availability of water in area changed over the years and how.
Ans. Less : Same : More
(8) Did the water quality change
Ans. More salt : less salt : same

FIREWOOD

(9) Has the quantity of firewood decreased
Yes/No
(10) Did wood collecting time change over the years as well as distance

RAINFALL

(11) Has rainfall patterns chanced over the years
Ans. Gotten worse : better : no change
(12) If conditions worsen how do you cope
Ans. Change stocking : Alternative income : Other
(13) During droughts do you sell your animals or do they just die
Yes/No
(14) During good rainy years do keep extra animals for outsiders
Yes/No
(15) Does the Headman/community make stocking decisions

(16) Is there a mechanism of regulations to adhere to decisions made ?
(17) Are there any changes in number of wildlife
Name a few:

FIGURE CAPTIONS

Fig. 1. Map of the Swakop catchment (modified from Jacobson *et al*., 1995), showing the position of Otjimbingwe. Inset: Position of the Swakop catchment in Namibia.

Fig. 2. Average annual rainfall at Otjimbingwe over the years.

Fig. 3. Browse line height (m) at sites in Otjimbingwe town, close to town (200 m away), and far from town (1200 m away).

Fig. 4. Histogram of tree trunk diameter (cm) close and far from Otjimbingwe.

Fig. 5. Tree nearest-neighbour distances (m) close and far from Otjimbingwe.

Fig. 6. Percentage organic carbon in soils. Otji1 = close to Otjimbingwe (north), Otji2 = far from Otjimbingwe (north), Otji3 = close to Otjimbingwe (south), Otji4 = far from Otjimbingwe (south), Tsaoclos = close to Tsaobis farmhouse (200 m), Tsaofar = far from Tsaobis farmhouse (1200 m), and Donkerhu = Donkerhuk Ost farm in a grassy area.

Fig. 7. Otjimbingwe human population size and annual rainfall from 1924 until 1954. Note that there is no correlation between population size and rainfall.

Fig. 8. Otjimbingwe livestock population size (in LSU) and annual rainfall from 1924 to 1954. Note that the correlation between number of LSU and annual rainfall is weak.

