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Past Climatic Conditions for Bokoni at Buffelskloof, Mpumalanga, Using $\delta^{13}C$ Analysis of *Prunus africana* and *Pittosporum viridiflorum* Tree Rings

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Abstract

Terrace farming flourished in Bokoni from the sixteenth century CE onwards. Bokoni farmers' resilience strategies, however, were severely tested during the third occupation phase (approx. 1780 to 1840 CE), when the mfecane destabilised the region. In order to reflect on the environmental conditions Bokoni farmers faced in this period the stable carbon isotope proxy rainfall records from *Prunus africana* and *Pittosporum viridiflorum* specimens that grew on the Buffelskloof site were studied. Because the Buffelskloof records postdate the occupation, the records are compared with a 1000-year *Adansonia digitata* rainfall proxy record from the Pafuri region. Deviations between the two are attributed to the juvenile effect, and when these are discounted there is a significant correlation between local and regional rainfall records. This suggests common large-scale synoptic forcing underlies regional rainfall variability, and the decadal-scale variability in the *Adansonia digitata* records indicates extremely dry conditions in the 1780 to 1840 CE period.

Keywords

Bokoni – stable carbon isotope – rainfall records – resilience – Buffelskloof

Introduction

The Buffelskloof (Buffalo's ravine) is a deeply incised ravine that contains an indigenous forest, which in part developed in the ruins of a stone-walled Bokoni site (Fig. 1). The Buffelskloof runs parallel to the Badfontein valley, south of Mashishing (formerly known as Lydenburg), where the 17th-18th century CE Bokoni capital Khutwaneng was located. The stone-walled settlement in the Buffelskloof was defensive, but included all the components that formed part of Bokoni villages and towns, such as homesteads, cattle enclosures, agricultural terraces and roads. The site's defensive location suggests that it dates to the third Bokoni occupation phase (approximately 1780-1840 CE).

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The presence of a large, terraced site in a dense gallery forest is a contradiction, as the terraced agriculture that was practiced is not tenable under a canopy forest. We considered two scenarios: first is the possibility that the occupation took place during climatic conditions that did not allow the development of the current forest structure, and second is the null hypothesis that the forest indeed existed, but was cleared by the inhabitants. Forest clearing may have been intentional in order to practice terraced agriculture, or an unintended by-product of wood-intensive activities, such as metalwork for which there is archaeological evidence near the ravine. Once the site was abandoned, the stone walls in combination with the topography formed a firebreak, which allowed the forest to develop in an area historically characterised by grassland (Hattingh 2014). The area around the ravine is now under commercial plantations; consequently, the grassland fire regime has not prevailed since the early 20th century CE.

The early 19th century CE was characterised by endemic violence, which resulted in the relocation of Bokoni settlements from gentle sloping valleys to defensive and defendable hilltop and ravine sites. Bokoni was not the only region impacted by violence. Conflict cascaded through large parts of South Africa, and the period generally has been referred to as the *mfecane*. The impact of the conflict extended beyond South Africa through large-scale movements of people into eastern Zimbabwe (Cobbing 1981) and Zambia (Kanduza 2008). The cause of this violence has been subject to much debate, but it has been linked to regional instabilities resulting from state formation, competition over trade, slavery, and food insecurity resulting from major drought events (Hall 1976; also see Hamilton 1995).

Hall (1976) suggested that the *mfecane* was the result of the failure of resilience strategies after a sharp decline in rainfall after 1789 in KwaZulu-Natal. He argued that the drought cycle was preceded by better than normal rainfall conditions which resulted in a relaxation of normal drought resilience strategies (Hall 1976: 700-702). Hall's climate model was based on a study of *Podocarpus falcatus* (now *Afrocarpus*) ring widths from the Karkloof forest in KwaZulu-Natal, supplemented by oral traditions from the region. This pattern is supported by Stager et al.'s (2013) high-resolution diatom records. The synoptic control of rainfall in KwaZulu-Natal is not the same as that in the Bokoni region, and so the extrapolation of the drought during the *mfecane* needs to be tested.

The resolution of previous environmental studies in the Buffelskloof area (e.g. Sjöström 2013; Hattingh 2014; Sjöström et al. 2017) is not detailed enough to grapple with the environmental fluctuations in the period leading up to and during the *mfecane*. The forest growing on the Buffelskloof Bokoni site would have been cleared during the occupation, and so it cannot yield trees that span the occupation period. It is also unlikely that any other old stand of trees in the region will provide a longer and more directly relevant climate record. Stable carbon isotope ratios ($\delta^{13}C$) in tree rings from southern Africa, however, have been shown to proxy climatic conditions (Hall et al. 2009; Woodborne et al. 2015; Woodborne et al. 2016). The closest proxy record derives from the Pafuri region, approximately 300 km north of the Buffelskloof site (Fig. 1).

