Settlement and land use between the 11th and 17th centuries in eastern Botswana

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This paper examines the distribution of known sites in the Central District against the agricultural potential of the landscape, using a computer application known as Geographic Information Systems (GIS). The ambitious goal of deriving a predictive model to assist in future archaeological surveys could not be reached. But along the way, the researcher stumbled on a curious pattern in the distribution of earlier and later Iron Age sites: they seem to have occupied different landscapes. The reason remains to be examined.

Archaeologists have long been interested in the relationship between human societies and the environment. A key problem in these considerations is the difficulty in correlating the chronology of cultural and environmental change. As a result, archaeologists have tended to focus on major environmental changes over long time periods (hundreds to thousands of years). Archaeologists are also aware of the need for societies to be adaptive to environmental fluctuations.

This study seeks to find out whether the environment influenced settlement location, particularly during the Toutswe tradition. The variables to be tested in the study are soils and hydrology. The thesis of this study is that arable soils and water availability are basic essentials for farming communities, and that if these variables are absent in an area, that area would have been least preferred for settlement by farming communities.

Hydrology and soil types have been chosen as the environmental variables best suited for this type of study. These two environmental variables have changed over time, but as compared to other variables like vegetation, the change is minimal due to the time it takes for them to change. The data on soil and hydrology describe the resource potential of the settled area. The linkages between the resource potential of a region and the settlement distribution within it say something about the occupants' economy.

In the context of this study, suitability of a piece of land is measured by its potential to support crop cultivation, pastures and by its hydrological status. Unless under compulsion, a society will avoid settling in a hostile environment. A simple rural village with an agricultural mode of production will need land, water, and building materials. All of these resources are unevenly distributed over space. An area is, thus, chosen for habitation after an evaluation of environmental variables essential to a society's mode of production. The type of settlement patterning is thus determined by spatial distribution of the environmental variables required by a society's way of life. An agriculture-oriented society will choose an area with arable soils suited to the type of crop they cultivate for settlement, so as to cultivate and have maximum harvests. Pastoralists will choose an area with pasture suited to the kind of stock they are raising for sustenance of the stock.

The story of the influence of human beings on nature and the latter on humans is an old one. The arguments by several scholars (*e.g.*, de Blij, 1996) have given birth to two schools of thought, namely environmentalism and possibilism. Environmentalism, also known as environmental determinism, posits that human behaviour, individually or collectively, is strongly affected by and controlled by the environment that prevails. It suggests that climate is the critical factor in this determination. This theory has attracted a lot of criticism, mainly for its discriminatory approach to the understanding and explanation of the human-environment relationship.

Some scholars, particularly those who entered the discipline of geography after training in history, came to reject determinism and subscribed to possibilism. They tended to stress the freedom of human beings to choose in their approach. Their argument was that human activity and behaviour is in a certain way affected by the natural environment, but people are the decision-makers and modifiers. For them the pattern of human activity on the earth surface is the result of initiative and mobility of human beings operating within a frame of natural forces. Without denying the limits every environment sets for human ambitions, they explored the scope of human action rather than the limits. Thus, the natural environment was viewed as offering opportunities rather than imposing limitations. The choice that a society makes depends on the requirements and technology available to them to satisfy these requirements. For example, societies like those in the study area will have chosen to settle on arable soils as their economy required that they cultivate in order to feed themselves. One of the themes central to the arguments of possibilism is the cultural factor that affects human behaviour.

Some scholars like Zimmerman provided a functional interpretation of resources (Mitchell, 1989:1). To Zimmerman

> neither the environment as such nor parts of the environment are resources until they are, or are considered to be, capable of satisfying human needs. That is, resources are an expression of appraisal and represent an entirely subjective concept. (cited in Mitchell, 1989: 1)

No two cultures evaluate and use the environment in exactly the same way. As already mentioned, an agriculture-oriented society is likely to choose a place with arable soils to settle on so as to cultivate and have satisfactory harvests. Pastoralists are likely to choose an area with pasture suitable for their livestock. In the study area, Denbow (1983: 206) and Kiyaga-Mulindwa (1993: 390) posit that there is a relationship between Toutswe settlements and arable soils. The basis for their argument is that Toutswe tradition communities led an agricultural and pastoral mode of production. Kiyaga-Mulindwa (1993: 390) states that

> There are also hundreds of sites such as Kgaswe and Maunatlala, with clear evidence of agricultural specialization, also corresponding well with their location on good sand/clay soils and favourable water resources.

Since they are not basically writing on the relationship of settlements with soil, and the assumed relationship is mentioned in passing, there is no evidence adduced by either Denbow (1983) or Kiyaga-Mulindwa (1993) which demonstrates the relationship they attested existed between settlement location and arable soils. Hall (1996:79) argues that additional information for Denbow's thesis (Denbow, 1983: 206) came from comparison of settlement patterns with the distribution of different types of soils (Hall, 1996:79). Denbow's (1983) category 2 and 3 settlements were in areas of poor sandy soils. In contrast, category one settlements, the ordinary villages at the bottom of the hierarchy, were often near to better arable soils, the same lands cultivated by Batswana farmers today (Denbow, 1983:205). The study aims to test if there is a relationship between archaeological settlements in the study area and arable soils and water sources through the use of Geographic Information Systems (GIS).

The Toutswe Tradition

A major part of the settlement in the study area comprises mainly of what has been termed the Toutswe tradition by Denbow (1983). The boundary of the study area includes areas from Serule going east towards Bobonong in the northeastern part of Botswana. In the south, the study area extends from Maunatlala going east up to Tsetsebje, and the western part of the study area are the fringes of the Kgalagadi desert (Fig. 1). In the eastern part of the study area are some settlements which have been found to be predominantly iron smelting sites, like Moeng and Makodu (Kiyaga-Mulindwa, 1993: 389).

