TRANSKEI GRASSLANDS: RECENT PHENOMENON OR ANCIENT ?

Honours Project

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Abstract

Acocks (1953) suggested that Transkei was once covered in Forest and Scrub-Forest and has possibly been transformed by the Iron Age farmers to grasslands. Feely (1985) suggested that the grasslands are ancient. I therefore used C isotope analysis to reveal whether there has been any change in the dominant vegetation during the Iron Age period. We measured the $\delta^{13}C$ value of the soil organic matter taken at various depths. These were taken from selected sites throughout Transkei that represented the grasslands, forests and grasslands suspected of once being forest or scrub-forest. The results show that the vegetation has remained stable. Those area that are presently covered in grasslands have remained grasslands for the time period represented by the depth of the samples taken. There is however a small shift in the forest and grassland sites to a lower isotopic value either as a result of changing vegetation or changes in the atmospheric [CO_2]. There is also archaeological, ecological and historical evidence supporting these results. There is evidence of settlements scattered along the coast and in river valleys during the Early Iron Age (AD 300 to AD 1000). The earliest evidence of settlements during the Late Iron Age dates to AD 1400. The impact of the farmers appears to be localised and the vegetation type appears to have remained constant although impacted on.

Key words: C isotope analysis, grassland, forest, Iron Age farmers, Transkei

Introduction

Acocks (1953) suggested that vast areas of Transkei that are presently covered in grassland were once under forest and scrub-forest. He appeared to have based his assumption on the Clementsian theory that assumed that the vegetation distribution resulted from climatic conditions and could therefore be mapped using climatic data (Feely pers. comm.). He suggested that these grasslands are fairly recent and are a result of human interference, namely the mutilation of forests by the local people, presumably for building material, fuelwood and due to the clearance of ground for agriculture. This still occurs today and would have further convinced him of his convictions.

Feely (1987), however, disagreed with Acocks' (1953) proposal, basing his theory on archaeological and historiographic evidence from elsewhere in southern and eastern Africa, areas that were supposedly also covered in 'secondary' grassland. West, Bond & Midgley (1999) found, using stable carbon isotope analysis of soil organic matter (SOM), that the forests of Hluhluwe-Umfolozi Game Reserve, KwaZulu-Natal, were also once under grassland. Meadows & Linder (1993) suggested that many Afromontane grasslands throughout Africa, previously thought to be of anthropogenic origin, are ancient grasslands, based on pollen analysis. Prins' (1994) analysis of phytoliths at an Early Iron Age site in Ntsitsana, Transkei, suggested that the area was dominated by C_4 grasses during the first millennium.

We decided to use C isotope analysis to determine the extent to which the vegetation has changed in the Transkei as a result of Iron Age farming and more recent practices. The extensive grasslands of Transkei have predominantly C_4 photosynthetic pathways, whereas the forests have predominantly C_3 pathways. We therefore used C isotope analysis of the SOM at various sites throughout Transkei to determine whether it was once covered in forest or scrub forest as suggested by Acocks (1953), or whether the grasslands are ancient, as suggested by Feely (1987). This technique of soil analysis has been successfully used throughout the world (Guillet, Faivre, Mariotti & Khobzi 1988; van der Merwe & Medina 1989; Ambrose & Sikes 1991; Stock, Bond & Le Roux 1993; Bond, Stock & Hoffman 1994; West et al. 1999).

The ratio of ^{13}C to ^{12}C ($\delta^{13}C$ value) of the SOM is used to determine the photosynthetic pathway of the dominant vegetation that existed during the accumulation of the relevant SOM. This is possible because the isotopic ratio of the vegetation is adequately preserved (Martin, Mariotti, Baldesdent, Lavelle, Vuattoux 1990). The SOM, however, does not precisely reflect the $\delta^{13}C$ value of the vegetation from which it was derived, due to fractionation during the decomposition of the vegetation (Martin et al. 1990). The atmospheric CO_2 levels have also increased over the last 20 000 years (Petit et al. 1999), possibly as a result of the burning of fossil fuels. These fossil fuels are isotopically lighter than present-day $\delta^{13}C$ values and results in lowering of the atmospheric $\delta^{13}C$ values by *c.* 2 ‰ (Martin et al. 1990). Therefore even if the dominant photosynthetic pathway remains constant, the $\delta^{13}C$ values of the vegetation may become more negative. There may also be small changes in the isotopic C ratios for a given photosynthetic pathway due to changes in relative humidity and the degree of stomatal closure (O'Leary 1993). These processes result in a change in the $\delta^{13}C$ values of the SOM with depth in the soil, even though the dominant photosynthetic pathway remains constant. If however, these factors are taken into account, this method appears to give reliable results of the relative change of the dominant vegetation.

The aim of this project is to determine if the grasslands of Transkei were once forest or scrub-forest and have recently (within the last 2 000 years) been transformed into grasslands as suggested by Acocks (1953) or are the grasslands ancient. It would seem that if people had an effect on the vegetation in Transkei it would most likely have been during the last 2 000 years based on archaeological findings (Maggs 1984).

Methods and Site descriptions

Two transects were selected perpendicular to the coast, to represent the historical vegetation dynamics in Transkei. They spanned from Port St Johns (31°36'16"S, 29 °31'25"E) to Maclear (31°05'29", 28°23'30") and from Coffee Bay (31°58'19", 29°09' 43") to the escarpment above Engcobo (31°36'31", 27°57'08") (Fig. 1). Three sectors were selected in each transect to represent the coastal lowlands, the midlands and the uplands. In each sector, where possible, three sites were selected that represented an area that was suspected to have been grasslands for at least the last 2 000 years, an area that has always been forest and an area that was possibly forest and has now been converted to grassland. A total of 12 suitable sites were found ranging in altitude from 50 to 1300 m. The location and the description of the sites are summarised in Tables 1 & 2. The mean annual precipitation ranged from 573 mm in the midlands to 1329 mm in the uplands and coastal areas, with Port St Johns having the greatest MAP (Hewitson, unpublished data). There is, however, a general decrease in MAP from the coast towards the escarpment and interior (Dent, Lynch & Schulze 1997). The mean daily maximum summer temperature is *c.* 25°C (Schulze &

