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by I. C. Baillie

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CHAPTER III

Land Capability

Soil maps alone are of limited use to development planners and they require interpretation in terms of production potential. It is the practice of the Swaziland Soil Survey to present land capability maps in addition to soil maps for most areas surveyed (e.g. Murdoch I96I), In the Land Capability classification used , the emphasis is on profitability rather than mere high productivity, so that account is taken of the costs of inputs in crop production as well as potential outputs. The factors affecting profitability are arbitrarily divided into two groups:

Soil factors ; which largely control the potential yield and also the magnitude of certain production costs e.g. drainage.

Site factors ; which have little direct effect on yields but which greatly alter the cost of attaining the lands potential.

Soil factors.

The most important characteristicsinfluencing a soil's potential under different crops are amongst those used in the differentiation of soils in the series classification. It is therefore superfluous to list an assessment for each seperate characteristic when drawing up the land capability map of an area as simular combinations of these characteristics will recur whereever a particular soil series is mapped.

The range of characteristics found in each series has been qualitatively combined and this combination has been rated for its suitability and potential under various cropping systems. The soils have been rated on a six rank scale for each of the different cropping systems. The scale runs from A to F, although F and E are usually combined for mapping purposes. For a particular cropping system, an A - rated series is adjudged to be free of any limitations, whereas a B - rated series has relatively minor limitations, either in potential yields or increased costs compared with an A - rated series giving simular yields. The ratings given to a soil series are subject to revision as more information becomes available and the whole table has been periodically reviewed and updated. The latest rating revision took place in early I968(Murdoch,I968) and they assume a commercial management of a reasonable standard . The assumption that fertilizers will be applied means that physical rather than chemical properties are given prominence.

Ratings Criteria for dryland farming.

Five of the ten cropping systems in the table 3.I are rain-grown and the ratings for these are almost wholly qualitative. General criteria taken into account are rooting depth , texture, drainage and nutrient status, as revealed by the crops performance. Purley analytical indications of low nutrient contents are not considered sufficient to downrate any soil. The performance of common crops on each series is also noted and incorporated into the ratings. The individual requirements peculiar to each cropping system are listed below. The cropping systems have been selected because of their economic importance at present or in the forseeable future, or because their specialised soil requirements show a high but restricted potential for otherwise poor soils.

(a) Maize - bean rotation. This is the backbone of the rural Swazi economy in the Highveld and Middleveld. It requires soils of medium to heavy textures, and rooting depth of at least 24 inches , but preferably greater than 36 inches. Drainage should be good or only very slightly impeded. Because the vegetation canopy in this system is rather sparse in the early part of the season, erodible soils are rather vulnarable and are downrated accordingly. Soils of limited depth, but with high structural stability and potential fertility (notably Sangweni series) are uprated for this system. (Murdoch, 1968)

(b) Cotton - sorghum rotation. This is the recommended counterpart of the maize and beans rotation for the lower rainfall areas. It has simular soil requirements , but in areas where it is important , inherent soil fertility is generally high. Because it is a dryland farming system in the areas of low and unreliable rainfall , the moisture holding capacity is of great importance, hence the upgrading of deep and heavy textured soils.

(c) Avocadoes. At one time it was thought that this crop would be highly profitable in the Western Middleveld, but marketing difficulties and agronomic problems have dimmed its early promise. It is highly hydrophobic and any soils with a suspicion of imperfect drainage have been downrated(Dodson, I960). The rating favours the very deep and light to medium soils.

(d) Pineapples. Pineapples are a crop of increasing importance in the Western Middleveld and can be grown in an extensive climatic belt running logitudinally down the country. Pineapples make fairly heavy demands on soil fertility, and are simular to , but less extreme than avocadoes, in that they are sensitive to poor drainage. Although this crop is actually fairly shallow rooting, deep and well drained soils of light to medium texture have been uprated in preference to more fertile soils with only moderately good drainage (Dodson et al , I965, Murdoch, I967).

(e) Planted pastures. At present very little pasture is planted but it is hoped that the practice will increase as the livestock industry intensifies (I'Ons,I967, and I968). Although pastures need care in establishment land preparation costs are not annually recurrent and , as the recommended pastures include leguminous species , the cost of fertilizers should be lower than for arable crops. (I'Ons and Kidner,I967). The consequently lower capitalization means that the shallower soils and soils with minor drainage limitations can be slightly upgraded for this system. These soils (notably the Pofane series) have moderate inherent fertility within the rooting zone of the pasture species, but are rather erodable for arable cropping.

Ratings criteria for Irrigated farming.

For the five irrigated cropping systems , more quantitive criteria are used. The first irrigability assessments in the Lower Usutu Basin (Murdoch and Andriesse,I964) were based on the standards derived from the United States(U.S.Bureau of Reclamation,I953) and Rhodesia(Thomas and Thompson I959). Since then these standards have been modified in the light of local experience. The modifications have been in detail rather than basic principals, and the current criteria are designed to seperate out soils with high available moisture holding capacities within the root zone, combined with reasonably high infiltration rates and permabilities. The rooting zone available moisture holding capacities are a product of the depth and the soil texture. If it is too low , the interval between irrigations becomes uneconomically short. The permeability is largely determined by the soil texture, and the mineralogy of the clay fraction. If the permeability is too low , runoff occours at economic water applications , with all the attendant problems of erosion , drainage and downslope salinity, as well as decreased irrigation efficiency.