> It is now believed that the Zhizo group of southwestern Zimbabwe and east-central Botswana...were the earliest iron age groups so far known to have lived in this area....in their northerly expansion, [the Leopard's Kopje people] established themselves at the site of Schroda, the largest known Zhizo site, located in the northern Transvaal. This expansion forced many of the earlier Zhizo groups to migrate westwards into Botswana. (Kiyaga-Mulindwa, 1993: 388)

Huffman goes on to add that

> At about AD 1000 Leopard's Kopje pottery suddenly appears over a large part of the Shashi-Limpopo region, Schroda is abandoned and its characteristic ceramic style (called Zhizo) disappears from south-west Zimbabwe and the northern Transvaal. A three-fold increase in Later Iron Age settlements with similar ceramics in eastern Botswana... indicates that these people moved west. (Huffman 1996:177)

Dates indicate that the area where the Toutswe-type sites are found was occupied generally between AD 700-1000. A lot of sites within Denbow's survey area have pottery common to the type found in Toutswemogala, so they were grouped into one assemblage to be called Toutswe tradition, which is named after Toutswemogala.

In terms of exposure to research, Reid highlights that the Toutswe tradition has had a fair amount of attention (Reid, 1998). Scholars who conducted research in the study area include Lepionka (1978), Denbow (1983), Segobye (1994) and Kiyaga-Mulindwa & Widgren (1993). Reid also includes in his review of the Toutswe tradition newly discovered sites near Palapye. The sites were discovered during an archaeological impact assessment conducted by Mason along the North-South pipeline. Most of the research in the Toutswe tradition area is credited to Denbow, who showed that Lepionka's thesis (Lepionka, 1978) was erroneous in identifying vitrified dung as iron slag. Denbow (1983) also conducted reconnaissance survey, which revealed a lot of previously unrecorded settlements in the area. Further to the south Segobye (1994) encountered sites which were previously not recorded. Kiyaga-Mulindwa & Widgren (1993) conducted a survey in the southeast edge of Denbow's survey boundary (Denbow, 1983) and recorded several settlements. Through pottery analysis, they tied the settlements to the Toutswe tradition and the process refuted the Denbow hypothesis (1983) that the Toutswe tradition came to an abrupt decline around AD 1300.

As mentioned earlier, Toutswe communities are thought to have led a subsistence economy mainly dependent on crop cultivation and pastoralism (Denbow, 1982, 1983; Segobye, 1994). Internal and long distance trade within the region was practised (Denbow, 1983; Segobye, 1994). Archaeological data suggest that sorghum and millet were the main crops cultivated by the Toutswe tradition communities. A hypothesis has been raised by some scholars (Denbow, 1982: 78; Kiyaga-Mulindwa, 1993: 389) that the Toutswe tradition declined because the area the society had settled lost its potential for yielding substantial millet and sorghum harvests.

Geographic Information System

Various scholars have given different definitions of what constitutes a Geographic Information System (GIS). The many definitions appear to derive from multi-varied functions of GIS (Star & Estes, 1990). A GIS manipulates data about points, lines, and areas to retrieve data for *ad hoc* queries and analysis. The observations are spatially distributed. It is important to emphasise the spatial dimension of data, as it will not be very useful to process non-spatial data by a GIS. In the database of the study, observations are settlements, which constitutes the point features, rivers are line features and soils are area features. A feature is a term from cartography meaning things to be placed on a map. Information mapped via GIS is used to solve problems, do queries, come up with answers or try out a possible solution (Clarke, 1997).

In archaeology, geographic information system application to prehistoric studies is a fairly recent phenomenon. In Botswana, this kind of study, is the first of its kind. In Africa its introduction is even more minimal. Sinclair (1987) is one of the few who have carried out GIS applications in archaeological research. He used GIS to process information on site distribution for Zimbabwe tradition sites' agro- economical zones, and to show relationship of rock art sites to granite outcrops in Zimbabwe (Sinclair, 1987). Sinclair was able to show that rock art location could be predicted from the location of granite outcrops. His research indicated a strong relationship between rock art location and granite outcrops, which are located in the eastern part of Zimbabwe. Sinclair also used GIS to study the relative densities of Khami phase architecture and Great Zimbabwe stone wall enclosures, and early farming communities (Sinclair, 1987).

In other areas outside Africa, like in the United States of America, GIS has been used in advanced researches like predictive modelling of prehistoric settlements, site classification and analysis, and the modelling of early historic trade in the eastern great lakes (Allen *et al.*, 1990: 319). Archaeological measurements, such as site size, location, age and number of dwellings, together with environmental measures (such as elevation, slope, aspect, local terrain relief and distance from water) have been used to predict the location of archaeological sites (Allen *et al.*, 1990). The above factors are good indicators as archaeological measurements, since human beings select settlements based on the proximity of resources like water and food, a comfortable micro-climate, and safety (Aronoff, 1989: 14). Basically, the strength of using GIS applications in archaeological research lies in its ability to be used in predictive modelling.

The underlying key to the success of these models lies in the fact that archaeological sites tend to recur in favourable environmental settings. With appropriate data, it is then possible to make predictions from relatively small samples of known locations to a much broader area. As much as humans are modifiers of the environment, settlement choices made by prehistoric people were strongly influenced or conditioned by characteristics of the natural environment. The environmental factors that directly influenced these choices are portrayed, at least indirectly, in modern maps of environmental variation across the area of study. These areas are still used for arable and pastoral agriculture. With the above assumptions, it is possible to develop an empirical predictive model for any particular area, as long as the area has been adequately sampled by archaeological surveys. The surveys will not be to look for sites only, but to find as much environmental data as possible about the sites. These will ultimately be used in GIS for building of a predictive model.