Fig. 2

Average Rainfall at Otjimbingwe over the years

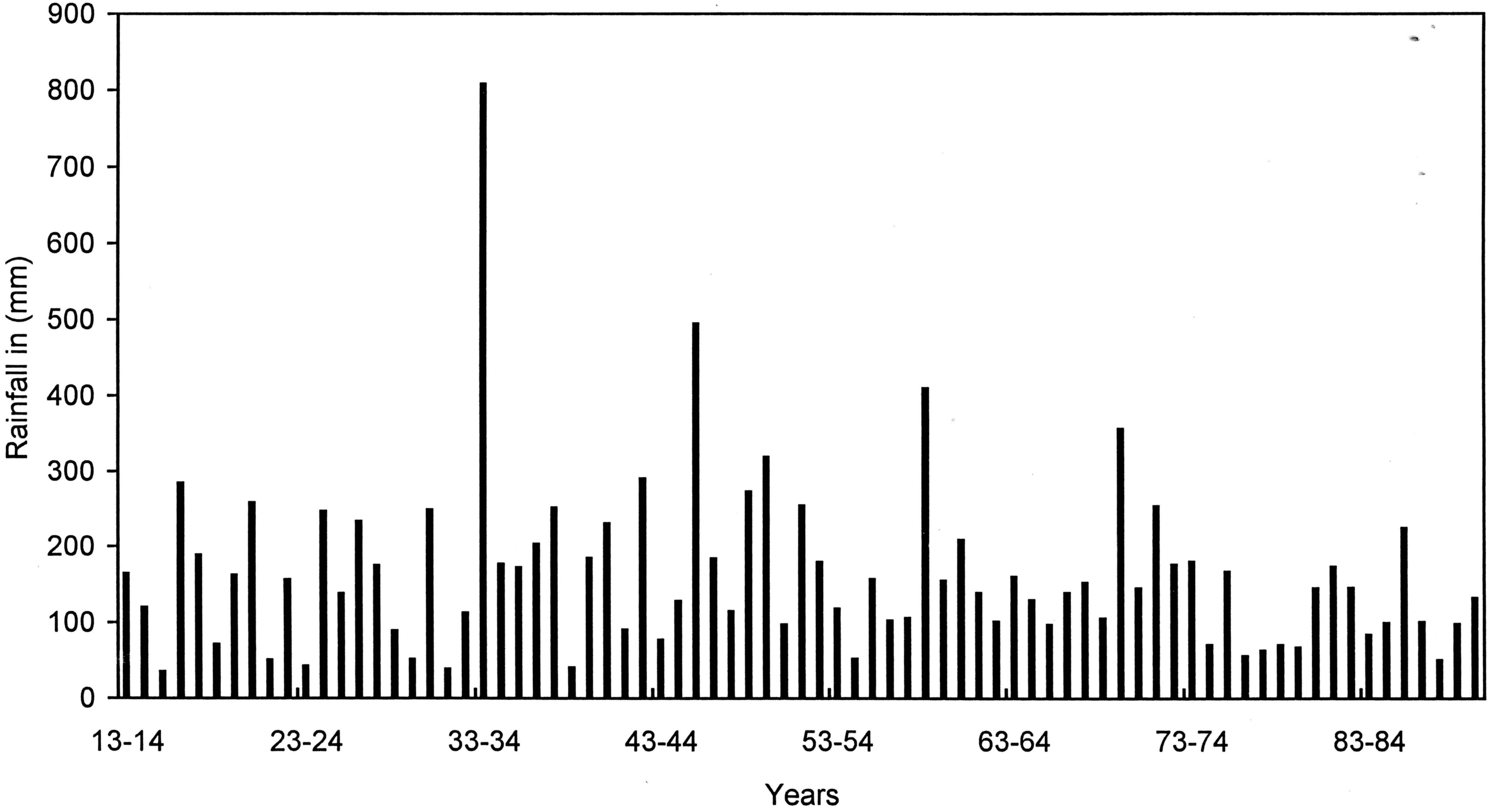