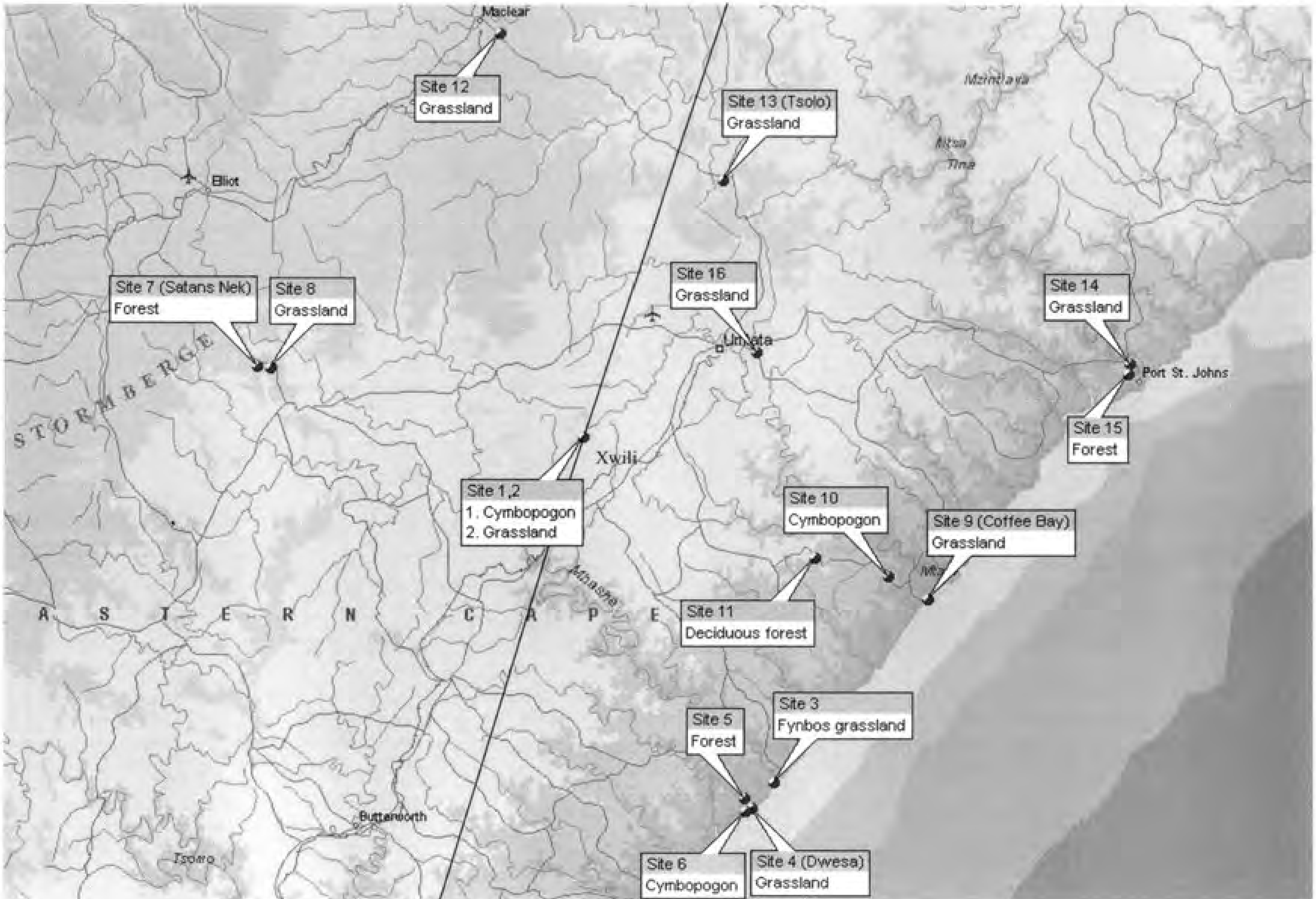


Figure 1 Map of the sites in Transkei. Area suitable for Early Iron Age settlements are to the right of the solid black line (Hoffman 1997)

Maharaj 1997). This is also the rainy season (Schulze & Kunz 1997). The midlands and uplands experience 1 -30 days of heavy frost per annum. The higher reaches of the uplands experience 31 - 60 days of heavy frost per annum; whereas the coast is frost-free (Schulze & Maharaj 1997). The river valleys that incise the midlands would most likely also be frost-free due to the continual anabatic and catabatic cycles.

The sites were mostly on dolerite although there were also sites on dune sand/dune rock and other sites on mudstone/sandstone/dark grey shale.

Table 1 Location and site description of sites selected for soil analyses in the Transkei. Abbreviations: altitude, Alt.; mean annual precipitation, MAP. The MAP data is from the climatology department of the Environmental and Geographical Science faculty, University of Cape Town.

Site	Latitude	Longitude	Alt. (m)	MAP (mm)	Aspect	Slope	Geology
1	31°43'13"	28°32'26"	1028	672.7	E	40°	Dolerite
2	31°43'14"	28°32'16"	1058	672.7	E	5°	Dolerite
3	32°15'37"	28°53'12"	100	1128.3	SW	10°	Dune sand, dune rock
4	32°17'93"	28°50'50"	93	1128.3	S	15°	Dark grey shale, mudstone, sandstone
5	32°17'03"	28°49'59"	60	1128.3	NNE	10°	Dark grey shale, mudstone
6	32°18'11"	28°50'03"	50	1128.3	S	5°	Dark grey shale, mudstone, sandstone
7	31°36'31"	27°57'08"	1250	1152.0	SE	45°	Dolerite
8	31°36'37"	27°58'43"	1300	1152.0	NNE	15°	Dolerite
9	31°58'19"	29°09'43"	50	1128.3	N	5°	Dark grey shale, mudstone, sandstone
10	31°56'16"	29°05'28"	306	1128.3	SW	40°	Dolerite
11	31°54'38"	28°57'31"	300	1028.5	SSW	60°	Grey & brownish mudstone, sandstone
12	31°05'29"	28°23'30"	1300	1080.4	S	30°	Dolerite
13	31°19'19"	28°47'26"	1000	747.6	E	10°	Dolerite
14	31°36'16"	29°31'25"	371	1353.9	none	0°	Light grey quartzitic sandstone
15	31°37'09"	29°31'22"	270	1353.9	W	10°	Light grey quartzitic sandstone
16	31°35'02"	28°51'04"	948	611.1	ESE	20°	Dolerite

The soil type varied from being black to dark red sandy clay on the dolerite, to black to very dark brown sand on the dune sand/dune rock (Table 2). The vegetation, according to Acocks (1953), is predominantly Dohne Sourveld and Highland Sourveld in the midlands and uplands, and Coastal Forest and Thornveld along the coast up to an altitude of about 450 m in the north to about 300 m southwards (Acocks 1953). *Themeda triandra* was the dominant vegetation type in the grasslands, except where *Cymbopogon* was present (Table 2). The upland forests appeared to be distinctive from the coastal forests (Cawe pers. comm.), with species such as *Podocarpus latifolius* being one of the dominant species in the uplands and *Heywoodia* being dominant in the coastal forests (Cawe pers. comm.). A more comprehensive list of species found at the various sites can be found in Appendix 1. This is, however, by no means an exhaustive list.

Where possible, deep dolerite soils were selected because the clay found in these soils minimises the movement of organic material up and down the soil profile and there is better physical protection of the SOM (Martin et al. 1990). There had to be no signs of soil disturbance that would cause mixing of the respective layers. Though earthworms may pose a problem they are normally confined to the upper 10 cm of soil (Martin et al. 1990). Each site was representative of the respective regions with regard to topography and vegetation. Although the dolerite soils were not always representative of the respective regions, as they usually occur as isolated outcrops, they did not appear to affect the vegetation distribution significantly.

The sites marked as grassland on Figure 1 (Sites 2, 3, 4, 8, 9, 12, 13, 14 & 16) were areas that were assumed to always be grassland. They were either found at high altitudes (Sites 8 & 12), where there were no trees visible, or on the coast (Site 3, 4, 9 & 14) where salt sprays would most likely have prevented the cultivation of crops and therefore prohibited people from clearing any trees for crops. The three midland sites (Sites 1,13 & 18) were randomly selected to represent the midlands.

Table 2 Soils and vegetation description of the selected sites in the Transkei. The data for the Acocks vegetation type data was published in Acocks (1953).

Site	Soil Type	Soil colour	Dominant genera & coverage (%)	Acocks vegetation type
1	Sandy clay to sandy clay loam	V dark brown	90% *Cymbopogon*, 2% *Cussonia*	Highland Sourveld & Dohne Sourveld
2	Sandy clay loam	V dark brown	*Themeda, Eragrostis, Sporobolus*	Highland Sourveld & Dohne Sourveld
3	Loamy sand	V dark brown	10% *Protea* and, 80% Grass	Coastal Forest & Thornveld
4	Loamy sand	V dark brown	30% *Aristida*	Coastal Forest & Thornveld
5	Sandy clay loam	Dark brown	*Heywoodia, Olea, Cussonia,*	Coastal Forest & Thornveld
6	Sandy loam	Black	80% *Cymbopogon*, 10% *Stenotaphrum*	Coastal Forest & Thornveld
7	Sandy clay loam +	Dark reddish brown	*Podocarpus, Curtisia, Cussonia*	Highland Sourveld & Dohne Sourveld
8	Sandy clay	Dark red	90% *Andropogon*, 5% *Aristida*	Highland Sourveld & Dohne Sourveld
9	Sandy clay loam	Black	*Stenotaphrum, Phoenix, Aristida*	Coastal Forest & Thornveld
10	Sandy clay loam	Black	*Cymbopogon, Miscanthedium*	Coastal Forest & Thornveld
11	Sandy clay	V dark greyish brown	*Combretum, Carissa, Entada, Maytenus, Ataxacantha*	Eastern Province Thornveld
12	Sandy clay	V dark brown		Highland Sourveld & Dohne Sourveld
13	Loamy fine sand to sandy clay	Black	90% *Themeda*	Southern Grassveld
14	Sand	Black	5% *Aristida*	Coastal Forest & Thornveld
15	Sandy clay	Dark brown	*Millettia, Tripetes, Monthotaxus*	Coastal Forest & Thornveld
16	Sandy clay	Black	50% *Themeda*, 10% *Sporobolus,*	Highland Sourveld & Dohne Sourveld

The forest and *Cymbopogon* sites were selected in close proximity to the grassland sites where they were present. The forest sites were located in forests that grew in gorges and were therefore protected from fires. They also had no visible signs of disturbance, such as coppices, that would have resulted after fires or the felling of trees. The forest at Site 7 (Satans Nek) had trees such as *Podocarpus latifolius* with a diameter of about 50 cm. These are fairly slow-growing and do not tolerate disturbances such as fires. The forests down at the coast also appeared to be mature forests.