GIS has been chosen for its ability to process and help analyse multivariate data. GIS also helps reduce the time taken to carry out a project. This is because it allows the usage of already existing data. Maps are usually produced for specific purposes, so specific map projections produce what is called thematic maps in the cartographic language. These are maps that show only one theme, for instance, a soil map of Botswana. Trying to plot features on an analogue map is a tedious process as it requires carrying out calculations continuously so as to achieve approximate location of the features across the surface of the map. Plotting the features using a GIS facility is easy as the program, in conjunction with properties of projections, carries out all the calculations. A map of Botswana on soil types of different areas of the country is easily reduced to the right or required scale and printed within a short period of time. The production of the map will take months if it was to be reproduced at a different scale. The use of mediums like a copier result in the distortion of maps, which in turn will lead to erroneous analysis (Aronoff, 1989: 142).

Data available, which has been collected by a GIS package, may not satisfy the requirements of the research one is carrying out so it becomes necessary that data be generated to satisfy those requirements. Using any available data without checking on its validity may produce very misleading and suspect results. Wrong conclusions may be reached due to some inconsistencies that occurred when the data were being compiled. In a real example, hydrology between two adjoining sheets was found to be inconsistent. The problem was traced back to 1:100 000 paper maps that were digitised and resulted from different management decisions at the time the maps were drawn. In this study, problems with data have been encountered with maps used for soils and hydrology. New data was collected to get around this problem.

It is apparent that even though GIS is a magnificent research tool, its applications may be rendered useless if proper measures are not taken during data collection and its management. The best way of getting around the problem of inadequate data or data that do not suit requirements of a particular research, is to conduct survey specifically for that research. This in its own is a costly exercise so researchers try and avoid it where possible, that is, by use of surrogates.

Methodology

The area of study covers 37497.64 sq km, which is covered by 56 map sheets of scale 1:50 000 (Fig. 1). This area is situated in East-Central Botswana between latitudes 21 and 23 degrees, and longitudes 26 and 29 degrees. The bulk of the sites constituting the database are Toutswe tradition sites (Denbow, 1983). The study has been conducted by inputting data on settlement location into the computer. Three types of data have been used to produce the map which shows relationship between soils and hydrology to settlement location (Fig. 2). The first type of data is data on settlement location. Several people collected these data on a number of surveys over a period of several years. The second type of data is the digital map of major rivers in Botswana. The third type of data is the digital map of the soils of Botswana.

The data on settlement was input into the computer using a Microsoft Excel spreadsheet. The settlement coordinates in the computer were converted back to their original format so as to allow the GIS programme to read them. Most of the archaeological settlements, which have been discovered during surveys in the study area, and Botswana at large, are recorded using the six-figure grid reference. This is the grid referencing of map sheets of 1:50 000 scale. Topographic sheets of this scale are favoured because they allow easy feature location due to their easy referencing style. It is necessary to convert the six-figure reference back to the original with seven figures for the *x*-axis and six figures for the *y*-axis, for example, Toutswemogala reads as 205417 before conversion and 0520500, 7541700 after the conversion. As it shows, affixing the first and last two figures in the y-axis and affixing first two figures and last two figures for the x-axis carries out the conversion.

The second conversion was that of geographic coordinates to Universal Transverse Mercator. The co-ordinates for some settlements were collected, especially sheet 2127 D3 and all of 2226 C4, using a Global Positioning System (GPS). GPS is a satellite-based navigation system developed by the United States of America's Department of Defence to provide a consistent, accurate method of navigation. GPS navigation uses satellite ranging to determine a position in relation to a set of satellites orbiting the earth (Robinson *et al.*, 1995). This system is thus more accurate to use for location of sites as compared to using already converted maps, which have a very high degree of error and are very subjective. The GPS that was used is Garmin 40, which gives out co-ordinates in geographical format. The geographical format is in degrees, minutes, and seconds. The coordinates of some of the settlements were confirmed using a superior version of GPS, Garmin 45. This type of GPS gives out location of points in UTM form.

The conversion of the geographic coordinates was done through a GIS programme called Xform, version 2.0. This programme converts coordinates from UTM to geographic and also from geographic to UTM. In map sheet 2226 C4, for example, Mmeotsogile was located as 25° 58′ 50″ south and 26° 23′ 50″ east. After the conversion it read as 0438215, 7458719.

The spreadsheet programme Microsoft Excel was chosen as one of the programmes compatible with GIS. It offers a wider variety of options in data management and manipulation as compared to other programmes like Dbase III or IV. These Dbase programmes have too many limitations so are time consuming. The reason for the choice of UTM system is for its cartesian basis. The geographic grid system is not cartesian so the unit distance on meridians is different from that on parallels. Actually the distance is only equal at the equator. Consequently, the geographic grid system is not suitable for establishing the coordinate system for spatial analysis (Chou, 1997: 98). Since the study involves the analysis of spatial phenomenon, it was important that UTM be used. Settlement coordinates input into the computer amounted to 546, and these were converted to map points.

The last minor conversion operation required the 'cutting' of maps on soils and rivers of Botswana to fit the study area. The maps on soils of Botswana and major rivers cover the whole country. Since only the part covering the study area was needed, it became necessary to draw and digitise the map of the study boundary. The digitised boundary was then used to cut both the soil and river maps which were then overlaid with settlement map points to produce a composite map. The maps on soil and rivers of Botswana were already in a digitised form, which had been done through the GIS programme, ARC/INFO.

Different methods have been used in locating the settlements. In his reconnaissance survey, Denbow (1983) used aerial photographs. There is a certain grass called *Cenchrus ciliaris* which grows predominantly on byre middens (Denbow, 1983). The grass appears as white patches on aerial photographs used by Denbow (1983). Through investigation of these patches, Denbow was able to locate the sites. There are several settlements though, which do not appear as patches on the photos. Kgaswe, for example, was recorded because the area was leased to a coal mining company so needed intense surveying. The survey was conducted by walking cleared transects at one kilometre intervals.