The objective of the analysis presented here is to test if the regional climate record emerging from the Pafuri baobab trees is an appropriate record to interpret the Bokoni trajectory. The assumption is not that subseasonal rainfall variability in Buffelskloof can be predicted from subseasonal rainfall in Pafuri (i.e. if it is raining in Pafuri it does not mean that it is raining in Buffelskloof), but rather that the large-scale synoptic systems that influence seasonal to decadal rainfall are common to Buffelskloof and Pafuri (Woodborne et al. 2016), and that relative terms such as "wetter" or "drier" might be common on the decadal scale across the region. The implication is that synoptic re-organisations that lead to extended periods of drought or extended wet periods, and would be classified as climatic shifts rather than weather variability, would be common across the region. To assess this we analysed the $\delta^{13}C$ record of a *Prunus africana* Hook. F. (Red Stinkwood) tree and a *Pittosporum viridiflorum* Sims (Cheesewood) tree from the Buffelskloof forest, and tested if these records proxy rainfall by comparing them with the fragmented c. 50-year instrumental rainfall record from the forest station. The local $\delta^{13}C$ records were then compared to the Pafuri baobab record to verify that rainfall variability is the same during the period of overlap. If so, we can assume that the coherence between the local record and the Pafuri baobab record can be extrapolated further back in time to elucidate the climatic conditions before the growth of the Buffelskloof forest, and indeed for the entire Bokoni period.

Background

Archaeology

Bokoni was a pre-colonial polity in north-eastern South Africa that extended from Orighstad in the north to Carolina in the south (Fig. 1) (Delius & Schoeman 2008; Maggs 2008; Schoeman & Delius 2011; Delius et al. 2012; Widgren et al. 2016). It represented the final expression of independent African farming communities in the region prior to and during the impact of colonialism, and was at its zenith during the second half of the second millennium CE. Although the polity and its associated social organisation was destroyed by historical events in the early