At each site where the soil was deep enough, a 70 cm deep pit was dug. Starting from the surface, about 200 g of soil was taken every 5 cm down the soil profile to a depth of 60 cm where possible. Care was taken not to contaminate the successive samples with the soil above it. The soil colour, texture and type down the profile were noted. Dead vegetation was randomly collected around each site to determine what the current isotopic input into the soil was. The slope and aspect was estimated and the location was determined using a GPS. The dominant vegetation and percentage cover was estimated within a 50 m radius around the site.

Laboratory procedures

The soil was ground using a mortar and pestle and sieved through 2 mm mesh to remove stones and large organic matter. The remaining larger particles of organic material were then floated off in water. The soil was left in the water for an hour for the soil particles to settle before the water was drained off. The fine clays did not settle completely. Aluminium sulphate should have been used for effective flocculation. Subsamples of the surface and bottom-most layers from each site were treated with concentrated hydrochloric acid to test for the presence of $CaCO_3$, by noting whether the soil effervesced or not. As none of the samples were contaminated with $CaCO_3$ except for the bottom-most layers (depth of 35 cm downward) of Site 13 (Tsolo) (Figure 1), it was not necessary to treat the samples with hydrochloric acid in preparation for the isotope analysis.

The vegetation material collected at the sites were oven-dried at 60°C for 48 hours and ground in a universal laboratory hammer mill to reduce the bulkiness. It was ground further in an oscillating ball mill to refine the material for the mass spectrometer.

The organic content of the soil sample from the surface layer and the bottom-most layer was determined. This was done by oven drying 8 g of soil at 105°C for 48 hours and then burning it in a furnace at 420°C for 16 hours, in order to burn off the organic material. The relative loss in mass was then calculated. The organic content of the soil was used to determine the mass of the sample needed for the mass spectrometer.

The vegetation and soil samples were air dried at 60 °C for 48 hours. Subsamples with masses varying from 0.216 to 4.050 mg, depending on the amount of organic material in the soil, were weighed out into tin capsules. Martin et al. (1990) suggested that the change in the C isotopic ratio decreases with decreasing particle size that may result in the fine SOM being mainly composed of the grasses and not as much from the trees. It is therefore important to ensure that a representative subsample is weighed into the tin capsules. The mass of the vegetation subsamples varied between 0.020 and 0.070 mg. Nasturtium with a $\delta^{13}C$ value of -29.3‰ and ANU with a $\delta^{13}C$ value of -10.4 ‰ were used as controls for the C_3 and the C_4 values respectively, in order to correct the results obtained from the mass spectrometer. The Nasturtium samples weighed between 0.040 and 0.050 mg and the ANU samples weighed between 0.040 and 0.060 mg. These controls were analysed after every three duplicates of soil samples. The $\delta^{13}C$ values were determined on-line in a Finigan

MATT 252 via a Conflo II and an open-split Carlo Erba NA 1500 elemental analyser. The reference gas used was calibrated against six National Bureau of Standards isotope references. The isotope ratios are expressed relative to the Chicago Pee Dee Belemnite (PDB) standard [$\delta^{13}C = ((R_{sample}/R_{PDB})-1) \times 1000$ where $R = {}^{13}C/{}^{12}C$].

The data was then plotted on an XY graph in Microsoft Excel (Office 97). The mean and standard deviation of the samples taken below 20 cm, beneath the surface, were determined using the same programme. These lower samples were averaged because there did not appear to be any general shift to a higher or lower $\delta^{13}C$ value during this period. The standard deviation represents the amount of shifting in the type of vegetation that took place. The shift in the $\delta^{13}C$ values of the soil surface from the mean, was calculated to determine the extent of the change in the type of vegetation.

The depth of the SOM was used as a rough estimate of the relative age of the soil layers. This method provides a good indication of how the vegetation has changed with time. It is, however, difficult to estimate the actual age of the SOM using this method.

Results

The $\delta^{13}C$ values appear to have remained stable with time at all the sites (Fig. 2 - Fig. 6). There is no evidence of change in any of the grassland sites from a C_3 dominated vegetation to a C_4 dominated vegetation (Fig. 2 - Fig. 4). The results indicate that the $\delta^{13}C$ values of the grasslands (C_4 vegetation) range from -16.0 to -11.9 ‰ and those of the forests (C_3 vegetation) range from -24.6 to -21.7 ‰. The deciduous forest at

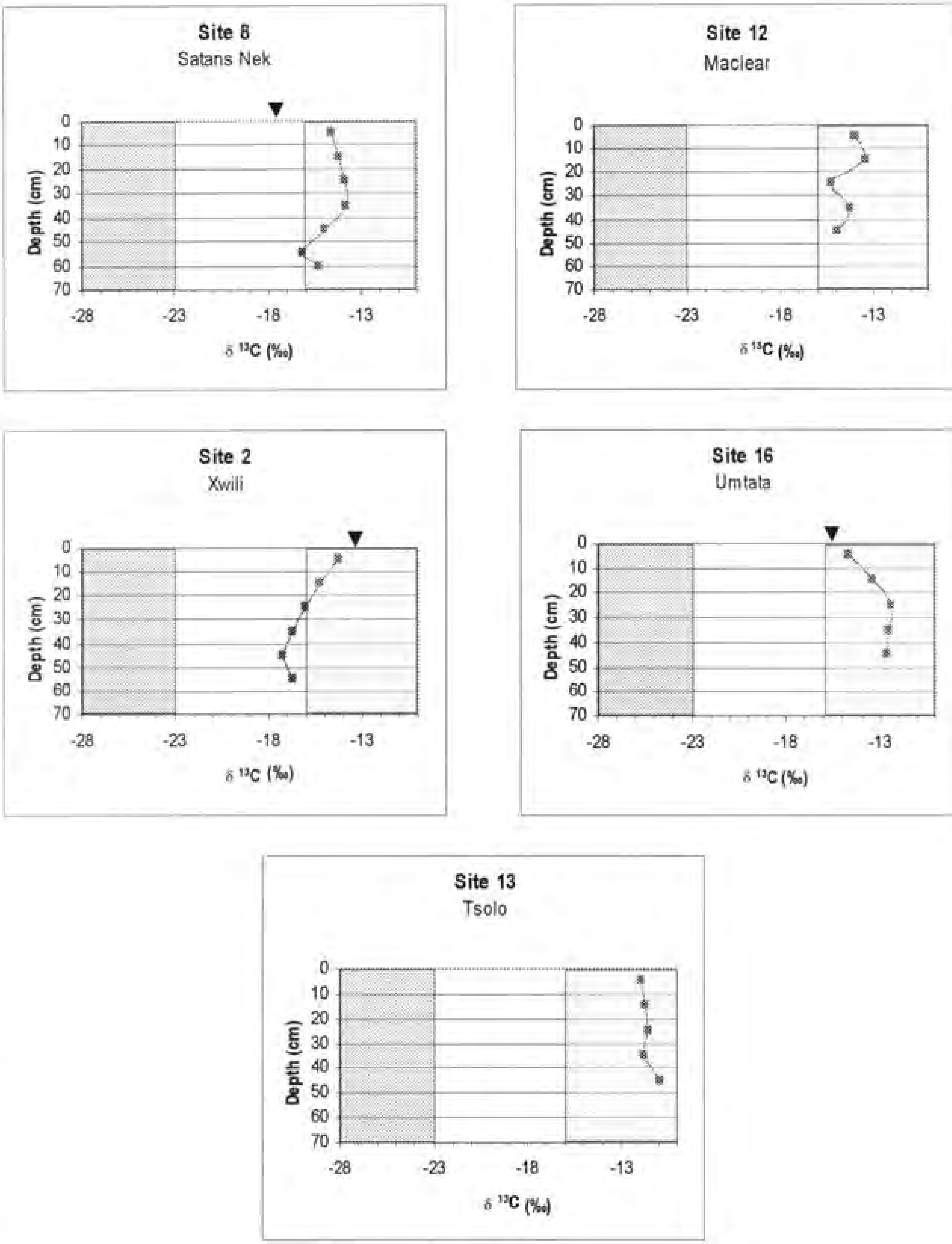
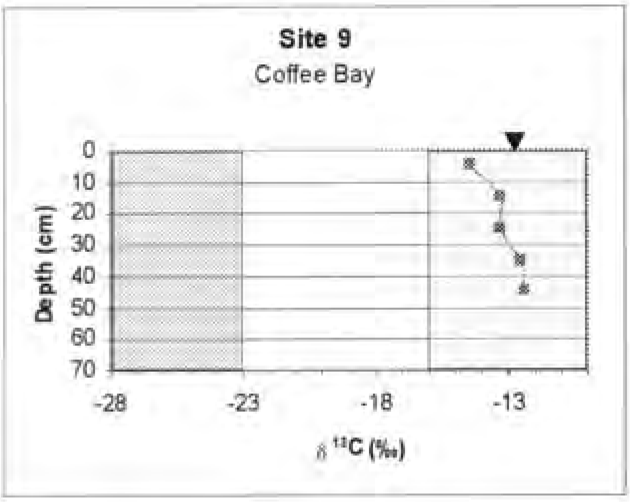