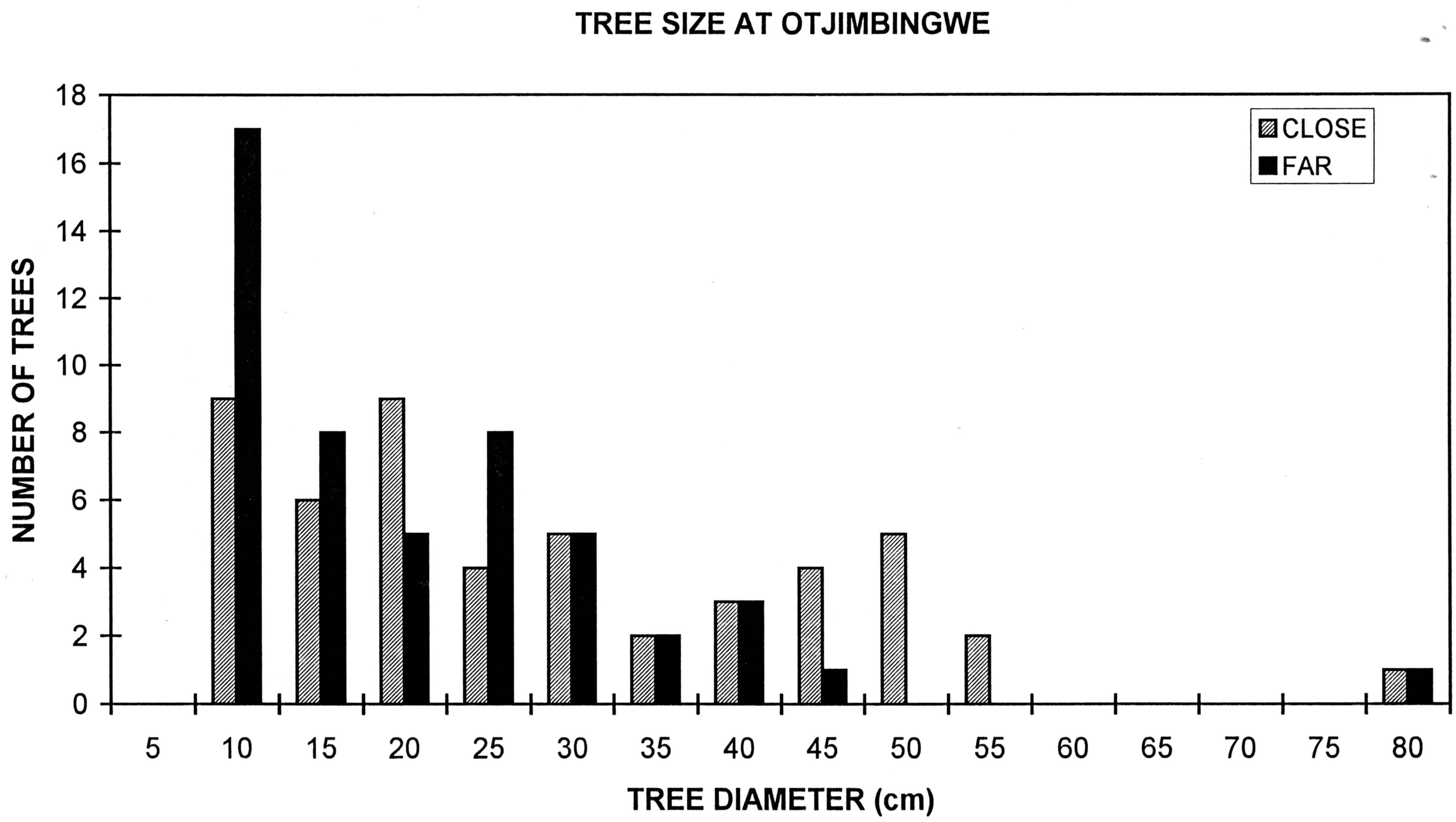
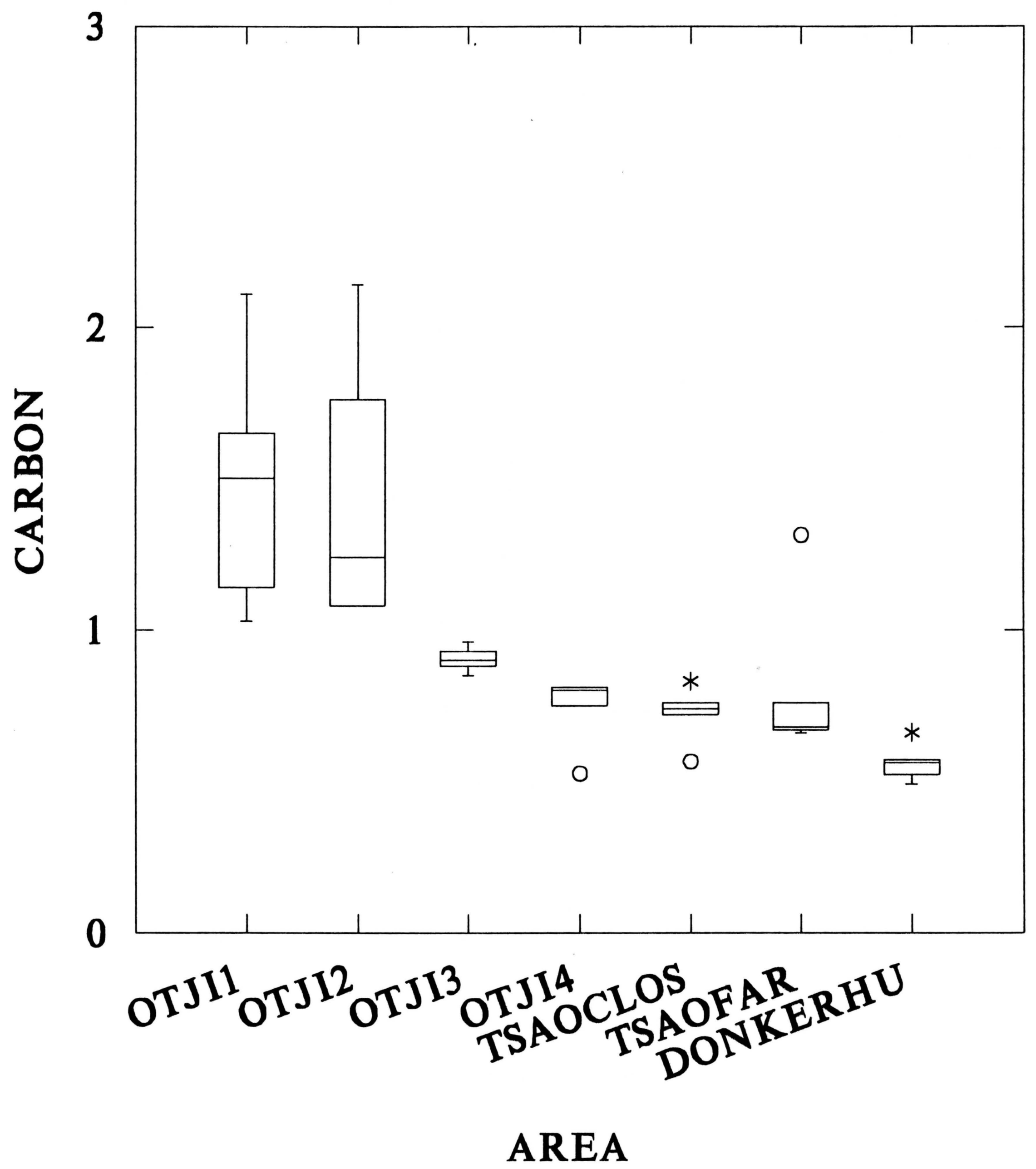
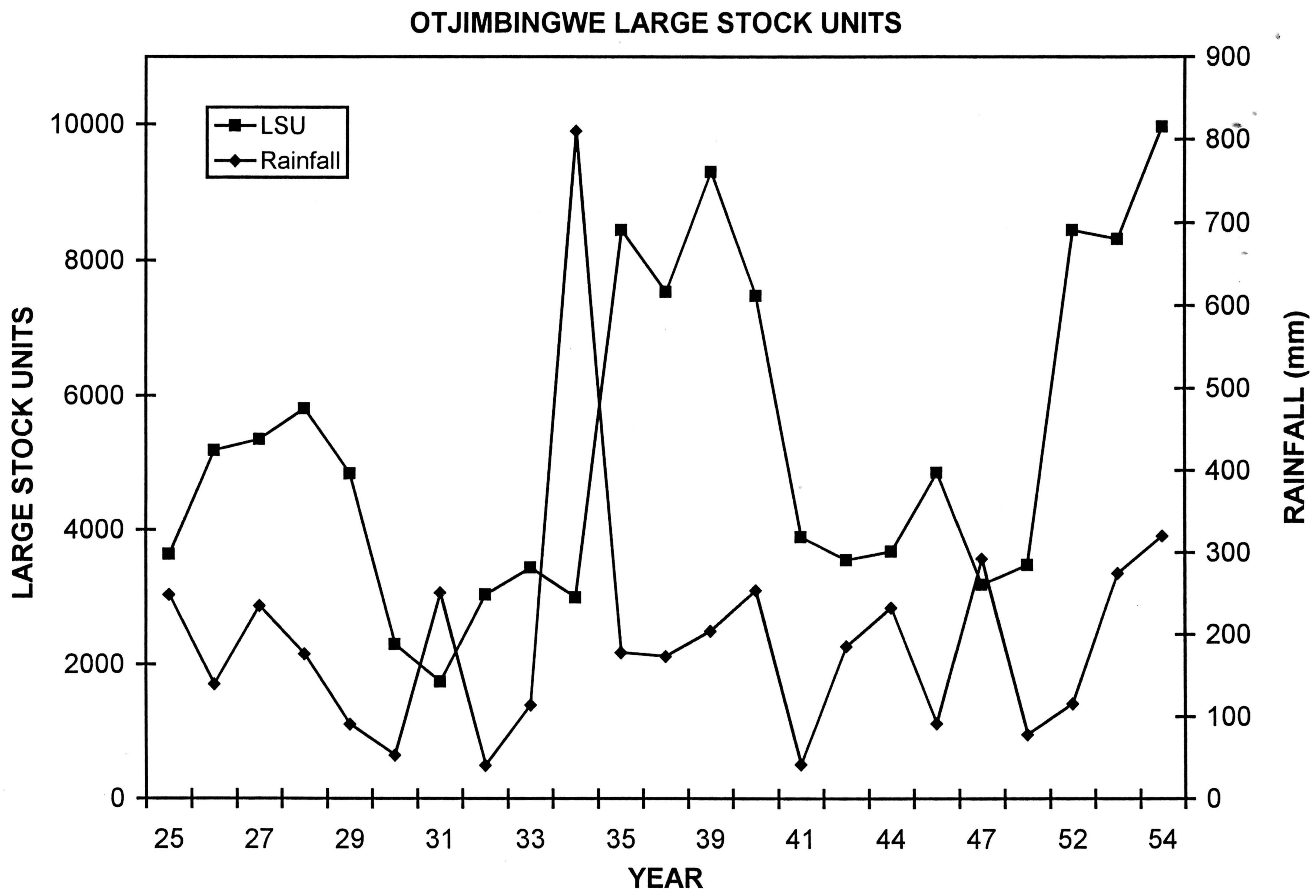