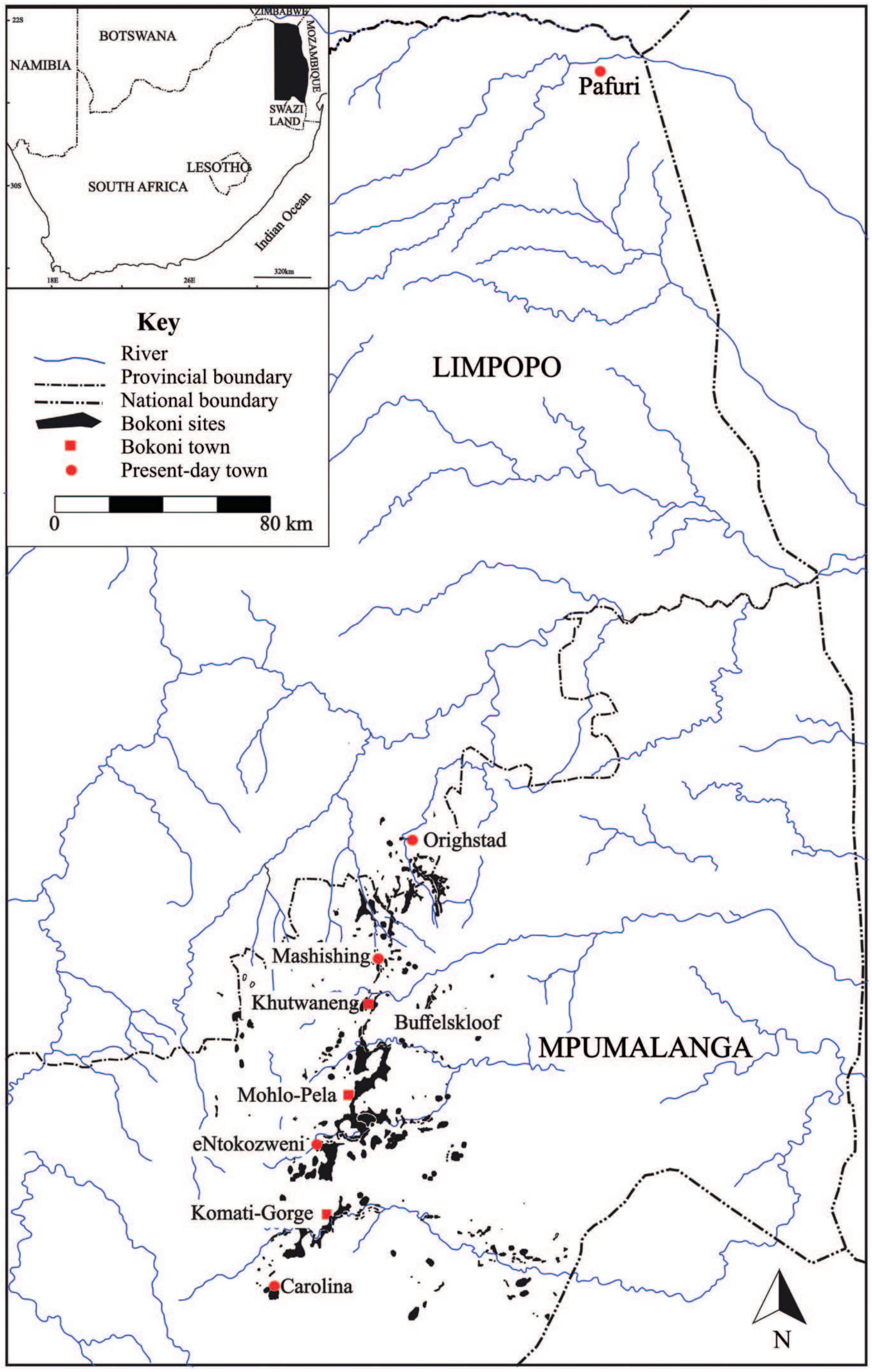

FIGURE 1 Map of the study area showing the Bokoni settlements and sites mentioned in the text

1800s, Koni is an identity to which some South Africans still affiliate.

Before these disruptions, Bokoni settlements comprised towns, villages and freestanding homesteads, all shaped by an economy based on crop production and stock herding. In Bokoni settlements, the balance between livestock and crops was materialised in the spatial configuration of homesteads. Homesteads were normally associated with terraced fields, and linked to the outside world through roads that channelled people and livestock through the fields and villages (Collett 1979, 1982; Delius et al. 2012; Widgren et al. 2016). The terraced slopes reconfigured the landscape into one more favourable for farming, because, inter alia, the step-like terraced slopes reduced soil erosion and increased soil fertility (Marker & Evers 1976; Solomon 2016).

Bokoni sites were not only spread spatially due to geographically informed settlement choices, but site distribution also shifted temporally. Settlements are divided into four different phases (Schoeman & Delius

2011: 17; Delius et al. 2012: 404). Phase 1 sites date to the 16th century CE and are only visible in the archaeological record in the southernmost Bokoni region, at sites such as Komati-Gorge Village 1. They are not recorded in oral traditions (Schoeman & Delius 2011: 17). Phase 2, dating to the 17th and 18th centuries CE, are characterised by settlements on the slopes of open valleys. Oral traditions record the important settlements and processes during this period, including a general shift northwards and the establishment of the capital sites Mohlo-Pela (northeast of eNtokozweni) and Khutwaneng.

Oral histories suggest that violence increased and started to negatively impact the region towards the end of this phase (Delius et al. 2012: 402). Initially, the violence was sporadic, before becoming endemic in the late 1700s/early 1800s CE (Prinsloo 1936; Delius et al. 2012; also see Winter 1912: 92; Hunt 1931: 279-280). The conflict was regional, affecting all major Mpumalanga polities, including Bokoni's closest neighbours, the Pedi polity and Ndzundza kingdom. The Ndwandwe, for example, attacked the Pedi polity (see Delius 1983), and the Ndzundza capital KwaMaza was attacked and destroyed in the early 1800s. At the height of the *mfecane* the Pedi attacked and destroyed the new Ndzundza capital at Esikhunjini (Schoeman 1998a, b).

Once violence became endemic, the primary settlement reason in Bokoni shifted from agropastoral concerns to safety. Sites dating to this period (approximately 1780-1840 CE) are classified as Phase 3 sites. Bokoni Phase 3 sites, like Buffelskloof, were located in defendable or defensive places, such as ravines and hilltops, allowing some of the communities to survive the conflict. In the 1820s, towards the end of this period of conflict, the Bokoni leader, Marangrang, started to embark on raids of neighbouring polities (Delius & Schoeman 2008: 153-154). Marangrang, however, was defeated and killed in 1828 CE, and subsequently Bokoni fell under the control of the Pedi polity. Phase 4 of the Bokoni sequence dates to the last half of the 19th century CE when Bokoni ceased to exist as a political unit, and the people of Bokoni were scattered and subsumed into other social groups or political contexts in and outside the region.

Resilient Farming

While our quarry is the environmental conditions leading up to and during the *mfecane*, and the challenges they posed to Bokoni farmers, it does not mean that we see these as defining African farming systems. Instead, we regard African farming systems as innovative, flexible and resilient. In the early second millennium CE, for example, farmers in the Shashe-Limpopo confluence area developed floodplain farming to overcome low and fluctuating rainfall conditions (Smith et al. 2007). In other areas, where only dry land farming was practised, rainfall fluctuations were managed through a series of resilience strategies, which included not planting in marginal fields during times of drought (Hall 1976). These farming systems were able to manage and adjust to local conditions. In addition, livestock was seasonally moved in response to expanding settlements, availability of pasture and water, and/or shifting disease vectors (Garlake 1978; Denbow et al. 2008; Smith et al. 2010).