Figure 2 The isotopic values of the soil organic material with depth for the uplands and highlands grasslands of Transkei. The graphs indicate the change in vegetation with regard to C3 (trees) and C4 (grasses) type vegetation over the past successive years. The time sequence is represented by the soil depth. The arrow head above the graphs indicate the isotopic value of the present vegetation. The left hand shaded bars are typical C_3 values and the right hand shaded bars are typical C_4 values. The sites can be found in Figure 1.



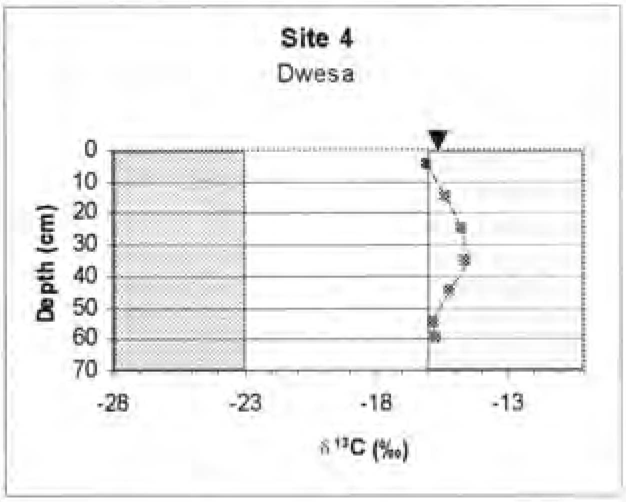
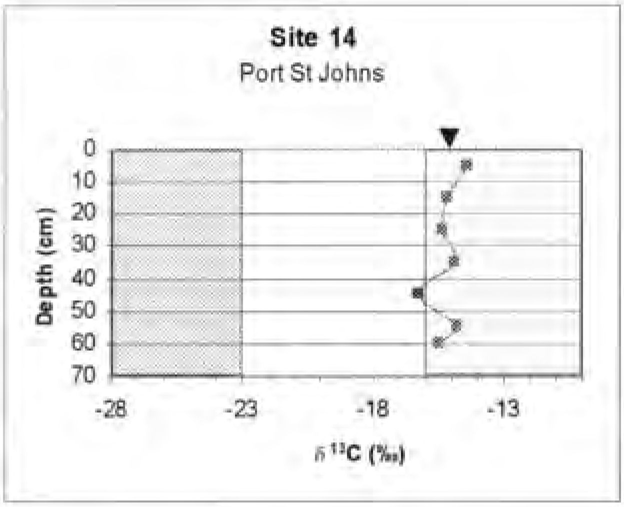


Figure 3 The isotopic values of the soil organic material with depth for the coastal grasslands of Transkei. The graphs indicate the change in vegetation with regard to C3 (trees) and C4 (grasses) type vegetation over the past successive years. The time sequence is represented by the soil depth. The arrow head above the graphs indicate the isotopic value of the present vegetation. The left hand shaded bars are typical C_3 values and the right hand shaded bars are typical C_4 values. The sites can be found in Figure 1.



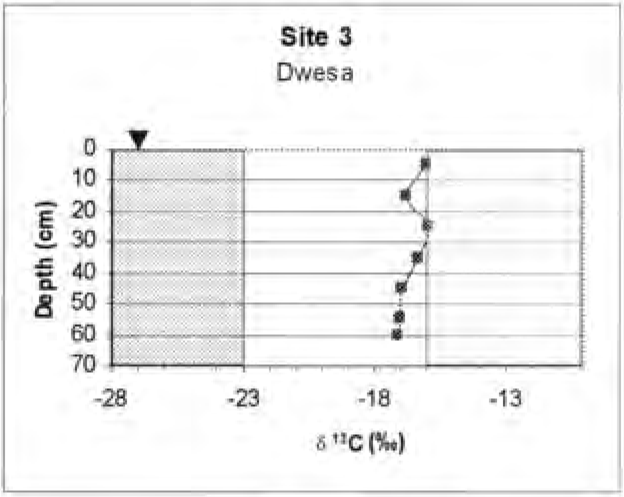
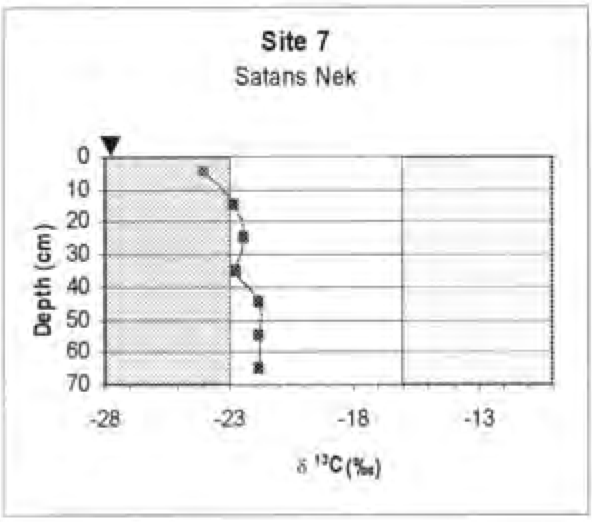
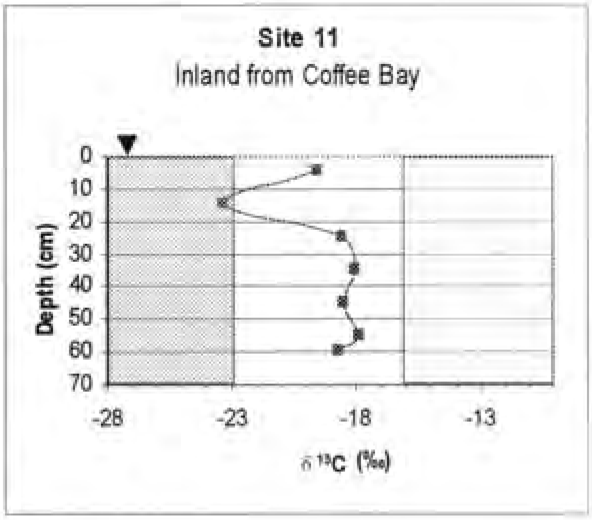
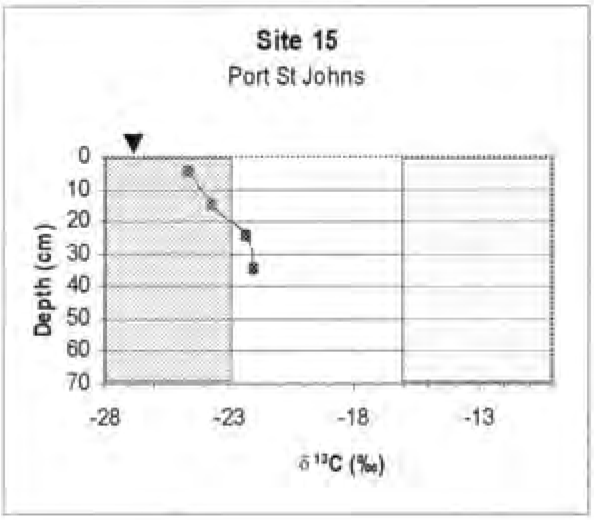


Figure 4 The isotopic values of the soil organic material with depth for the coastal grassy fynbos of Transkei. The graphs indicate the change in vegetation with regard to C3 (trees) and C4 (grasses) type vegetation over the past successive years. The time sequence is represented by the soil depth. The arrow head above the graphs indicate the isotopic value of the present vegetation. The left hand shaded bars are typical C_3 values and the right hand shaded bars are typical C_4 values. The sites can be found in Figure 1.