Fig. 4


TREE SIZE AT OTJIMBINGWE
NUMBER OF TREES
0
2
4
6
8
10
12
14
16
18
CLOSE
FAR
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
TREE DIAMETER (cm)



CARBON
3
2
1
0
OTJI1
OTJI2
OTJI3
OTJI4
TSAOCLOS
TSAOFAR
DONKERHU
AREA


OTJIMBINGWE LARGE STOCK UNITS
LSU
Rainfall
LARGE STOCK UNITS
RAINFALL (mm)
YEAR
0
2000
4000
6000
8000
10000
0
100
200
300
400
500
600
700
800
900
25
27
29
31
33
35
39
41
44
47
52
54

long parallel mountain ranges. There is a thin layer of sandy soil overlying a schist geology. There is a gradient in annual rainfall of 80 -200mm on these farms as follows: Changans-80mm, Tweespruit -120mm and Quabis -200mm. Currently these farms are all used for commercial purposes.

Overgrazing

We used a distance measuring wheel to measure the distance from water points on each farm. Every 100, 200, 300 , 500 and 1000 m , three soil samples were taken (20 m apart) and the amount of grass was measured using a Levi bridge (Muller - Dombois and Ellenberg 1974). The Levi bridge is a one-meter-long linear frame with holes 10 cm apart along its length. The legs of the bridge are placed over the strip of vegetation to be measured and the pins are lowered vertically one after the other. The heights at which they first touch a plant part was recorded.

Soil samples

(a) Organic Carbon

Organic carbon is a reliable measure of soil quality and is a useful index of nitrogen availability in desert soils (Foth and Turk 1972). The soil samples were collected at 50 m and 500 m from water points. The samples were first sieved (sieve size 2 000 μm) to exclude stones and other large material. After this we measured the amount organic carbon lost by burning the soil in a muffle furnace at 900 °C for 6 hours. Dry soil was weighed before and after burning, and the weight loss recorded as percentage organic carbon.

(b) Bioassay

We planted 10 seeds in the soil in each of 10 pots in order to assay the nutrient quality of the soil samples taken (following Olsvig-Whittaker and Morris 1982) . We used *Cynodon dactylon* , radish *(Raphanus sativus)* and *Arabidopsis thaliana* in these experiments. Only *Cynodon dactylon* germinated during this study. We measured root and shoot lengths of 1 median-sized plant per soil sample.

RESULTS

Grass Height

Changans Farm:

Within the 100m mark from the water point, there was no grass available. The amount of grass as well as average grass height increased from the 200 m mark with an average grass height of 0.6 cm to1000 m (average grass height of 0.8 cm). The mean ± S.E. of grass height from 0-1000m on this farm is 0.213± 0.24 for 15 points.
There was no significant correlation between average grass height and distance from the water point (t=2.1, p=0.054,d.f=13)(Fig. 2).

Amount Of Organic Carbon

Changans Farm:

There was a significant correlation between the amount of organic carbon and the distance from the waterpoint ($F=0.453$, $P=0.513$, $D.F=13$). The mean ± S.E. amount of organic carbon was 1.57 ± 0.31 % .

Tweespruit Farm:

There was no relationship between the amount of organic carbon and the distance from the water point ($F=0.970$, $P=0.343$, error d.f.=13).The mean ± S.. amount of organic carbon was 1.88 ± 0.12 %.

Quabis Farm:

There a significant correlation between the amount of organic carbon and the distance from water point ($r=0.71$, $F=12.891$, $P=0.003$, error d.f. =13). The mean ± S.E. of the amount of organic carbon was 1.62 ± 0.06 %.

DISCUSSION

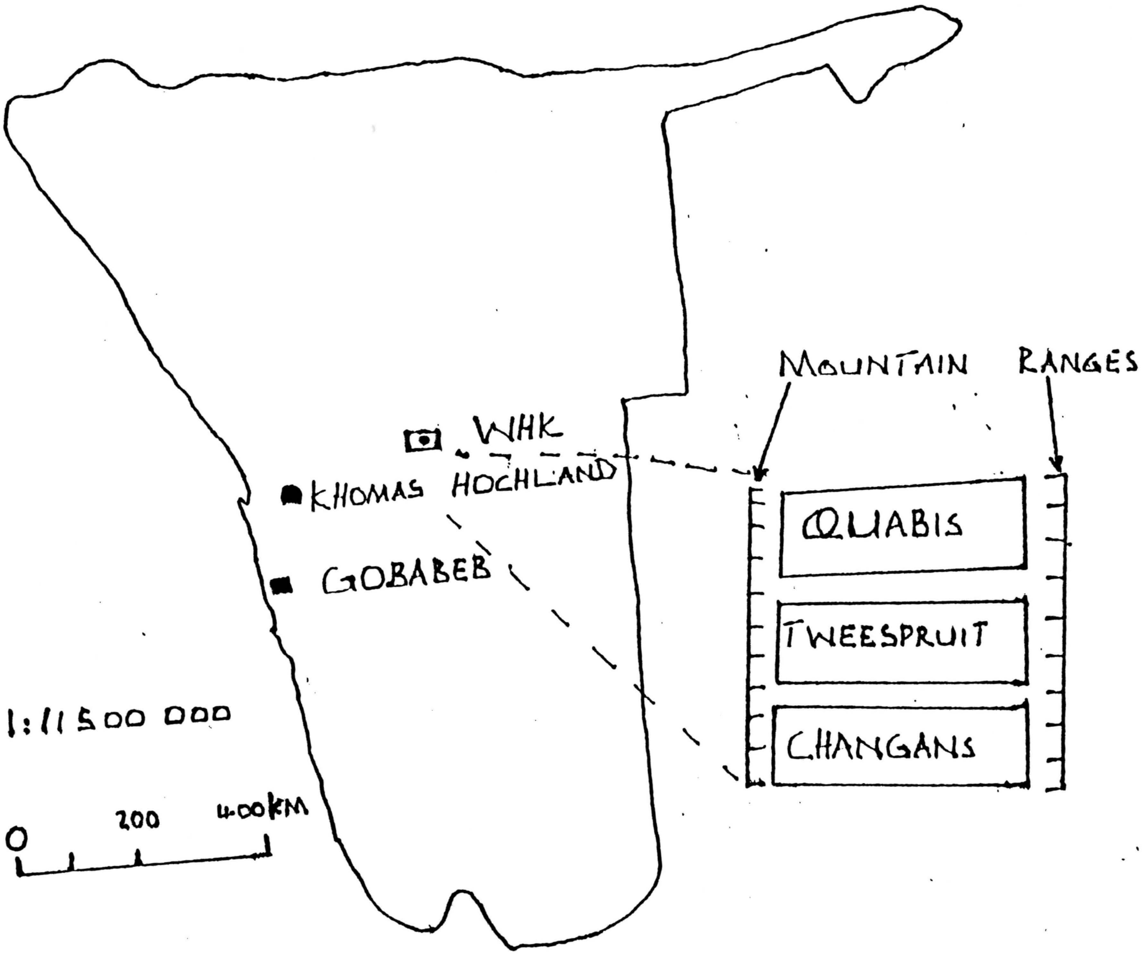
From our results, the hypothesis that the amount of grass as well as grass height increases with increasing distance from water holes correlated with our findings on the three farms. Within the first hundred metres from the water points, there was no grass available at all. The amount of grass and height started to increase from the 200 m mark on both Changans and Tweespruit with average grass height ranging from 6.0 and 1 cm respectively. We expected Quabis, with the highest amount of rainfall, to have more grass than the other farms. The reason for this difference from our prediction is probably greater land degradation, especially bush encroachment, on Quabis. When we measured the amount of carbon on all farms, our result indicated that Tweespruit farm has the highest amount followed by Quabis and then Changans. The reason for that could be that Quabis and Changans have been more severely degraded than Tweespruit. From these findings we can conclude that Tweespruit can recover faster than the other farms if the conditions on these farms are not be overgrazed in future.