African indigenous crops also are adaptable to varying soils and weather conditions (Van Wyk & Gericke 2000). Indigenous crops used by the people in Bokoni included millet and sorghum (Hattingh 2014: 11; also see Hattingh 2018). In pre-colonial southern Africa sorghum was an important crop because it is well adapted to dry, hot climates making it more drought-resistant. Sorghum is also able to withstand a certain amount of waterlogging. Different crops may have been preferred depending on certain climatic conditions (see Van Wyk & Gericke 2000).

Present-Day Environment

Buffelskloof is in the summer rainfall region of southern Africa that experiences convectional thunderstorms and orographic precipitation. The Inter-Tropical Convergence Zone (ITCZ), the El Niño Southern Oscillation (ENSO) as well as ocean and atmospheric interactions are some of the factors that control the climate in Mpumalanga (Tyson & Preston-Whyte 2000). The Drakensberg Escarpment further regulates rainfall, as Buffelskloof lies in the rain shadow, making the climate slightly drier (Mucina & Rutherford 2006). The current annual rainfall is 570-1910 mm – the majority of the rain falls during the summer season (October-March) (Burrows & Burrows 2003).

The site is at an altitude of 1415 m above sea level. Temperatures vary greatly due to altitude and anabatic and katabatic conditions present in the ravine. The high forests of Buffelskloof experience cooler temperatures compared to the warmer lower regions of the ravine, and on average snow falls every five years (Burrows & Burrows 2003). Despite the microclimate patterns, interannual climate variability is influenced by the larger-scale climatic patterns.

On a regional scale, the mean annual temperature in the surrounding region ranges between 10°C in the winter months and 23°C in the summer months. According to information from the Lydenburg Weather Station, 29.1°C is the highest average temperature experienced in summer, and 27.0°C is the highest temperature experienced in winter. The lowest average temperatures are 16.8°C in summer and 12.2°C in winter (Lydenburg Weather Station data obtained from the South African Weather Service in 2016). In the winter season frost occurs on nine days a year on average (Mucina & Rutherford 2006).

The biomes in the Buffelskloof region comprise forests (Afromontane forests) and grasslands on the upper slopes, while lower slopes are characterised by open woodlands or wooded grasslands (Burrows & Burrows 2003).

Previous Palaeo-Climatic Research in Southern Africa

The occupation of Bokoni from at least the 16th century implies that the people of Bokoni probably experienced the end of the Little Ice Age (1400 to 1800 CE), as well as the wetter periods post-1800 CE (e.g. Holmgren et al. 2003; Norström et al. 2005, 2008; Smith et al. 2007; Ekblom et al. 2012: 69; Woodborne et al. 2016). Such generalised interpretations of past climate have been updated with the availability of an increasing number of high-resolution climatic data from several regions of southern Africa, with different types of analyses being used as proxies. They include stable isotopes from fauna (Smith 2005; Smith et al. 2007) and flora (Norström et al. 2005, 2008; Hall et al. 2008, 2009; Woodborne et al. 2015), pollen (Scott et al. 2008), phytoliths (Sjöström 2013; Hattingh 2014; Sjöström et al. 2017), charcoal (Hall et al. 2009; Hall 2010), and speleothems (Ekblom et al. 2012). Hall et al. (2009) identified how rainfall controls $\delta^{13}C$ values in tree rings of *Mimusops caffra* in KwaZulu-Natal, South Africa.

A more locally relevant record is the baobab $\delta^{13}C$ record from Pafuri (Woodborne et al. 2015). This record presents a 1000-year proxy for rainfall variability and identifies the large-scale synoptic patterns that drive the variability. Another baobab $\delta^{13}C$ record from Mapungubwe (Woodborne et al. 2016) demonstrates that the main elements of the Pafuri baobab record manifest regionally. They show the onset of dry conditions in the early part of the 17th century CE and the persistence of xeric conditions until the late 19th century CE., both being the local manifestations of the Little Ice Age. Evidence from speleothems suggests that air temperatures were also lower at this time (Sundqvist et al. 2013). The driest conditions occurred around 1840 CE when oral history indicates a widespread drought, coinciding with the *mfecane*. It is most likely that the Bokoni settlement at Buffelskloof dates to this period.

Some environmental data from phytolith research based on Ic and Iph index values are available for the northern Bokoni region. Ic index values are proxies for temperature regimes reflected in the distribution of C3 and C4 plants, and are calculated through measuring the Pooid phytoliths relative to the sum of Pooid, Chloridoid and Panicoid phytoliths. The Iph index values are proxies for environmental moisture, and are calculated by comparing the proportions of Chloridoideae to Panicoideae phytoliths (Bremond et al. 2008; Sjöström 2013: 37; Hattingh 2014). The first local study used phytolith research on the nearby Lydenburg fenn to reconstruct a long-term climatic pattern for the region, and suggested that throughout the Bokoni sequence the Iph index indicates mesic conditions (Sjöström 2013; also see Sjöström et al. 2017). The Ic index showed slight variations, but overall temperatures were similar to today, with the coolest conditions occurring at approximately 1000 CE (Sjöström 2013: 67). The second study focused on grass and domesticate crop phytoliths from Bokoni sites, suggesting that the climatic conditions during the occupations at Buffelskloof (Phase 3) and Komati Gorge (Phase 1) were different from each other (Hattingh 2014, MSc thesis). These calculations led Hattingh to suggest that the Buffelskloof occupation took place during cooler and drier climatic conditions than today. Both studies provide valuable information on the large-scale trends in the region, but do not inform on the detailed environmental conditions during the period leading up to and during the *mfecane.*