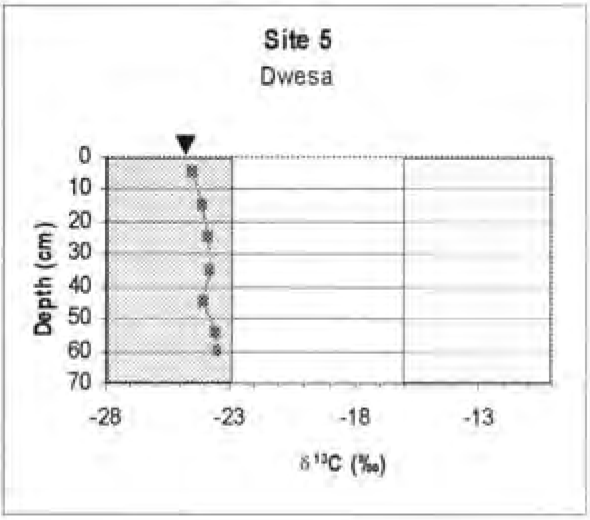


Figure 5 The isotopic values of the soil organic material with depth for the forests of Transkei. The graphs indicate the change in vegetation with regard to C3 (trees) and C4 (grasses) type vegetation over the past successive years. The time sequence is represented by the soil depth. The arrow head above the graphs indicate the isotopic value of the present vegetation. The left hand shaded bars are typical C_3 values and the right hand shaded bars are typical C_4 values. The sites can be found in Figure 1.

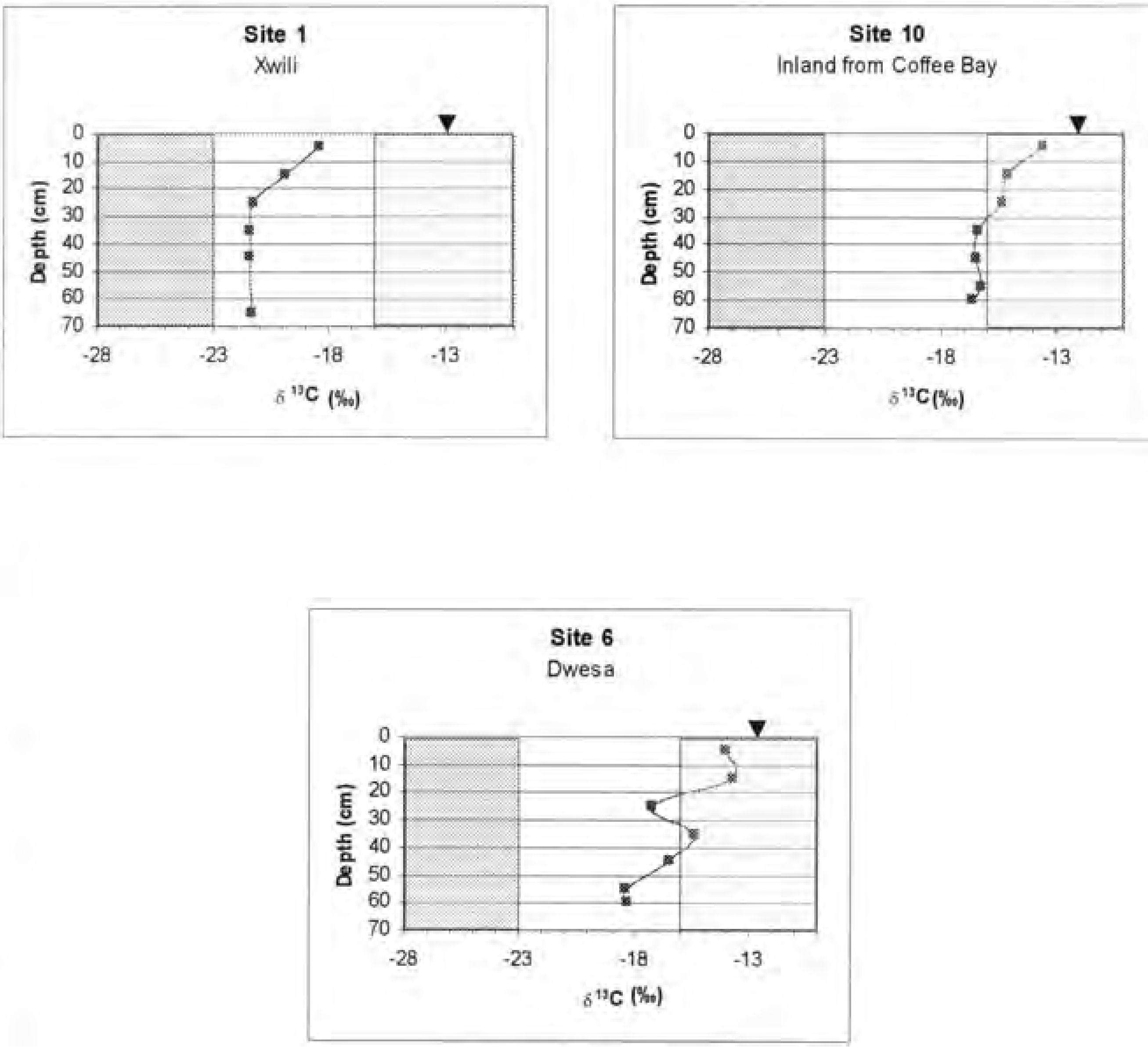


Figure 6 The isotopic values of the soil organic material with depth for areas in Transkei that we assumed had forests in the past as indicated by the *Cymbopogon*. The graphs indicate the change in vegetation with regard to C3 (trees) and C4 (grasses) type vegetation over the past successive years. The time sequence is represented by the soil depth. The arrow head above the graphs indicate the isotopic value of the present vegetation. The left hand shaded bars are typical C_3 values and the right hand shaded bars are typical C_4 values. The sites can be found in Figure 1.

Site 11 (inland from Coffee Bay) (Fig. 5) is not included in the forest range because it did not have a typical C_3 value. The range between -21.7 and -16.0 ‰ is considered to be intermediate and probably a mixture of C_3 and C_4 plants. O'Leary (1988) suggests that the C_3 range should be between -25 and -29 ‰ but mature forests such as those at Site 5 (Dwesa) have a $\delta^{13}C$ value of -25 ‰. We have therefore set the upper limit of the C_3 range at -23 ‰.

The mean $\delta^{13}C$ value for the nine grassland sites ranged from -11.4 to -16.67 ‰ (Table 2) and there was little variation with time at each site, with the exception of Site 8 (Satans Nek), as can be seen from the standard deviation (Table 2). The shift in the $\delta^{13}C$ value from the lower layers to the surface layer, however, was small. The greatest shift, of 2.37 ‰, towards a more positive $\delta^{13}C$ value was at Site 2 (Xwili). The $\delta^{13}C$ value of the surface soil was, however, in equilibrium with that of the current vegetation as can be seen from the arrowhead that represents the $\delta^{13}C$ value of the present vegetation.

In the pure grassland sites there appears to be a general shift in the $\delta^{13}C$ value towards the C_3 range in the upper layers. The greatest shift of -2.22 ‰ took place at Site 16 (Umtata). There were no trees visible near the site. There was, however, *Helichrysum*, a C_3 plant, present and the carbon isotope ratio of the present vegetation was in equilibrium with that of the surface layer. This suggests that there may have been an increase in *Helichrysum* over the ages.

Site 13 (Tsolo) was the most enriched site in $\delta^{13}C$. Although there was no evidence in the upper layers of $CaCO_3$ it may have influenced the results indirectly. The vegetation had recently been burned so there is no value for the carbon isotope ratio of the present vegetation.

The carbon isotope ratios of the forest sites fluctuated little over time (Table 2). They have, however, gradually become more negative with time, as with the grasslands (Fig. 5). In comparison, Site 11 (inland from Coffee Bay), a deciduous forest, has fairly consistently had an intermediate $\delta^{13}C$ value. The $\delta^{13}C$ ratio of the surface layer of all the forest sites except Site 5 (Dwesa) are not in equilibrium with that of the present vegetation (Fig. 5). The present vegetation is substantially more negative.