Lastly, we measured the root and shoot lengths of plants that was grown from the soils the three farms and the results show that there is a great difference in shoot lengths, with Tweespruit having the highest average followed and finally Changans, and no significant difference on root length.

We conclude that overgrazing around water point can be reduced by establishing many water points within an area than making one fixed water point.

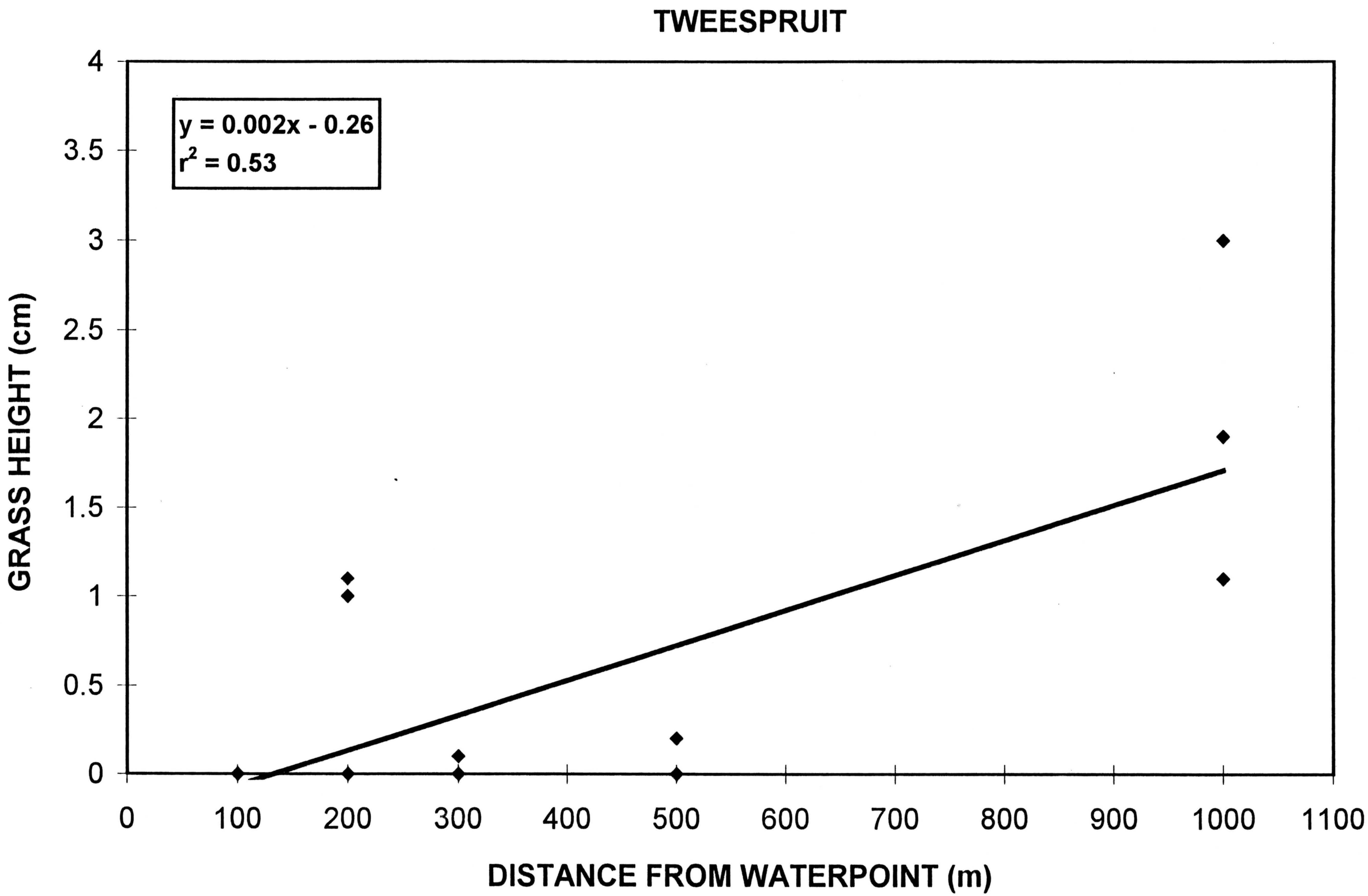
Van den Eyden, V., Vernemmen, P. & Van Damme, P. 1992. *The ethnobotany of the Topnaar*. University of Ghent, Ghent, Belgium.
Van der Merwe, J.H. (ed.). 1983. *National atlas of South West Africa*. National Book Printers, Cape Town, South Africa.

Fig.1.