Methodology

Sample Selection

The sampling strategy was one of convenience in which the sample comprised natural tree mortalities. Two trees were sampled from the Buffelskloof Private Nature Reserve in 2014 CE: a dead stem of a *Prunus africana* and a fallen *Pittosporum viridiflorum* specimen that was damaging the archaeological stone walling on the Bokoni site. Both *Prunus africana* and *Pittosporum viridiflorum* are evergreen trees that can grow up to 25 m tall, and are commonly found in Afromontane forests (Van Wyk & Van Wyk 1997: 152; Schmidt et al. 2002: 138). Both trees were located sufficiently far away from the stream to ensure that they did not respond to riparian water (see Loader et al. 2007: 33). The *Prunus africana* specimen started to show signs of dieback in 1990, while the *Pittosporum viridiflorum* specimen had recently fallen.

This sampling strategy differs from the traditional dendro-climatological approach that would require reproduction in multiple specimens to verify the local climate record (Loader et al. 2007). This would require many more trees to be sampled, which is not possible within a forest reserve, and indeed few old-growth forest patches are associated with Bokoni occupations that would facilitate higher sampling intensity. Instead of developing a stand-alone climate record, the sampling strategy employed here aims to assess if the baobab climate record is locally applicable.

Sample Pre-Treatment

Discs were removed from each tree using a chainsaw, and a belt sander was used for the initial sanding process, using grit sizes ranging between 60 and 120. For the finer grits (800-1200) an orbital sander was used to reveal the ring structure. Ring identification was done under a light microscope (20-50× magnification). Individual rings were traced around the circumference of the disk, and then scored with a sharp blade along a single radius. Scoring with a blade allows the isotope samples to be drilled along this radius without contamination from a marker and ensures that the ring identification is retained for cross referencing with the isotope samples. A total of 151 rings were identified in the *Prunus africana* specimen, and 51 were identified in the *Pittosporum viridiflorum* specimen.

Samples for isotope analysis were extracted using a 2 mm drill bit. Two sequences of drillings were sampled from the radius on which the rings had been scored (Fig. 2). The second sequence was drilled immediately adjacent to the first but with a 1 mm radial offset in order to ensure complete sampling of the radius and to increase the resolution of the analyses. Each isotope sample was then assigned the ring number into which it fell, as well as an estimate of the ring or rings included in the drilling. The latter portrayed the extent to which the 2 mm drill hole spanned more than one ring in the case of high ring density, or less than a ring in the case of wider rings.

In traditional dendro-climatological research the sampling units are the annual growth rings of the trees, but the approach used here has been shown to retain the climate signal despite the potential interannual blurring (Hall et al. 2009). Since this study aims to compare the local record with the baobab record, it is important to note that the baobab record is not annually resolved (Woodborne et al. 2015, 2016). It is a composite record from multiple trees that is dependent on an age model derived from radiocarbon dating. The error of the age model for the baobab record is estimated to be ±5 years. While single-ring resolution in the Buffelskloof analysis is desirable, it is not necessary since the comparative dataset is at a much coarser temporal resolution, and, similarly, the Bokoni archaeology is not resolved better than a decadal scale. When comparing the Buffelskloof climate record with the baobab record the analysis is focused on the decadal variability.

In other studies (McCarroll & Loader 2004; Norström et al. 2005; Hall et al. 2008, 2009; Hall 2010; Woodborne et al. 2015, 2016) a soxhlet pre-treatment with Tuluene/Ethanol was used. Rinne et al. (2005) demonstrated that α-cellulose extraction with sodium chlorite and sodium hydroxide yielded the same result as the soxhlet treatment. The method from Rinne et al. (2005) was followed in this study. Samples were treated with a sodium chlorite solution (4.3 g sodium chlorite, 3 ml of acetic acid, and 600 ml of distilled water) at 70°C for an hour, and then the process was repeated. Afterwards, samples were rinsed with distilled water and subjected to 10% sodium hydroxide solution (10 g NaOH and 1000 ml of distilled water) at 70°C for 45 minutes. After rinsing with distilled water, the process was repeated with a 17% sodium hydroxide solution. After rinsing with distilled water 1% hydrochloric acid solution neutralised the NaOH and samples were rinsed with distilled water and oven dried at 70°C overnight.