The use of aerial photos as a survey method for settlement location has limitations in that sites without *Cenchrus ciliaris* do not show on the low-lying areas. Most of the areas Denbow targeted for his investigation were hilltops. The absence of *Cenchrus ciliaris* "was noted particularly in areas of current land use like farms and villages where the growth of *Cenchrus ciliaris* was not pronounced" (Segobye 1994: 83).

Also aerial photography was least reliable on the harder granite gneiss kopjes found in the eastern portion of the study area where granite outcrops and sparse vegetation cover made identification of middens more difficult (Denbow, 1983: 83). The limitations of aerial photography as a survey method, as has been discussed above, indicate that there is a high probability that some sites have been overlooked in the survey as they were not immediately recognisable.

Segobye used stratified, systematic, random and judgemental sampling as her sampling techniques (Segobye, 1994). On sheet 2226 D1 she located 39 sites. Segobye also used aerial photos in her survey (Segobye, 1994). Some of the settlements in the study area were discovered during mitigation work along areas of development like the North-South water pipeline (Reid, 1998). Personnel of the National Museum Monument and Art Gallery discovered the other settlements during reconnaissance survey, especially those of Late Iron Age in the Northeast part of the study area.

The limitations of aerial photography, as pointed above, means that there is a possibility of having more unrecorded settlements in the area, so any analysis carried out on the distribution of settlements in the study area has to take into account the above survey limitation. In the analysis of distribution of settlements in the study area, concentration has been put on areas like Kgaswe, Mokgware and surroundings of Toutswemogala. These are the three areas in the study area where survey was more intensive in its approach as compared to the rest of the study area which was covered by reconnaissance survey only. It will be erroneous to carry out a comparison between the data from the various researches as different methods were used to collect the data.

Soil and hydrology

As the parent rock of an area is one of the five soil forming factors, it is important that geology be mentioned when doing analysis of suitability of soil for any particular economic activity. The geology of an area is important as it determines the hydrogeology and the types of soils found in that area, that is, the texture and colour of the soil. Geology of an area refers to the types of rocks found in that area. The geology of the study area has been presented by the major rock types, but there are numerous pockets of small rock types, which have been influential in the formation of soil types found in the area. These small rock types are Dolerite sheet and stock, Lotsane formation, Tswapong formation, Seleka formation, Moeng formation and Beaufort group (Geology Map of the Republic of Botswana 1998). There is an indication in the geology map used that moving from the southwestern part of the study area due northeast, there is a change from large layer of rock type to pockets of fragmented rock types which have been described above as numerous. The major geologic structures in the area are Lebung group, Ecca group, Shoshong formation, Mahalapye granite, Archaen undifferentiated migmatites with undifferentiated meta-sediments, Karoo basalts, Granite sheet and stock, and Archaen gneissic with bondes gneiss (Geology Map of the Republic of Botswana 1998).

Even though the parent rock is mainly where soil develops from, soil may not necessarily develop from underlying consolidated bedrock. Many fine agricultural soils are formed from loosely consolidated sediments laid down by streams, winds, glaciers, or waters of lakes (Levin, 1990:121). There are some soils also, like the soils of Kgalagadi system, which have developed from aeolian activity thousands of years back, and these are largely without a geological structure.

Soil has been defined as a mixture of fragmented and weathered rocks and minerals, organic matter, air, and water that can support plant and animal life (Levin, 1990:120). Basically five factors are involved in the formation of soil. These are climate, parent material, topography, time, and biological activity. Climate is the most important among them. Climate influences the two most important characteristics of the soil, which are texture and colour.

> In the geological and pedological literature, texture refers to the form, size and arrangement of the particles constituting a deposit of soil. Texture influences the capacity of a soil to retain moisture, its tilth, and to some extent the ease with which it will yield nutrients. (Vita-Finzi 1978:75)

The use to which soil is put then, is largely determined by its physical properties, namely the size, shape, and arrangement of its particles, the volume and form of its pores, the effective depth of the soil from which plants can draw nutrients and its mineral composition. The flow and storage of water, the movement of air and the ability of the soil to supply nutrients to plants are determined by these physical properties, which differ greatly for the small and large particles. The large size particles are stone, gravel, and sand and the small size particles are silt and clay.

In addition to physical properties of the soil, suitable distribution of capillary (fine) and non-capillary (large) pore-spaces is essential for the proper physical condition of soils and plant growth by regulating root aeration and moisture retentive capacity of the soil (Raychaudhuri, 1966: 42). With the above definition of arable soils, technical competence and manpower of the exploiting population also have to be taken into account when considering matters such as the ease with which a particular area could be worked. Moisture retention is strongly affected by organic content, as is the crumb structure, hence the feel and fertility of the soil. This factor heavily affects the type of vegetation found at a particular place. The vegetation will in turn influence the type of economic activity found at a place.

The availability of water to plants is much more important to the ecosystem than the amount of precipitation (McKnight, 1990: 326). This means that a settlement is likely to be located in an area that has got a soil with good water retention characteristics. Soil with good water retention capacity is said to be soil with good moisture holding capacity and good surface drainage. Moisture holding capacity refers to amount of water that can be stored by the soil for use by plants. Since normal summer rainfall does not supply enough moisture for rapidly growing plants, maximum crop yields depend upon the soil's ability to absorb and hold available water until it is needed (Raychaudhuri, 1966: 47). Drainage is the relative rate of removal of water, which is in excess of the amount that can be absorbed by the soil. Drainage depends upon the balance between water capacity and infiltration rate. Soil texture and structure may control the balance. Clays have numerous small pores which may retain water for long periods but which also restrict infiltration rate. Sands have few but much larger pores which permit water to pass through quickly (a rapid infiltration rate), but have low water retention capacity. A loam provides a more balanced supply, water in the small pores and air in the big pores. If water is retained such that the soil remains wet for the large part of the growing season, then the moisture retention capacity is not good. When the water retention capacity is good, there is no water problem (Raychaudhuri, 1966).