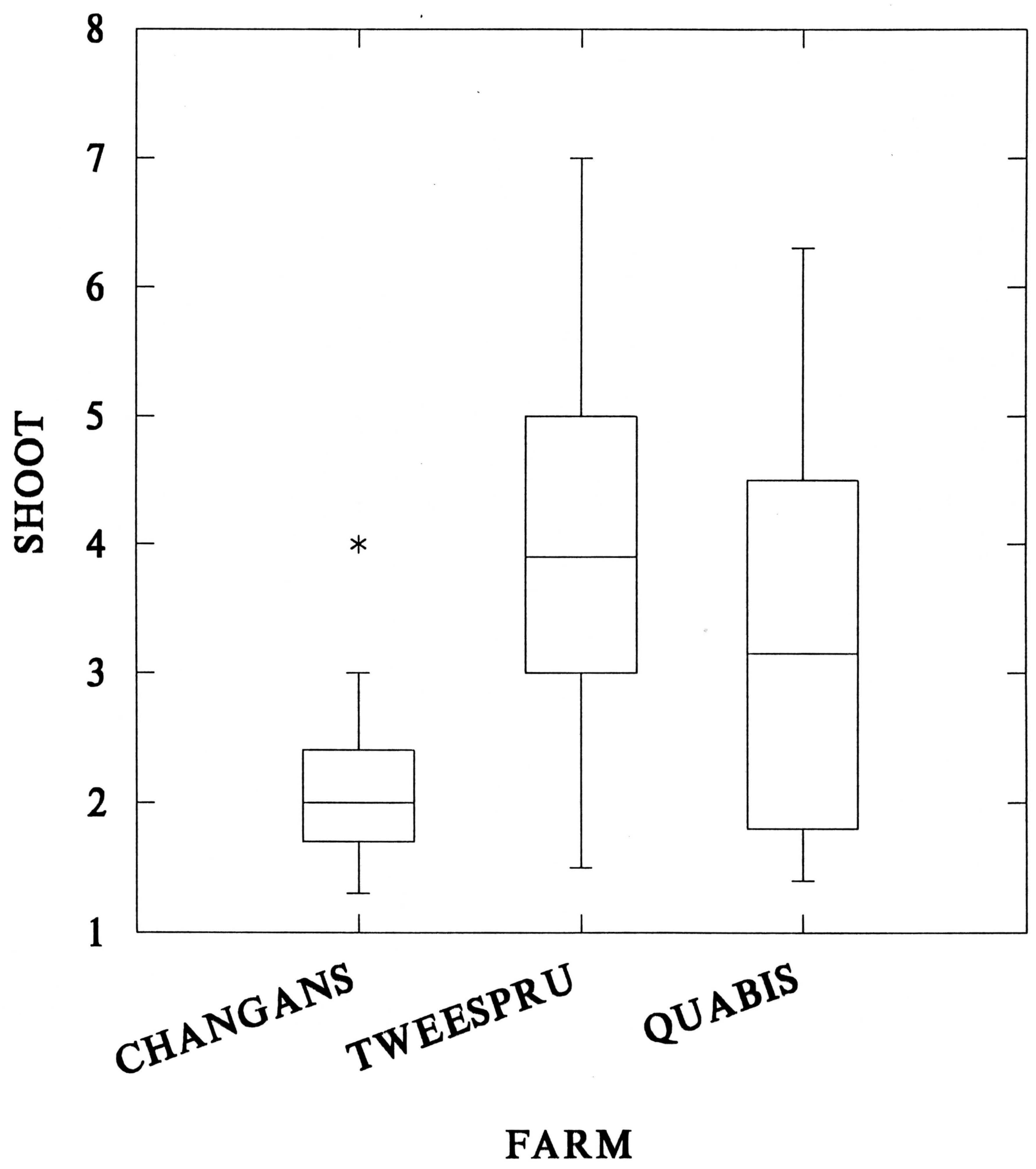
WHK
KHOMAS HOCHLAND
GOBABEB
MOUNTAIN RANGES
QUABIS
TWEESPRUIT
CHANGANS
1:11 500 000
0
200
400KM

Fig. 3



TWEESPRUIT
y = 0.002x - 0.26
r² = 0.53
GRASS HEIGHT (cm)
0
0.5
1
1.5
2
2.5
3
3.5
4
0 100 200 300 400 500 600 700 800 900 1000 1100
DISTANCE FROM WATERPOINT (m)

Fig. 5



Although this is only an indication on a small area, this can be a true representation of every area in Namibia that is bush encroached. Becker (1993) pointed out that the estimated annual loss to the agricultural sector as a result of bush encroachment at $100 million. The production capacity of many farms has dropped down to 30%. In some cases bush encroachment has reached proportions where the forage of graze land is totally destroyed.

Quabis receives approximately 160.2 $\pm$ 44.4 mm of rainfall annually, which is sufficient to result in mass germination of trees and hence bush encroachment. The amount of rainfall is apparently crucial to this process because the neighbouring fams which have higher stocking densities but lower rainfall (e.g. the farm Niedersachsen: mean $\pm$ S.E. annual rainfall = 101.2 $\pm$ 50.6 mm) do not suffer bush encroachment, but rather are totally denuded of vegetation by overgrazing.

Fixed Water Points

As the farm Quabis is very dry, drinking water for the livestock comes from underground aquifers and is then pumped to fixed points where livestock come to drink. This idea of locating one fixed water point in one area has reduced grass cover surrounding the water point. As a result of trampling and overgrazing as the animals come together, the grass species are not given time to recover. In such situations, the bushes (mostly the thorny *Acacia reficiens*) are avoided and therefore given time to multiply as they are not eaten at all. Hence, bush encroachment is particularly sever near water points.

Erosion

As we have seen the problem of fixed water points on the grass growth (overgrazing - Chapter 2), it is clear that soil erosion caused by both wind and running water can not be avoided. The soil is then easily eroded, thus removing nutrients from the soil and making it less and less fertile. On the other hand, the already existing bushes prevent the soil nutrients from being washed away and therefore greater quantities of nutrients accumulate on the stems of the bushes. This favourable condition makes it easier for the bushes to grow and multiply faster. This condition seems to have a great contribution to the problem of bush encroachment on this farm (Quabis).