FIGURE 2 *Pittosporum viridiflorum* sample disk after the process of ring identification and drilling

Samples aliquots with masses between 0.05 mg-0.07 mg were weighed into tin cups using a Mettler Toledo balance. Isotopic analysis was done using a Thermoquest EA 1110 elemental analyser integrated with a DeltaV Advantage stable isotope ratio mass spectrometer using a Conflo III interface (ThermoFinnigan, Bremen, Germany) at the Mammal Research Institute at the University of Pretoria.

Data Correlations and Corrections

The δ^{13}C value of atmospheric carbon dioxide has not remained constant through time, with the most noticeable decrease attributed to industrial emission (Keeling et al. 1989). An additive correction for this effect is required (McCarroll et al. 2009). We used the southern hemisphere dataset of Francey et al. (1999) with updates available online (http://cdiac.ornl.gov/ftp/db1014/isotope.cgo). A correction for the effect of changing water-use efficiency in trees because of elevated atmospheric CO_2 levels followed the methodology described by Woodborne et al. (2016). Rank order correlations between time-series datasets was done using the online tool KNMI Climate Explorer (http://climexp.knmi.nl/correlate.cgi)

Chronology

The chronological resolution of the rings was tested using radiocarbon analyses of the centre rings of each tree.

Wood samples from the innermost rings of each tree were submitted to Beta Analytic (Miami, USA) for AMS radiocarbon analysis. Samples were subject to the standard acid/alkali/acid pre-treatment. Calibration was done online using Calib 7.1 (http://calib.qub.ac.uk/calib/calib.html) and the southern hemisphere calibration dataset for older samples and using CALIBomb (http://calib.org/CALIBomb/) and the southern hemisphere SHZ1_2 calibration dataset for younger samples.

Climatic Data

Isotopic time series derived from the trees were compared to the climatic data from the Buffelskloof forest station instrumental record. The unit of analysis is the austral growing season defined as July-June with the year in which the season starts being assigned. The record provides precipitation information from 1959 to the present with a few missing years.

Results

The centre of the *Prunus africana* specimen yielded a radiocarbon age of 140±30 BP (Beta 409140). Unfortunately, this date falls into the period in which multiple calibration intercepts occur and without extensive additional analyses it is not possible to assign an age for this tree. Assuming annual ring formation, the ring count suggested that it started growing in 1852 CE, and this date falls within the one-sigma range of the radiocarbon calibration. The centre of the *Pittosporum viridiflorum* specimen yielded a radiocarbon age of 102.4±0.3 pMC (Beta 409141), which calibrates to 1956 CE. The local calibration dataset of Vogel (2002) places the date between 1954 and 1956 CE. The ring count suggests that it started growing in 1943 CE. Uncertain ring identification in the earliest part of the *Pittosporum viridiflorum* specimen affects both the dating sample and the ring count for the tree. Although the dating sample was taken from the pith of the stem, it still comprises several rings, and the relative growth in the first few years of a tree means relatively more wood is contributed to the sample from the more recent rings rather than from the innermost ring. It is therefore not surprising that the ring count slightly exceeds the radiocarbon age. The period in which this tree started growing is also a particularly sensitive part of the calibration curve that immediately predates the onset of the bomb carbon spike in atmospheric ^{14}C levels. In 1942, the atmospheric ^{14}C level was approximately 99 pMC (percent modern carbon); 15 years later it was 106 pMC. The incorporation of several rings with a bias towards the more recent rings in the dating sample would conceivably reconcile the radiocarbon result that was obtained with the ring count. As the ring count of the *Prunus africana* and *Pittosporum viridiflorum* specimens are consistent with the radiocarbon age, annual ring formation is assumed, and the chronology for the climate record is based on the ring counts. This chronology provides a testable framework for both comparing the climate proxy records between the two trees from the Buffelskloof forest and comparing the climate proxy record from these trees with that of the Pafuri baobab record.

The isotopic time series from the *Prunus Africana* and *Pittosporum viridiflorum* specimens are presented in Fig. 3. The assumptions made in the chronology are vindicated by the fact that the two time series yield records that are very similar to one another. The deviations of the Buffelskloof trees from the Pafuri record are attributed to juvenile effects in a closed canopy forest.

The Buffelskloof forest station rainfall data was then compared to the *P. Africana* (Fig. 4). The comparisons between the isotopic time series of the *Prunus africana* and *Pittosporum viridiflorum* specimens and the baobab record are statistically significant ($r = 0.370$, $p = 0.003$, $n = 82$ and $r = 0.418$, $p = 0.04$, $n = 34$ respectively for the two trees) using a 5-year running average and a 3-year delay. The 3-year delay was determined by successively applying a range of delays between 5 and −5 years to determine which lead/lag time best correlates with the baobab record. This lead/lag range is within the error range of the age model for the baobab record, and the true age of the baobab record could fall within this range. The main deviations between the records occur in the juvenile years of the Buffelskloof trees: the first 20 years of growth for the *Prunus africana* specimen and perhaps the first 5 years of growth of the *Pittosporum viridiflorum* specimen. This can be attributed to a combination of the juvenile effect as well as an interaction with competing trees in a gallery forest that affects trees that are growing below the canopy (Schleser & Jayasekera 1985; Leavitt 2010). If a canopy effect is indicated, then this would imply that the forest was already well wooded and that the Bokoni site was abandoned by 1860 CE, when the *Prunus africana* specimen started growing.