The largest changes in the $\delta^{13}C$ value are as expected in the *Cymbopogon* sites (Fig. 6) and they have all become more positive with time. As can be seen from the position of the arrowheads, *Cymbopogon* has a $\delta^{13}C$ value of about -12.4 ‰ and appears to have a strong influence on the isotopic signature of the soil organic material. Site 1 (Xwili) had a strong C_3 signature and at present has an intermediate signature. There are still remnants of a forest in the form of 17 large *Cussonia* species, with an estimated average height of 10 m and an estimated average diameter of 50 cm along the eastern slope where this site was situated. Sites 6 (Dwesa) and 10 (inland from Coffee Bay) had intermediate signatures that have become strongly C_3 with time and appear to have almost reached equilibrium with that of *Cymbopogon*. Although there have not been large fluctuations in the carbon isotopic ratios with time (Table 3), there has been a gradual shift to a more positive $\delta^{13}C$ value (Fig. 6). This shift appears to have begun fairly recently when compared to the rest of the profile.

Table 3 Mean $\delta^{13}C$ values and the standard deviation of the soil organic carbon of the samples taken down the soil profile below 20 cm from the surface, and the shift in the $\delta^{13}C$ value of the surface layer from this mean. The negative sign indicates a shift to a more negative $\delta^{13}C$ value a positive sign indicates a shift to a more positive $\delta^{13}C$ value.

Biome	Region	Site	Mean $\delta^{13}C$ of subsurface layer (‰)	Standard deviation	Surface isotopic shift (‰)
Grassland	Midlands & uplands	16	-12.48	0.14	-2.22
Grassland	Midlands & uplands	13	-11.40	0.46	-0.50
Grassland	Midlands & uplands	8	-14.81	1.00	+0.21
Grassland	Midlands & uplands	12	-14.82	0.51	+1.22
Grassland	Midlands & uplands	2	-16.67	0.53	+2.37
Grassland	Coastal	9	-12.72	0.48	-1.68
Grassland	Coastal	4	-15.18	0.57	-0.82
Grassy fynbos	Coastal	3	-16.67	0.51	+0.67
Grassy fynbos	Coastal	14	-15.32	0.56	+0.92
Forest	Midlands & uplands	7	-22.06	0.42	-1.94
Forest	Coastal	15	-22.12	0.18	-2.48
Forest	Coastal	5	-23.74	0.22	-0.76
Deciduous forest	Coastal	11	-18.31	0.36	-1.19
Cymbopogon	Midlands & uplands	1	-21.30	0.09	+2.90
Cymbopogon	Coastal	10	-16.19	0.52	+2.59
Cymbopogon	Coastal	6	-17.12	1.26	+3.12

Discussion

The results clearly indicate that the vegetation type has not changed with time in the forest and grassland sites, except for the deciduous forest at Site 11 (inland from Coffee Bay), which appears to show a very recent change to a C_3-dominated vegetation type. Grasslands have always dominated those areas that are grassland at present for the period represented by the soil depth. These grasslands cover virtually all of the midlands and uplands of Transkei. Dardis & Beckedahl (1988) suggested that the palaeosols found near Tsolo at a depth of 20 - 30 cm were about 2 000 years old, based on data from Cedarville and Mbolompo Point elsewhere in KwaZulu-Natal and Transkei, respectively. Although this cannot be extrapolated to all the sites, it does give a rough estimate of the time period required to develop soils in the Transkei. The sandy soils at Dwesa for example appear to be aeolian and may therefore have developed faster than the midland and upland sites. There were also no distinct horizons that would be indicative of well-developed soils.

In the top 30 - 35 cm of the coastal and inland grassland sites, there appears to be shift to a more C_3 type of vegetation, except for at Site 2 (Xwili), which tended towards a more C_4 type of vegetation. Cole and Monger (1994) suggested that the increase in atmospheric CO_2 during the last deglaciation has led to a decline in C_4 plants, and Ehleringer et al. (1997) suggested that increasing atmospheric CO_2 would favour C_3 species. This shift to a stronger C_3 signal may therefore be as a result of a change in the dominant vegetation to more C_3-type vegetation.

It is, however, possible that the photosynthetic pathway has remained constant but the C isotopic signature of either the vegetation or the SOM has changed, or both. Talma & Vogel (1992) suggested that *c.* 2 000 BP the atmospheric $\delta^{13}C$ value reached a peak of *c.* -5.5 ‰ and has since decreased by 2 ‰. This results in a paralleled decrease in the $\delta^{13}C$ value of the vegetation as it utilises the atmospheric CO_2. There may also be isotopic enrichment of the SOM with time due to fractionation during mineralization (Martin et al. 1990).

Grasses have a relatively short life history and may therefore be more sensitive to atmospheric CO_2 changes, as they are better able to adapt physiologically to changes in environmental conditions. The short life history may also cause them to be more susceptible to species composition changes, depending on the frequency of fires. It is therefore difficult to determine whether it is the grass vegetation that is becoming more enriched or if it is the species composition that is changing to a more C_3-type of vegetation.

The marked increase in the $\delta^{13}C$ value of the grassland at Site 2 (Xwili) would most likely be as a result of C_4 grasses becoming more dominant with time, possibly due to frequent burning. The top layer of SOM appears to be in equilibrium with the extant vegetation that is predominantly *Themeda triandra*. Fleming (1852) noted that during the mid 1800's there were extensive plains of grassland inland, and that these were rich in wild flowers. With an inevitable increase in population over the last two centuries, the fire frequency has possibly increased and become too frequent to sustain a rich species diversity. Site 2 (Xwili) was situated near a homestead and it would be normal practice to burn the grass in a controlled manner each year around the homestead to protect it from veld-fires. The grass is also often burned to improve the grazing for the following summer season. This would result in the trend described above. The low species diversity found throughout most of the grasslands of Transkei may possibly also be accredited to too frequent fires.

The fynbos grassland sites have an intermediate isotopic ratio that most likely would be as a result of the competition between the C_3 fynbos and the C_4 grasses. There is no significant trend towards a C_3- or C_4-dominated vegetation, although there appears to be a certain amount of fluctuation (Table 3). The extent of the fluctuation would most likely be dependent on the variability of the fire frequencies in the respective areas. If there is a high fire frequency the vegetation would tend to be more dominated by grass species, as appears to be the case in these grassy fynbos sites.

The present forest vegetation has a strong C_3 signal, but it is not in equilibrium with the surface SOM except for at Site 5 (Dwesa). This suggests that the vegetation has recently changed to a more C_3-dominated type of vegetation, more so for Sites 7 (Satans Nek) and 11 (inland from Coffee Bay) than for Sites 5 (Dwesa) and 15 (Port St Johns). The former sites were located within 20 m of the forest margin. Although the selected sites appeared to be mature forest, it may well have been fairly recently established, being so close to the forest margin. Site 15 (Port St Johns) was *c.* 200 m from the forest margin, where there was a transition to scrub-forest near the summit. This forest site would therefore most likely have been established for a longer time. The same applies for Site 5 that was located a few kilometres into the forest at Dwesa. This suggests that the forests are expanding in certain areas. This may be as a result of the increasing atmospheric CO_2 as suggested for the grasslands. However, if this were the case then one would expect Site 5 (Dwesa) to also show a more marked general shift to a more negative $\delta^{13}C$ value with time, which is not apparent. It may also possibly be due to the exclusion or inhibition of the adjacent grassland fires. These forests are usually found in gorges, requiring the fire to burn downhill to reach the forest margins and are therefore not as intense.

The question then arises, why should the fire be excluded more so now than before? It may be that an ever-increasing population, whose status is reflected in their cattle, would require more grazing areas for their livestock. The farmers are also becoming more sedentary, and therefore do not move their entire household in search of better pastures, putting more pressure on the grassveld in the vicinity of their settlements. The grass biomass would therefore have decreased and does not carry fire to the same extent as previously.

Site 11 (inland from Coffee Bay) is a peculiar site. The extant forest that appears to be well established, has a substantially lower $\delta^{13}C$ value than the SOM. The SOM C isotopic signature is intermediate, suggesting a strong grassveld component. Prins (1993) found an Early Iron Age site in the vicinity and suggested that although the major vegetation type has persisted, there are signs of a significant loss in biodiversity. This suggests that this site was mutilated by the Early Iron Age farmers, allowing grass to invade in patches. The C_3 component may be from the trees, which were not selected by the farmers, as the farmers appeared to require specific species (Prins 1993). Since the Iron Age, the grasslands may have been sustained by fire, until recently becoming forest. At a depth of 15 cm there is a strong C_3 signal that may be as a result of a period when fire was excluded. It may, however, also be due to contamination. This site should be further investigated as it may show the typical influence of the Early Iron Age on the forests.