How A Bush-Encroached Area Can Reverse Itself From A Low Productivity To A High Productivity Area Again

With time the bushes have grown very thick and competition among them begins. This will result in weaker bushes/trees dying out, resulting in lower bush densities. Additionally, as the trees grow, more carbon is added to the soil by dead trees/ bushes. This adds more nutrients to the soil which eventually allows the growth of grasses. If the situation is not further disturbed (i.e. overgrazing does not continue), an area that has been encroached can become productive again (Fig. 2).

RESULTS

Nearest-neighbour distances and tree size/age

There was a significant positive correlation between nearest-neighbour distances and tree size ($r = 0.94$, $F= 83.11$, $P=0.001$, error d.f. = 13) (Fig. 3).

There was a significant negative correlation between the coefficient of variability (c.v.) in nearest-neighbour distances and tree size ($r=-0.5$, $F=5.27$, $P=0.04$, error d.f. = 13) (Fig. 4).

Soil organic carbon

There was significantly more organic carbon in the soil under large trees (2.43 $\pm$ 0.04 %) than under small trees (1.60 $\pm$ 0.01 %)($t = 4.86$, $P = 0.000$, d.f. = 16.7) (Fig. 5). The amount of organic carbon under small trees was similar to that found in the open areas between trees (1.62 $\pm$ 0.06 %).

DISCUSSION

The results of this study support the predictions of the cyclical model of bush encroachment (Fig. 2), namely:

(1) as trees get older and bigger, they become spaced further apart due to competition between them, and

(2) soil organic carbon increases under the larger trees, enriching the soil. Thus, grasses may return in these enriched patches. Contrastingly, there was no more organic carbon under small trees than there was in the open areas, indicating that small areas do not enrich the soil under their canopies.

We conclude that bush encroachment is not a permanent problem, and that the situation can return to normal (i.e. open woodland) when overgrazing is stopped.

Many farmers have attempted to remove trees that appear through the process of bush encroachment. Such practices can temporarily alleviate the problem of reduced grass productivity (Becker 1993, Rietfontein Farmers' Association 1993) and hence increase the stocking rate for cattle and sheep. However, the idea of cutting down trees without stopping overgrazing cannot solve the problem in the long term because only the symptoms are treated and not the causes. Thus, continued overgrazing will cause the problem with bush encroachment to return.

ACKNOWLEDGMENTS

We thank Ben Ngairorue and the staff of the Desert Ecological Research Unit of Namibia (especially Vilho Mtuleni and Inge Henschel) for assistance during this study. We thank Veon Van Rooyen, K. Schulze and J. Maartens for permission to work on their farms. This study was funded by a U.S. Agency for International Development (U.S. AID) grant to D. Ward, U.N. Safriel and M.K. Seely and a grant to the Desert Research Foundation of Namibia from the Swedish International Development Agency for the Summer Desertification Project.

FIGURE CAPTIONS

Fig. 1. The geographic position of the farm Quabis in Namibia.

Fig. 2. A schematic diagram of the cyclical model of bush encroachment and recovery.

Fig. 3. The relationship between $\log_{10}$ median nearest-neighbour distance and median canopy diameter of *Acacia reficiens* on Quabis.

Fig. 4. The relationship between $\log_{10}$ coefficient of variation in nearest-neighbour distances and median canopy diameter of *Acacia reficiens* on Quabis.

Fig. 5. Box and whiskers plot of the percentage organic carbon in soils under 15 big and 15 small *Acacia reficiens* trees on Quabis.

FIG. 2.