Discussion

Implications for Our Understanding of the Environment in Bokoni

If the juvenile effect in the *Pittosporum viridiflorum* record and the *Prunus africana* record are excluded from the analysis, then the overlap between the two Buffelskloof trees is significantly correlated ($r = 0.407$, $p = 0.008$, $n = 41$).

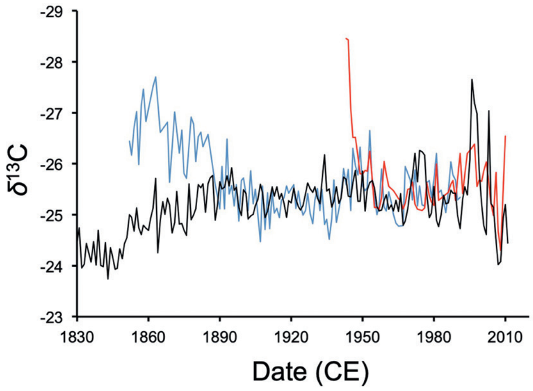

FIGURE 3 Comparison between the annualised $\delta^{13}C$ rainfall proxy records from a *Prunus africana* (blue) and a *Pittosporum viridiflorum* (red) from Buffelskloof and the *Adansonia digitata* (black) from Pafuri (Woodborne et al. 2015, 2016). The y-axis scale is inverted so that high rainfall is at the top of the plot and low rainfall at the bottom.

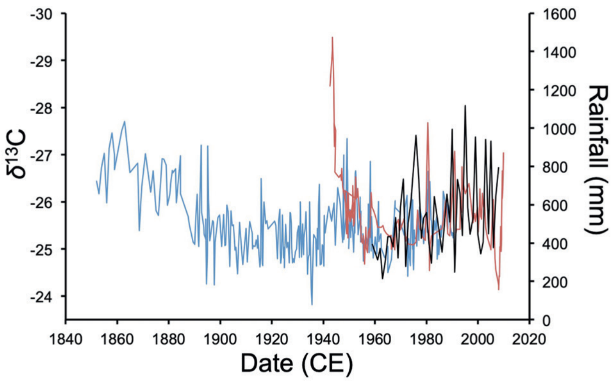

FIGURE 4 Comparison between the $\delta^{13}C$ rainfall proxy records from a *Prunus africana* (blue, left y-axis) and a *Pittosporum viridiflorum* (red, left y-axis) and the instrumental rainfall record (black, right y-axis) from Buffelskloof

Combined, the records spans the period from 1895 to 2013 CE. The significant correlation between the Buffelskloof data and the baobab record indicates that the two regions were influenced by similar climatic factors. Although the Buffelskloof record does not extend back in time to provide a localised record of climate during the Bokoni occupation, the correlation with the baobab tree record allows this longer record to be used.

The location and architectural configuration of the Bokoni occupation in Buffelskloof suggest that it probably formed part of the third occupation phase, which started in the late 18th century CE and continued well into the first half of the 19th century CE. If this interpretation is correct, the site was occupied not only in times of social upheaval, but also under environmental conditions that would have posed a challenge to farmers. Beginning in the 1740s, conditions were drier than present, some 100 years after the onset of drier conditions in 1650 CE which are associated with the Little Ice Age. Conditions became very dry during the 19th century CE, with the driest period being between approximately 1820 and 1850 CE (Fig. 5).

The Pafuri baobab record (Woodborne et al. 2015) shows that the drought discussed by Hall (1976) did indeed manifest as far north as the Limpopo River Valley. The baobab record from Mapungubwe (Woodborne et al. 2016) shows that the onset of drought conditions commenced even earlier in the west. The climatic mechanism that is proposed for the drought conditions at this time is an eastward displacement of the rain-bearing cloud band that is responsible for the summer rainfall region in southern Africa (Woodborne et al. 2016). This large-scale synoptic rearrangement provides a mechanism that links the droughts in the Limpopo River Valley and KwaZulu-Natal, which manifests as the most severe and regional persistent drought in southern Africa in the last 1000 years.

Implications for Farming Practices in Bokoni

Bokoni farmers had developed a specialised system centred on terraced farming on gentle gradient hillslopes, characterised by very specific soil types, which allowed them to overcome the lower rainfall in the second half of the 18th century CE. This period, however, still posed substantial challenges to people in Bokoni. Crop failures and subsequent food insecurity in other parts of South Africa, combined with regional political processes, resulted in very troubled times, which forced the Bokoni communities to abandon their surplus-producing settlements and move to defensive and defendable sites.