The sites that were vegetated with *Cymbopogon* show the typical transition from a C_3-dominated or intermediate vegetation to a more C_4-dominated vegetation. *Cymbopogon* is indicative of disturbed sites. At a depth of *c.* 25 cm, there appears to be a significant shift in the $\delta^{13}C$ value to a more positive value, indicating a shift to a more grassland-type vegetation. The consistency of this phenomenon suggests that it may be as a result of the influence of the Late Iron Age farmers on the vegetation.

Site 1 (Xwili) is located in the midlands, an area that would have only recently been colonised by people (Maggs 1984). It was possibly a forest or scrub-forest before, as there are still remnants of large *Cussonia* and various other tree seedlings. It is also in close proximity to various extant settlements that would have required wood for building material and fuel. The forests are now protected and people are encouraged to buy wood for building material, but there is still evidence of people harvesting the indigenous trees.

Site 10 (inland from Coffee Bay), although in the broken lands about 8 km from the coast, shows a similar trend, although more variable. It was located on an interfluve in a shallow rivulet depression about 20 m deep and 100 m wide, surrounded by grasslands typically found throughout Transkei. This would most likely be the reason why the $\delta^{13}C$ values of the deeper-lying layers are bordering on the C_4 range and were not once more forested.

Site 6, which is found on the coast at Dwesa, shows two distinct changes in the vegetation. The first change, at a depth of 35 - 55 cm, may be as a result of the Early Iron Age settlements and the second change at a depth of 25 - 15 cm as a result of the Late Iron Age settlements. The transformation during the Early Iron Age would also have been slower and over a longer period of time. This may be depicted in the gradients seen in the graph (Fig. 6), if the graph does represent the two Iron Age periods. These Dwesa sites are now protected within a reserve and may therefore revert to scrub-forest.

Although there is evidence of some change from a more C_3 dominated vegetation towards a more C_4 dominated vegetation, Acocks' (1953) suspicion that the vast areas of Transkei had been transformed from Forest or Scrub-Forest to grasslands, appears to be unfounded.

Restrictions of crops, wood and grazing

There is archaeological, ecological and historical evidence supporting the hypothesis presented here. Maggs (1984) suggested that the Early Iron Age settlements were present in the Transkei between AD 300 and AD 1000 according to the distribution depicted in Figure 1. As mentioned above this may be the period represented at Site 6 (Dwesa) at a depth of 35 - 55 cm.

According to Maggs (1984) the earliest Late Iron Age site was found at Mpame and dated to *c.* AD 1400. Prins (1993) records two sites found at Ngosi and at Nqukwe dated at *c.* AD 1820 and *c.* AD 1955 respectively. This suggests that during the Late Iron Age (AD 1000 to historic times) the people must have retreated northwards and have only recently returned to Transkei. Prins (1993) also notes a distinct lack of Iron Age settlements along the Mzimvubu River from AD 800 to AD 1800. Derricourt (1977) listed the areas where Late Iron Age settlements were found, according to the reports of travellers dating from the mid 1500's to early 1800's (Table 4). According to his maps the Late Iron Age settlements were scattered in a broad band along the coast during the early 1600's to early 1800's. These were generally in close proximity to the major rivers. The midlands appeared to be occupied by the San tribes. The Thembu tribes moved into the midlands to near Tsolo along the Mzimvubu River between 1600 and 1650, and in 1770 they moved up the Kei River valley into the midlands.

The lack of Iron Age evidence does not necessarily mean that there were no settlements in Transkei between 1000 AD and 1400 AD. It may be that they were few and far between. Clay sherds would be the more obvious evidence available of Iron Age settlements and these would be hard to find in such a large expanse of area.

Table 4 Settlement in the early Transkei (Derricourt 1977)

Date	Settlements
Pre-trading period travellers	
1552	Coast eastern Transkei eastwards
1554	Coast Mid Transkei eastwards
1593	Inland Eastern Ciskei/ Western Transkei eastwards
1635	Coast Western Transkei
1686-8	Coast S. Natal west to Ciskei
Trading period travellers	
1736	East to Western Transkei inland
1752	East to Qora inland
Conflict period travellers	
1782	West from Eastern Transkei coast and inland
1791	East to Eastern Transkei inland
1809	East to east of Kei River inland

The Iron Age farmers would have been dependent on C_4 crops such as millet, and sorghum and beans, a C_3 spp (Maggs 1984, van der Merwe & Tschauner unpublished). Maggs (1984) suggested that the crops required a summer rainfall which occurs as far south as East London. The Early Iron Age farmers would also require a good supply of wood and sweet grazing for the cattle (Maggs 1984). The distribution of land to meet all these requirements becomes narrower with the inland margin tending towards the east coast, as one moves southwards, coming to a point near East London (Fig. 1). This appears to follow a similar distribution as the extant forests. The coastal forest extends quite far inland at Port St Johns, as a result of the Mzimvubu River valley and then tapers off closer towards the coast as one moves southward. The midland and upland areas to the west and southwest of Umtata do not appear to have been inhabited by the Early Iron Age farmers. Only with a change in the weather pattern (Prins 1993), the introduction of maize, or the ability to sell corn produce at a local market, would these people be able to colonise the midlands and uplands to a greater extent.

There is, however, no evidence to suggest that the climate has changed significantly over the last 2 000 years (Preston-Whyte & Tyson 1988). The speleotherm from the Cango Caves indicates a decrease in temperature of about 1°C from *c.* 2 000 BP to *c.* 700 BP and also indicates that the temperature has since increased by 0.5°C. Ehleringer, Cerling & Helliker (1997) suggested that a lowering in the temperature would favour C_3 species. If the area had a poor productivity of C_4 crops before the drop in temperature, it would indicate that these crops were already functioning at the limits of their habitat tolerance. Therefore, a further decrease in the temperature may have tipped the balance away from C_4 crops. However, the increase in the CO_2 levels (Petit et al. 1999) would favour C_4 species (Ehleringer et al. 1997). The productivity of the C_4 species would most likely, therefore, not have changed significantly. If it had, the farmers would more likely have moved closer to the coast where conditions would have been more suitable, and not left the Transkei altogether.

The last glacial maximum would also have had a negligible effect on the Transkei as a result of the ameliorating effect of the Benguela current that would have maintained the temperature along the east coast (Hewitson pers. comm.). This should however be tested further using temperature, precipitation and $[CO_2]$ records, and growing the various crops used, under controlled conditions. The coastal conditions would have to be modelled using known data.

Derricourt (1977) suggests that the Iron Age farmers started colonising the midlands between 1779 and 1819. There was also some evidence of Late Iron Age settlements near Tsolo during the mid 1800's. There was, however, little evidence of cultivation at Tsolo (Feely pers. comm.). The livelihood of the farmers probably also became more centred around their cattle, hence the movement into the midlands for better grazing. It is therefore more likely that vast areas of the midlands have only recently (mid 1800) been inhabited by Late Iron Age communities, with change in farming practices, the introduction of maize and improved trade and transport. The sites selected for the carbon isotope analysis do not depict this change except for possibly at Site 1 (Xwili). This is probably because the destruction by the farmers would have been localised and these sites did not coincide with these areas.

Only in the early 1900's is there an account by Henkel (1903) of wheat farms in the so-called upper districts and sorghum grown in the midlands. The Sorghum, however, may only have been found in isolated areas as described by previous accounts above. Today there are some farms to be found on the valley slopes southeast of the upland plateau near Engcobo. There appears to be niches suitable for the cultivation of C_4 crops in these river valleys that are also often cloaked with indigenous trees.

If we consider the mean annual precipitation (Table 1) we find that the greatest rainfall, averaging *c.* 1145 mm per annum, is in the northern coastal areas and the foot-slopes of the uplands, which is where these crops are cultivated. According to Schulze & Maharaj (1997), these are the more productive areas for sorghum cultivation, capable of producing more than 8 t. ha^{-1}. $season^{-1}$. These areas are usually characterised by forests. Although sorghum can be produced in the midlands the output is meagre (< 4 t. ha^{-1}. $season^{-1}$) (Schulze & Maharaj 1997) and probably unreliable.

Shellfish also appeared to be an important component of the Iron Age farmers' diet. There is evidence of large shell middens all along the coast (Derricourt 1977). It is likely that as the Iron Age farmers moved southwards they would have kept along the coast and found suitable sites inland from there. They generally appeared to move up the river valleys to penetrate the midlands. This may explain the distribution pattern of the Early Iron Age farmers as depicted by Maggs (1984).