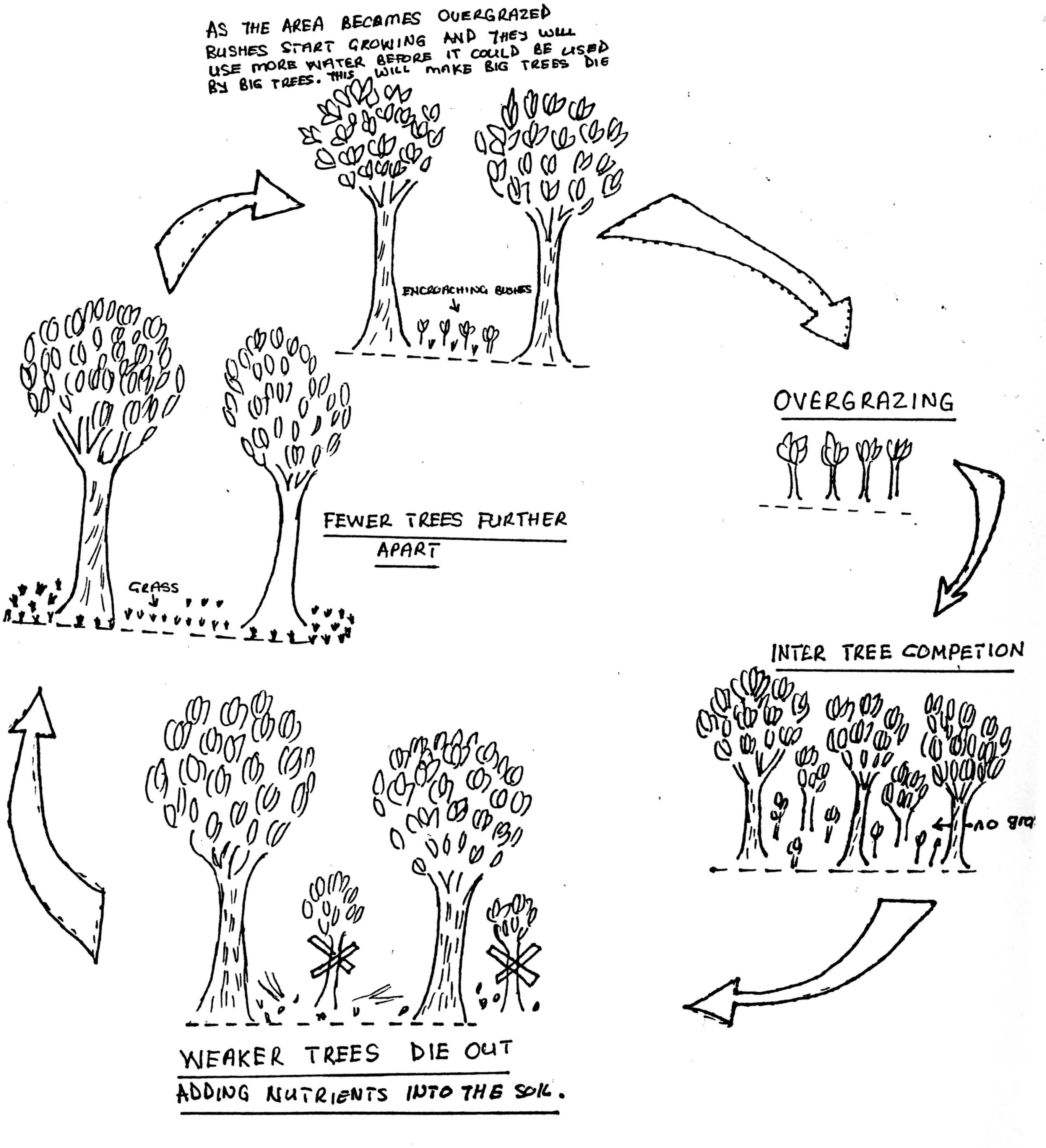
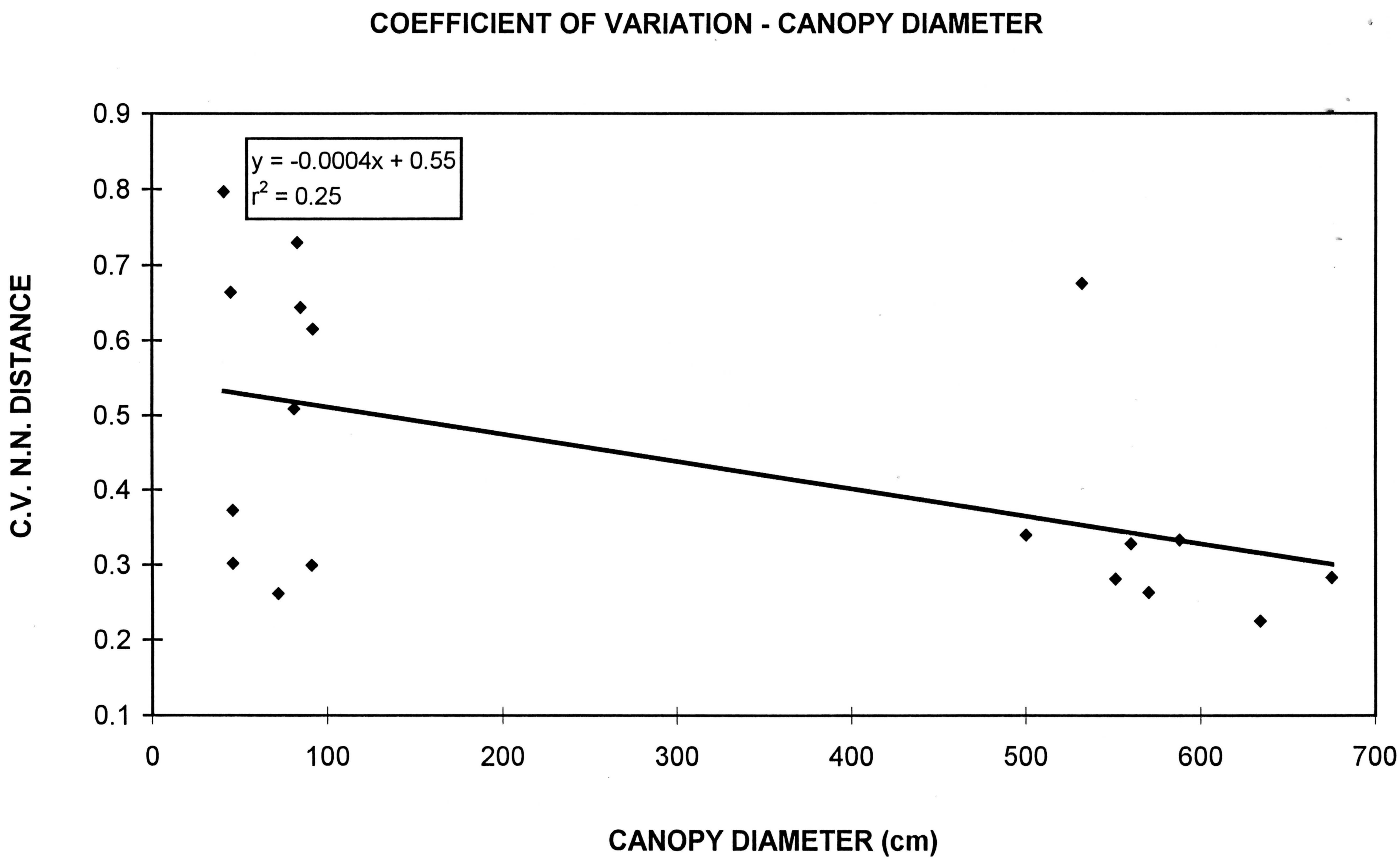

AS THE AREA BECAMES OVERGRAZED BUSHES START GROWING AND THEY WILL USE MORE WATER BEFORE IT COULD BE USED BY BIG TREES. THIS WILL MAKE BIG TREES DIE
ENCROACHING BUSHES
OVERGRAZING
INTER TREE COMPETION
FEWER TREES FURTHER APART
GRASS
WEAKER TREES DIE OUT
ADDING NUTRIENTS INTO THE SOIL.

FIG. 4.



COEFFICIENT OF VARIATION - CANOPY DIAMETER
y = -0.0004x + 0.55
r2 = 0.25
C.V. N.N. DISTANCE
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
CANOPY DIAMETER (cm)