If an area has got soils with good moisture holding capacity and good surface drainage, then the hydrogeology of that area must be good, except in cases where soil has been deposited as sediments in an area. It must be emphasised here that the water under discussion here is capillary water, the type available to plants. This is the only stage at which plants can access the water in the soil. Water is the major limiting factor in plant productivity in the semi-arid tropics and in such dryland areas, periods of varied and limited water supply are to be expected. Throughout the semi-arid regions, precipitation is both varied and unpredictable which causes people residing in these areas to practice more than one farming method. Denbow suggests that the Toutswe people had adopted a two way system, whereby they used soils with a high water retention capacity like clays during periods of inadequate rainfall and soils with a balanced water retention capacity like loam during periods of adequate rainfall (Denbow, 1983: 89). High water retention capacity meant that the soils drained slowly and so could provide some moisture for plants when there had not been adequate rainfall. The balance can be disturbed by human mismanagement. Denbow (1982:76) suggest that this equilibrium was upset by the Toutswe society through the exceeding of the carrying capacity of pasture on the fringes of the Kgalagadi.

Botswana's climate is characterised by one salient feature, its position. The country is in the center of southern Africa, so it is far away from the moderating effect of maritime weather and sources of moist air. The country is thus characterised by little cloud formation for most of the year until in summer when the Southeast trade winds bring in warm moist air from the warm Agulhas current from the Indian Ocean. This seasonal pattern of rainfall renders all the drainage in the country ephemeral, except the Okavango that has its supply from the monsoon rains in Angola. The drainages are also characterised by flash floods, which renders most of its big rivers in the east, some of which are mentioned in the study, sometimes un-crossable.

The rivers that drain the study area are the Shashe, Thune, Motloutse, Mhalatswe, Bonwapitse and Lotsane. Most of the tributaries of these rivers rise in the various hill ranges east of the Kgalagadi. A river that drains the plains northwest of Mahalapye northwards into the Lotsane river system, for example, traverses the Mokgware hills, which form a watershed separating the northeast draining Maitsokwane river from the Mhalatswe river draining southeast. This tributary is known as the Kutswe River. The Shashe meets Ramokgwebana to form the main Shashe, which flows along the Botswana and Zimbabwe border till it meets the Limpopo. The Thune River has two tributaries, which drain the area Northeast of Palapye. The tributaries are Sefophe and Phakwe. Lotsane river has Maitsokwane and Kutswe river as its main tributaries in the Mokgware land system. East of Palapye in the Tswapong area, the Lotsane river is joined by Dikabeya and Susulela and it empties into the Limpopo river which flows along the Botswana and South Africa border till it meets the Shashe at the confluence. The Bonwapitse and Mhalatswe rivers drain the Shoshong hills area and flow in a southeasterly direction where they join the Limpopo.

In the study area, all water supplies are ephemeral too, and reliance is placed upon wells and boreholes. In the eastern half of the area, the underground water is near the surface and wells abound especially in the hilly areas. Some areas like the Tswapong hills have some springs, which are capable of providing water all year round, but these also are subject to the limiting factor which is rainfall. Their output may dwindle down if consecutive years of no rainfall persist.

Soil Categories

The study area has at least ten major soil units of the sixteen that cover Botswana (Soil Map of the Republic of Botswana, 1990). These major soil units are acrisols, arenosols, calcisols, cambisols, leptosols, luvisols, lixisols, planosols, regosols, and vertisols. The land suitability for rainfed crop production map (Fig. 2) has been created based on the soil map of Botswana. Data used for the soil variable in this study is the one on soil suitability for rainfed crop production. This data is a product of computer simulation of potential yield of crops based on soil and climatic characteristics. The crops used in this simulation include sorghum and millet, which are the two crops known to have been cultivated by the societies within the area of study (Kiyaga-Mulindwa, 1993:338). The computer simulation is also based on the physical suitability for rainfed cropping. Physical suitability is determined by a combination of climatic and soil factors. Emphasis has been placed on rainfall when compiling the data as it is the most important of the two factors and is also variable both spatially and temporally. Some areas which have been termed unreliable in arable cropping in Botswana, have been labelled so because they receive little rainfall and not necessarily due to soil quality, or fertility, except for the vast Kgalagadi, which has a layer of limestone close to the surface.

The physical suitability of the soil is found in its water holding capacity and fertility. Soil water holding capacity is a particularly important characteristic due to the importance of moisture stress as a determinant of crop yield. The combination of average rainfall and physical suitability of soil have been averaged down to the results in Table 1 in the appendix. The difference in average rainfall over the whole of Botswana has been used to create climatic zones. The Climatic zones that the study area falls within are Tsetsebjwe, Tonota, Machaneng, Rakops, Mahalapye, Kalamare, Serowe and Palapye (Fig. 3). The boundaries of these zones have been drawn according to the annual average rainfall the zone receives, and the zones are named after the centres of rainfall data collection in them. The climatic zones differ in terms of the amount of rainfall they receive, with Tonota climatic zone receiving the highest within the study area and Tsetsebjwe the lowest. The soil fertility reclassification of the map has been done with the influence of these climatic zones, but the map does not necessarily conform to boundaries of the climatic zones as they appear in the original map. The soil reclassification is oriented more towards its fertility and potential for arable agriculture.

Although there are generalisations of soil fertility, there are some soil units that are very fertile, and those that are very infertile. The fertile soil units include those under Serowe climatic zone. This soil unit falls under category B (Fig. 2) which is moderately high in terms of fertility (see Table 1 in appendix). This soil unit has a high density of settlements as compared to other soil units under the Serowe climatic zone. The soil unit is predominantly a luvisol which has an approximate yield of about 1060 kg/ha for sorghum and 640 kg/ha for millet (see Table 2 in appendix). The infertile areas are located in several parts of the study area. These include the Tswapong hills range east of Radisele which is an extension of the Mokgware hill range, and the Shoshong hills. All the three areas are leptosols. These areas have been found to be entirely not suitable for any form of rainfed agriculture. The areas around Toutswemogala and the Mokgware hill range have been found to be very low in fertility, with an average of 270-520 kg/ha for sorghum and 150-390 kg/ha for millet (see Table 1 in appendix). Despite the fact that the above areas, including Shoshong hills, have been found to be very low in fertility and therefore are not suitable for rainfed crop agriculture, the areas are fairly occupied. These areas have land constraints in the form of erosion and a generally rocky terrain. The areas around Mokgware and Shoshong have been described as having good aquifers that are close to the surface.