Therefore, the selection of such places, including Buffelskloof, as residential and thus farming sites was not driven by farming but by security concerns. Bokoni farmers tried to reconstruct 'traditional' Bokoni settlements, including agricultural terracing, in these new locations, but the refuge sites tended to be in narrow gorges or on hilltops. Often the soils in these locations were less nutrient

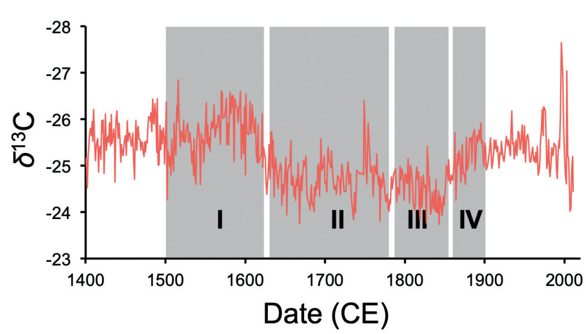

FIGURE 5 Bokoni occupation phases in relation to the annualised $\delta^{13}C$ rainfall proxy records from the *Adansonia digitata* (black) from Pafuri (Woodborne et al. 2015, 2016). The y-axis scale is inverted so that high rainfall is at the top of the plot and low rainfall at the bottom.

rich than in the traditional locations and had different moisture retention abilities. These new conditions would have posed substantial challenges to the Bokoni farming system. In addition to managing different soil conditions, farmers at Buffelskloof faced reduced sunlight hours per day due to the topography of the ravine (Hattingh 2014).

The climatic conditions prevailing during the middle of the 19th century CE would have posed additional challenges (Figs. 3-5). It is likely that farmers offset changing rainfall levels through crop species and variety selection. Similar practices have been observed in present-day Kenya by the first author. There, farmers maintain a crop variety diversity and base planting choices on prevailing conditions. In line with this, Hattingh (2014) suggested that the choice to abandon *P. glaucum* cultivation in favour of *E. coracana* at Buffelskloof might have been an attempt to adapt to local conditions. She also suggested that due to rainfall, soil nutrient levels and sunlight hours per day, yields would have been lower than at earlier occupation sites.

As indicated above the conflict impacted the whole region, including Bokoni's two closest neighbours and trade partners. This instability would have affected regional social and trade networks that previously allowed communities in Bokoni to navigate localised environmental challenges. In addition, older practices such as transhumance and farming cattle out that were used traditionally to manage grazing would have been difficult in the light of endemic conflict. The impact of this would have been compounded when the lower rainfall levels reduced the available suitable grazing for livestock.

Each of these factors would have been manageable through traditional strategies such as those discussed earlier in this paper (e.g. Hall 1976; Smith et al. 2007, 2010). The combination of all these factors, however, posed an extreme challenge to the people of Bokoni, and probably resulted in some form of food insecurity, which also was observed in several other *mfecane* contexts (e.g. Hall 1976; Kinsman 1995). The need to obtain food might have contributed to the increased raiding of neighbouring polities by people from Bokoni under the leadership of Marangrang (see Delius & Schoeman 2008: 153-154). At the time this would not have been an exceptional strategy (see Kinsman 1995).

Other communities, who had turned to raiding during the *mfecane*, however, recovered after these troubled times and returned to farming in spite of the low rainfall levels that continued until the middle of the 19th century CE (Fig. 5). This was not the case in Bokoni, which had ceased to exist as an independent socio-political entity. The region was now under the control of the Pedi polity and the colonial Boer settlers, who established the town Mashishing (then Lydenburg) in 1847 and parcelled out the surrounding area into Boer farms. In this new context, the social, economic, political, and structural configuration that underlay Bokoni terrace farming had been disarticulated and destroyed. Consequently, terrace agriculture, which was characteristic of earlier sites in Bokoni, did not continue after the end of the third phase of Bokoni occupation.

Conclusion

The stable carbon isotope proxy rainfall records from the *Prunus africana* and *Pittosporum viridiflorum* specimens from Buffelskloof reflect climatic patterns going back to the late 19th century CE. It is suggested that periods between 1890 and 1960 CE were slightly wetter than more recent periods. This time depth does not cover the periods associated with the Phase 3 Bokoni occupation in Buffelskloof, but the extrapolation of the baobab record from Pafuri allows inferences about the climate during earlier Bokoni occupations. The Baobab tree record from the 1740s until the 1850s appears to be drier than present-day climate. The archaeological evidence for phase II sites suggests that Bokoni farmers successfully managed the lower rainfall regime, until endemic violence in the region forced them to move to defensive and defendable sites, such as Buffelkloof, in the late 18th/early 19th century CE. Bokoni farmers continued to farm at these sites, but the drier conditions may have posed additional challenges to the decision making of farmers.

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