The impact of Iron Age on the vegetation

Kay (1833) noted that during the early 1800's the diet of the local people in the southern reaches of Transkei consisted mainly of milk, boiled corn, millet and sorghum. The crops were usually grown in the river valleys where there was sufficient water and the soil was more fertile. Kay (1833) noted that during the early 1800's, the Late Iron Age farmers used wooden spades that were fashioned at both ends for cultivation. The women would choose a suitable site on valley bottoms and near the slopes where the soil would be fertile and moist, and spread the seeds over the existing vegetation, usually grass. Then, using the wooden spade, they would turn the soil and vegetation. This would bury the seeds and simultaneously kill the competing vegetation. As the seeds began to sprout the men would erect a loosely-structured fence, made from branches, around the cultivated field. After harvesting the crops the fencing material would be used for fuelwood.

Site 10, near Coffee Bay may be a typical example of this kind of practice, being a shallow rivulet depression rich in loamy soils that may have been ideal for cultivation. As shown by the SOM analysis this change also appears to have been fairly recent.

The fact that they used wooden spades implied that iron smelting was not all that prolific in these parts of Transkei, as a metal hoe would have been preferable for digging. Therefore, wood would only have been required for building material and fuelwood. The huts were still the traditional beehive design and were usually 4 to 5 m in diameter (Kay 1833) and were probably made from relatively thin long branches. They would therefore most likely have been selective in the types of wood for building material and implements. They would also have chosen fuelwood with a high calorific value such as *Acacia* species and *Olea europea* (Prins 1993). Sites 1 (Xwili) and 6 (Dwesa) may be typical examples of such a practice where the forest would have been opened up allowing for the invasion by grass. This may have increased the probability of fires in patches that killed many of the remaining trees. Although there would have been a significant impact on the vegetation, it would have been localised, as would the cultivated area, and would not have resulted in the kind of destruction envisaged by Acocks (1953).

Kay (1833) noted in his diary dated 1801 that vast areas of grasslands at the base of the Winterberg and near Mount Coke and towards Bruintjies Hoogte just to the south of Transkei, reminded him of England and that they were rich in herbaceous plants. Fleming (1852) also recorded seeing large and extensive plains of grass and wild flowers in Transkei that reminded him of Devonshire, England. Bruyns (pers. comm.) has also found numerous endemic species in the grasslands of Transkei and adjacent areas (Appendix 2) suggesting that the extant vegetation is probably older than 2 000 years.

Secondly, the densest populations of people throughout the Iron Age in South Africa were to be found in the present-day KwaZulu-Natal and Mpumalanga areas (Maggs 1984). They then spread southwards from there, steering away from the midlands and uplands and more along the coastal stretch (Maggs 1984). One would assume that areas such as Port St Johns and the Mzimvubu River valley would have been mutilated to a far greater extent than the areas that are presently covered in grasslands in the midlands and uplands, and yet the landscapes are still cloaked with forests. Tsolo was another Late Iron Age settlement as discussed above. Although there are no trees to be found on the plains, the koppies in the area are still covered in savanna scrub.

The effect of climate and edaphic factors on the vegetation distribution

If we consider the climate, those areas that are currently covered in grasslands experience low rainfall and heavy frosts. Only in the broken lands closer to the coast are forests and scrub-forests to be found on the hill tops. This is probably due to a higher humidity and MAP and less frost. Hilly terrain does not usually experience frost because of the continual air movements up and down the slopes as the air warms and cools. The relatively adverse conditions of the midlands and uplands would directly limit the distribution of Forests and Scrub-Forests and be more conducive for fires.

These grasslands stretch over vast areas and the topography is undulating over most of the area. A fire would therefore easily spread once initiated. Kay (1833) reports of a number of instances of people and cattle being struck dead by lightning. Lightning counts since the 1970's suggest that the ground-flash density increases from 1 - 2 flashes. km^{-2}. an^{-1} in the southwest of Transkei to 5 - 6 flashes. km^{-2}. an^{-1} in the northeast. There would therefore probably be a high incidence of fire. The heavy frosts would also kill the grass vegetation making the grasslands more flammable. Fire and frost may therefore play a crucial role in the maintenance of the grasslands and the exclusion of forests, as has possibly been the case for the last 2 000 years at least. This may account for the lack of change as shown Figures 2 and 3.

About 65 % of the midlands southwest of Umtata have fairly shallow sandy-clay-loam soils *c.* 10 - 30 cm deep (Schulze Maharaj, Crosby & Crosby 1997). This includes areas such as Xwili that has shallow lateritic soils and gleyed horizons. These edaphic factors are indicative of conditions that are not conducive for forests. Soil depth alone does not appear to limit forest distribution, as many of the forests investigated were found in soils varying from 15 - 50 cm.

The edaphic conditions, however, are more likely to be a secondary consideration, as most of the soils are sandy-clay to sandy-clay-loam and deeper that 50 cm (Table 2; Schulze Maharaj, Crosby & Crosby 1997). There also does not appear to be a substantial difference in the vegetation cover between the above-mentioned stretch of midlands and the rest of the midlands and uplands. This should however be researched further by correlating vegetation with soil analyses.

Conclusion

The extant grasslands appear to have always been grasslands. The vegetation appears to have remained stable, based on C isotope analysis, archaeological and historical findings. There is however no doubt that the Forests are being severely mutilated (Acocks 1953; Maggs 1984; Evans 1936; personal observations).

Frost and fires may be the primary agents maintaining these grasslands. Some of these fires would result from lightning, but many would be anthropogenic. The low species diversity of the grasslands may be a result of too frequent fires and overgrazing near the larger settlements.

Although the edaphic factors may not have a large influence on the vegetation distribution, they may, however, be significant and should be considered.

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Appendix 1 The dominant vegetation and percentage cover at each site

Site	Vegetation & coverage (%)
1	2% *Cussonia*, 90% *Cymbopogon*
2	100% grass (*Themeda triandra*, *Eragrostis*, *Sporobolis africanus*)
3	10% *Protea* and *Leucodendron*, 3% *Watsonia*, 80% Grass
4	95% Grass (30% *Aristida*, 5% *Andropogon*), 1% *Helichrysum*, 2% Cyperaceae, 1% *Gazania*, *Dierama* and *Watsonia*
5	*Olea capensis capensis*, *O. capensis macrocarpa*, *Trichocladus crinitus*, *Ochna arborea*, *Rhus*, *Cussonia*, *Umzimbeet*
6	80% *Cymbopogon*, 10% *Stenataphrum*, surrounded by scrub forest
7	*Podocarpus latifolius*, *Curtista dendata*, *Cussonia*
8	90% *Andropogon*, 5% *Aristida*
9	*Tenotaphrum secondatum*, *Phenix*, *Aristida junstiformis*, Patches of *Acacia karoo*.
10	*Cymbopogon*, *Miscanthedium*
11	*Combretum kraussti*, *Carissa bispinosa*, *Entada*, *Maytenus*, *Ataxacantha*
12	90% *T. triandra*, 8% *Aristida*, 1% *Festuca*
13	100% grassland, *Aloe* & scrub bush on surrounding koppies
14	95% Grass (5% *Aristida*), 5% *Protea* - confined to lower slopes (*P. roupellii* & *P. caffra*)
15	*Milletia sutherlandia*, *Tripetes bequartia*, *Monthotaxus*, *Cola*
16	100% Grassland (50% *T. triandra*, 10% *Sporobolis*), 1% *Helichrysum*

Appendix 2 Some endemic species found in the area (Bruyns pers. comm.)

Species	Location
Succulents on arid cliff faces in river valleys of Transkei	
Huernia pendula	Kei & Bashee
Aloe reynoldsii	Bashee
Haworthia glabrata	Bashee
Orbea macloughlinii	Umtata & Titsa
Ceropegia lineans subsp. *tenuis*	Kei
Ceropegia radicans subsp. *radicans*	Kei
Grassland endemics of Transkei	
Ascelepias peltigera	
Ceropegia tomentosa	
Ceropegia bonkeri	
Brachystelma caffrum	
Arid areas south of the Kei River and again north in KwaZulu-Natal	
Ceropegia ampliata	Willowmore to Kenya & Madagascar
Ceropegia Africana	Willowmore to Mozambique
Ceropegia haygarthii	Cape Peninsula to Natal
Ceropegia stapeliiformis	Grahamstown to Northern Province