Modern land use

One aspect which has not been discussed or researched in relation to the Toutswe tradition, in terms of settlement, is the way the Tswana live. In the Tswana societies, a two way method of settlement is practised; that is living at the lands nearer to cultivable soils during the rainy season and moving to the villages during the dry season. The villages are not necessarily on good soils, as is demonstrated by big villages such as Kanye, Ramotswa, Molepolole, Serowe and Moshupa, but are rather within good supplies of water even for the dry season. This dual method of living allowed the utilisation of temporary storage of water where it collects during the rainy season at the lands while at the same time producing food, and then moving near to permanent sources of water during the dry season. The same pattern or way of life probably existed in the Toutswe communities, with people living in areas like Toutswemogala and Kgaswe, which is in close proximity to fertile soils, during the wet season when water was easily available, and at areas with poor soils but good hydrology like Shoshong during the dry season.

Basing on the fact that the area of Shoshong and Mokgware has underground water near the surface, it is possible to interpret that wells were dug in the past as it is being practised even to date. Another point that can be considered is that, although the study area and the whole of eastern Botswana are characterised by climatic fluctuations that bring out dry spells, there are periods of intermediate wetness. The presence of water at the sources of rivers like Serule can be attributed to the geology of the area. All rivers of Botswana, as mentioned already, are ephemeral, so the only time water is present in them is during the wet season. Only in areas where the bedrock is close to the surface and is not permeable, will pools of water be located along the rivers like in the Tati and Mhalatswe River. It is possible to sink wells at the headwaters of Kutswe River in Mokgware hills as the geological structure of the area is granite.

The exploitation of the soil for crops or livestock depends on whether water is available in sufficient and reliable quantities to sustain the growth of grass and crops, and to support settled communities. The availability of water depends on the climate and the bedrock and its overburden of weathered material and sediments. The hydrogeology map indicates that the area around Mokgware has good water aquifers as can be noted by the present boreholes sunk in the area and wells that are along the Kutswe River. As Figure 2 shows, there is an indication that settlements were located along areas of sources of water as they form a linear pattern along the Morupule, Nakatsakgama and Mmamorutshe river which are the tributaries of the Lotsane river.

Site distributions

As already highlighted, the site data was collected by several people during both reconnaissance and pragmatic survey, but the majority of these were collected by reconnaissance survey. The collection of data by reconnaissance survey then means that only the location of settlements is known and its cultural affinity, which was ascribed through analysis of surface collection so as to date the site. The above method of analysis of settlements means that many attributes of the settlements have not been explored.

The lack of exploration of the settlements is a limitation that hinders proper predictive modeling with GIS as only two variables are present, arable soils and water sources. It will be misleading to try and carry out any modeling for probable settlement location based on these two variables only as some prominent settlements, in terms of their length of occupation and size, like Toutswemogala and Bosutswe, have been found to be located away from water sources and arable soils. The location of these settlements indicate that for any meaningful modeling to take place, some other aspects like the social setting of these sites have to be taken into consideration.

Figure 2 shows that settlement distribution is uneven over space in the study area. Despite the fact that some areas have not been surveyed in the study area, there is an indication that some areas within the study area where research has taken place were more preferred. Although there are some factors that might have affected decision making on settlement location, it is the choice of an appropriate area with close proximity to water which took precedence over other factors. The map shows that in locations where water sources are present, settlements were located nearer to rivers at these areas. This is in line with Denbow's (1983: 206) suggestion that arable soils, which were in close proximity to rivers, were preferred.

For example, at places like the Motloutse River, where even though there is an indication of clustering of settlements among favoured soil types, these clusters occur along the river. Another indication is in the area between Nakatsakgama and Morupule river, Kgaswe area, which has a high concentration of settlements and is in close proximity to these rivers. The soil unit in this area falls under the Serowe climatic zone and its fertility class is moderately high with an average yield of 650-775 kilograms per hectare (see Table 1 in appendix). Some settlements are located on soil units of low fertility, as well as away from sources of water. These are soils of Dikalate area and Toutswemogala which are in class E and F. It can be inferred that water for these settlements was drawn from reservoirs that kept water for a short period during the rainy season, which allowed collection by containers for storage, like clay pots.

There is a high density of settlements in the Mokgware hills range, which is an area of very low soil fertility (soil class F). This area though, has very good sources of water as discussed above, but water cannot be said to be the only variable that drew the communities to settle in the area. There area some other aspects like the lucrative pasture which the communities are likely to have exploited as the Toutswe are known to have been a cattle keeping community. The area in fact, is still being used as a cattle keeping zone by the Bangwato.

Some other factors have to be considered when doing deeper analysis of the data as settlements are located on different topographic units like the sites of Bosutswe, Shoshong, Taukome, and Toutswemogala. Decisions of location for the above mentioned settlements were not based on suitable arable land, since they are located on poor soils, but on other factors, for example, security as all of them are on hilltops. Bosutswe is far away from water sources but near to soils of moderate fertility, that is class C.

The map also shows that Later Iron Age settlements are more to the east of the study area. Some settlements which are mainly classified as Late Iron Age sites, like Letsibogo, lie along the Motloutse River. The soil category of this area is predominantly class E, which is low in fertility, especially towards the eastern extent of the research area as the area experiences the rain shadow effect. The low fertility of soil must have restricted the practice of arable agriculture. Although there is this discerned pattern, further analysis of the pattern has to be done with the rest of the cluster of these settlements as they are linked to the Zimbabwe Tradition, which has settlements in both South Africa and Zimbabwe, with the majority of them being in Zimbabwe. The settlements along the Motloutse could mean that the area was used for herding by the communities of the Zimbabwe Tradition, as the area is not good for rainfed arable agriculture due to little rain it receives and the poor soil fertility.

Although there is a clear pattern in the location and distribution of settlements in the map, it does not necessarily indicate that areas which have no settlements on them, like areas in the south-eastern part of the study area, did not have favourable soil types on them. There is in fact, a strip of highly fertile land, category B (see Table 1 in appendix), which is adjacent to the Limpopo river where the Molapo river joins the Limpopo. There is currently no recorded archaeological sites along this area because there has not been any research work or survey to identify any sites. The above limitation is because data which have been used to map settlements were collected by several researchers on a series of research projects, so it can be said that the pattern that comes out of the map is where research has already taken place (see appendix in Mookodi, 1999). Further research on areas where no settlements appear now might locate some more settlements and reveal a different pattern from the one in this study.

Conclusion

Figure 2 indicates that the two variables, arable soils and hydrology, were influential in decision making for location of Toutswe settlements. Hydrology played a principal role in the decision making as areas with poor arable soils have settlements closer to water sources, except for what has been categorized as major centers by Denbow (1983), that is, Bosutswe and Toutswemogala. Another pattern discernible from the mapped data, although it cannot be emphasized upon due to inadequate survey of the study area, is that as one moves away from the area affected by rain shadow, due Southwest there is improvement in hydrology. The increased rainfall also increased moisture availability to plants. One can hence interpret that the Toutswe communities were sandwiched between the unreliable soils of the Kgalagadi and the poor soils of the area largely under the rain shadow effect, that is, the area under the Tsetsebjwe climatic zone.

On the other hand, even though some pattern can be seen in the distribution of settlements across soil units according to their fertility, the pattern is not as clear as with hydrology. This can be attributed to the inadequate and unbalanced survey of the study area. Patterns in settlement location are determined by a community's way of life. As much as this is true, it is apparent from the patterns arising from where research has taken place that settlements did not always occur on good soils and good hydrology. Other factors like the socio-political behavior of the community may have played a part in the settlement patterns, since humans use their culture to interact with environment.

Another aspect is that due to the set parameters, which are water sources and arable soils, there are some factors in the study area that might have hindered the location of settlements due to their physiography. These are features such as the Tswapong hill range, which have been classified as unsuitable for cultivation in the map. Since the map for soil fertility is a thematic map, elevations of the ground are not shown so features like hill ranges are not depicted. The Mokgware, Shoshong, and Tswapong hill ranges only appear as places unsuitable for crop cultivation.

From what has been discussed as the limitations of the study, and the continued discovery of settlements within the study area and the whole of eastern Botswana, we can only make tentative statements and conclusions on the arising patterns of the settlements around the study area and other areas of Botswana. Further research at more balanced scale, with similar methods of survey employed, is needed for the area so as to get a total view of the settlement patterns in the area and to be able to make a predictive model of the study area.

Appendix

Table 1. Agricultural yield per soil type, see in conjunction with Fig. 2

Soil type	Fertility level	Sorghum kg/ha	Millet kg/ha
A	High	1500-1770	1070-1270
B	Moderately high	1220-1460	860-1060
C	Moderate	980-1180	670-880
D	Moderately low	720-950	450-670

E	Low	470-950	250-470
F	Very low	270-520	150-370
U	Unreliable	0	0
N	Dominantly not suitable	0-370	0-270

Table 2. Soil unit fertility

Soil Unit	Potential
Leptosols	No agricultural potential.
Planosols	220 kg/ha sorghum, 100 kg/ha millet. Occur in very limited areas around the Mokgware hills.
Regosols	480 kg/ha sorghum, 300 kg/ha millet. Very stony, low water holding capacity, generally infertile, high percentage of unworkability, very shallow to shallow, excessively drained, sandy loams to clay loams.
Calcisols	510 kg/ha sorghum, 340 kg/ha millet. Moderately deep to very deep, moderately to somewhat excessively drained, greyish to pale brown, fine sandy loams to silt loams.
Arenosols	740 kg/ha sorghum, 510 kg/ha millet. Sandy soils of the western part of Botswana and they occupy two thirds of the country, very deep and very low moisture holding capacity, moisture is not easily available to plants due to the soils profile, poor in moisture retention so very low in amount of available moisture, limited crop production due to moisture stress.
Lixisols	880 kg/ha sorghum, 580 kg/ha millet. Increasing clay with depth, can sustain only a few crops due to its limited fertility.
Acrisols	840 kg/ha sorghum, 600 kg/ha millet. Predominantly acidic soils and they occur in pockets in the hardveld, coarse sandy loams to clay, moderately deep to very deep, moderately drained to well drained, dark yellowish brown to red.
Luvisols	1060 kg/ha sorghum, 640 kg/ha millet. Predominantly in the eastern part of Botswana, have well developed profiles, good water holding capacity, more fertile than most soils in the country, deep to very deep, sandy clay loams to clay.
Cambisols	1150 kg/ha sorghum, 800 kg/ha millet. Most fertile soils in Botswana. Occurs predominantly in the northeastern part of the country in the Mpandamatenga area. Deep to very deep, moderately drained to well drained, sandy loam to clay.

Notes

Mr. Don Mookodi is currently a GIS specialist working for an environmental consultant in Gaborone. His thesis, supervised by Alfred Tsheboeng, was completed in 1999. The original contains a section on calibrated radiocarbon dates and an appendix of site coordinates which have been omitted. For this version, the text was pruned and the order of paragraphs in the final sections rearranged for clarification. A number of references and quotations in the text had to be deleted.

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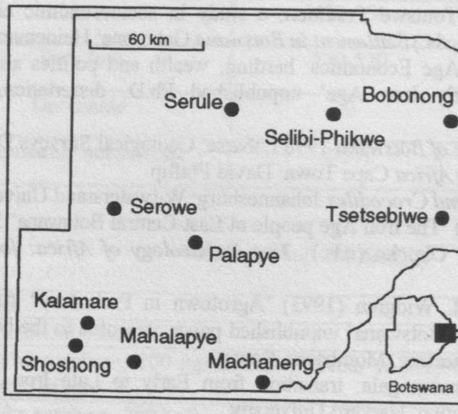

Fig. 1. The study area.

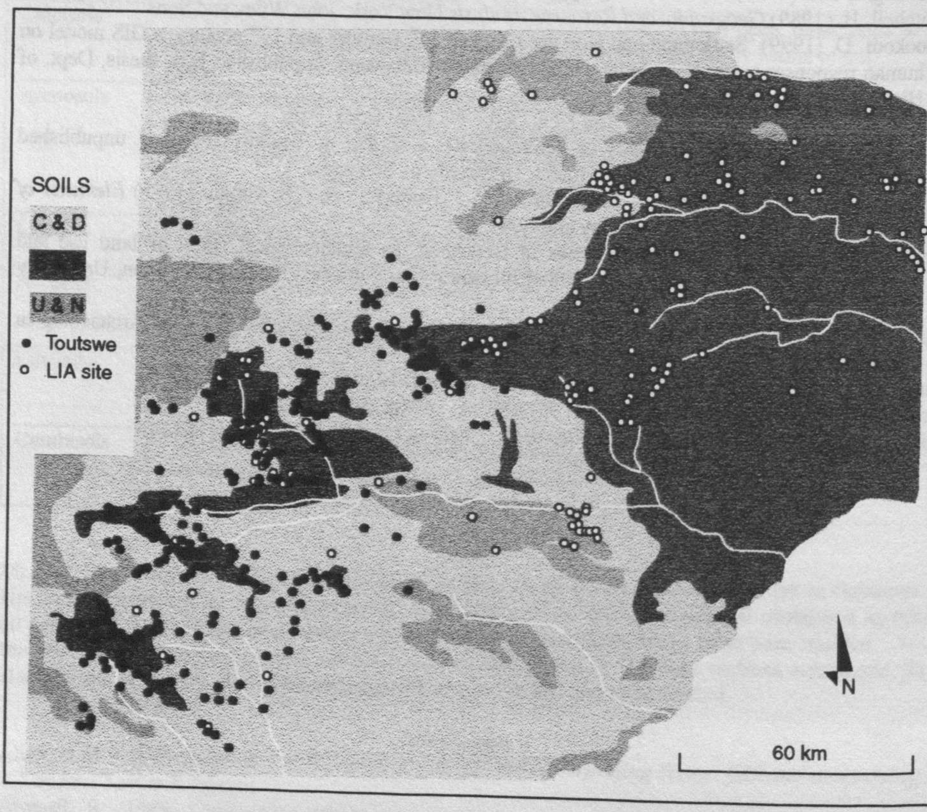

Fig. 2. The distribution of Toutswe tradition and Late Iron Age sites against the different soil types in the study area.

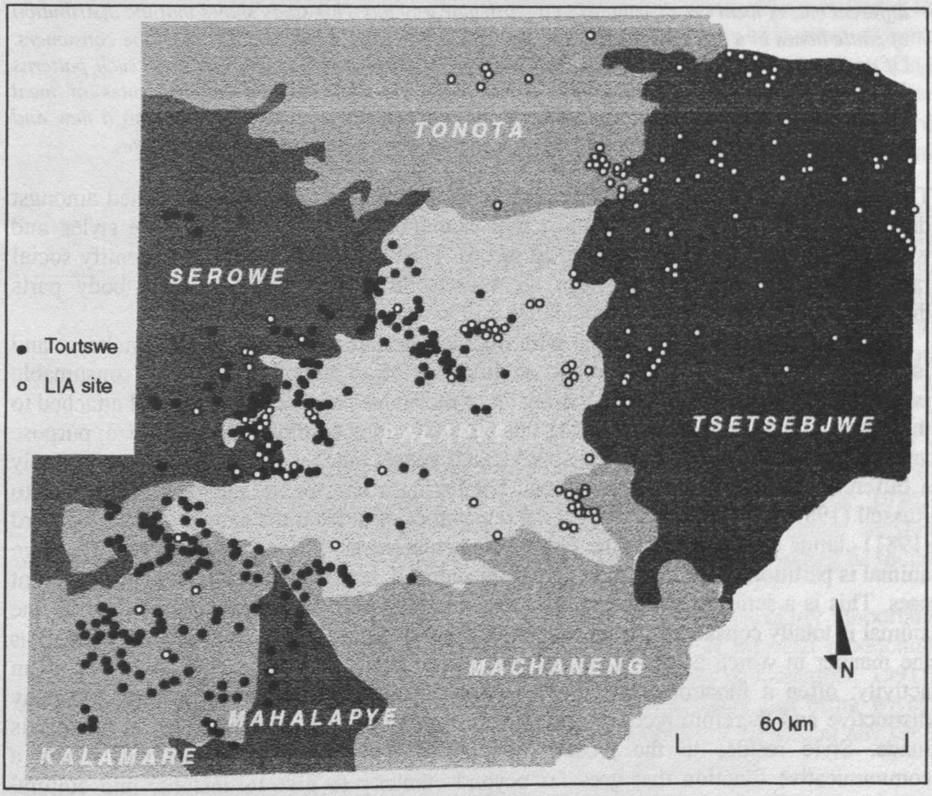

Fig. 3. Toutswe tradition and Late Iron Age sites against the climatic zones of the study area.