The effects of individual soil properties on general irrigability are listed below. Specific soil requirements for the individual cropping systems are found in the sections covering those crops.

Texture. All series with an A rating for irrigated rotation fall into the textural range fine sandy loam to "light" clay (light here refers to minaralogy and implies a small proportion or the complete absence of expanding 2:I lattice clays). However textural requirements vary greatly according to the cropping system under consideration.

Depth. It has been found in Swaziland that the depth criteria used elsewhere are too stringent to give a true estimate of the potential of loacl soils (Murdoch, I968). The first minimum permissible depth taken was 36 inches (Murdoch and Andreisse,I964) which is the shallower limit of class III in the Bureau of Reclamation Classification (U.S.B.R.,I953). Since then it has been progressively reduced as Swaziland Irrigators have gained experience in irrigating shallow soils. So far this skill has advanced to the stage taht Ubombo Ranches Ltd. are now irrigating some land predominantly covered by the S (Lowveld) Set , which has less than I4 inches(35cms) of heavy textured soil over a simular or lesser depth of soft weathering basalt. This upgrading of shallow soils has been vindicated by a recent numerical examination of soil series - crop yield relationships (see below).

Structure and Consistance. These , in themselves , are not irrigability criteria, but strongly developed coarse blocky , prismatic or columnar structures and very hard dry consistance are good field indicators of low permeability or poor drainage.

Permeability. No extensive laboratory studies have been made of the hydraulic properties of Swaziland soils, but such measurements that have been made confirm the morphological indicators such as structure , consistancy and colour, and the qualitative experience gained by irrigators. Thus the columnar structured subsoils of some Z (Lowveld) Set profiles have hydraulic conductivities of the order of 0.0I - 0.I inches per hour, whilst R Set soils , often with higher clay contents than the Z (Lowveld)Set subsoils give hydraulic conductivity measurements in the I - 2 inches per hour range (Murdoch and Andriesse,I964, and E.D.Coles private communication, I968). The only extensive areas of Z (Lowveld)Set so far irrigated have required expensive field drainage and deep ploughing, whereas large areas of R set soils are irrigated satisfactorily without drainage.

Salinity and Alkalinity hazards. The U.S.D.A. standards i.e., exchangeable sodium percentage less than I5% and electrical conductivity of the soil aqueous extract less than 4 mmhos per centimeter, have been found to be applicable in Swaziland(Richards et al, I954). However measurements taken in unirrigated soils or newly developed soils can be misleading as they do not always indicate the extent and rapidity of salinization in some soils upon irrigation.

Man-made saline soils were a prominent feature of early Swaziland irrigation, although they generally only occupied limited and topographically vulnerable areas (Lea, Murdoch and Dicks, 1963) However, timely draining and leaching have rectified many of these saline spots, and alkalinity did not develop to the degree of requiring chemical amendment.

Natural Fertility. Because of the high capital investment in irrigated land, it has been assumed that the cost of the fertilisers needed to fulfil a soil's potential is marginal Thus, inherent natural fertility plays no part in the assessment of irrigability. The assumption that irrigators are willing and able to apply fertilisers liberally was vindicated by the onset of iron chlorosis in some Lowveld sugar-cane areas. This was attributed to over-fertilisation with phosphatics on soils with low free iron contents such as C (Lowveld) and K sets (Jackson, 1964, quoted in Jones and Murdoch, 1965, and Murdoch, 1965).

Irrigated cropping systems. The following specific soil requirements for the individual cropping systems refer to gravity - distributed surface irrigation schemes.

Rotation of Annuals. The possible crops included are cotton, winter wheat, maize, groundnuts and winter vegetables. At present, any large scale expansion in some of these crops (expecially vegetables) would be faced with marketing problems, but experiments have shown that they are all agronomically feasible (Venn, Lea and Gibbs, 1962, and Swaziland Department of Agriculture, 1966). The crops in the rotation require good soil drainage, (Lea, Murdoch and Cornish-Bowden, 1965; Lea and Murdoch, 1964) and heavy textured soils are downgraded compared with their sugar-cane ratings. The shallow S (Lowveld) set soils are given a D-rating for this system, but this may be raised in the future.

Sugar-cane. The ratings are similar to those for the irrigated rotation of annuals, but heavy textured and shallow soils are upgraded. Thus C (Lowveld) set has a B-rating compared with its C-rating for the rotation. In 1966 S (Lowveld) set was upgraded from a D to a C-rating. It is giving excellent yields on several estates generally without recourse to more frequent and lighter irrigations.

Rice. As a member of the South African Customs Union, Swaziland has access to the highly protected South African rice market, in which the current price is about twice the world free trade price. This makes rice a very profitable crop and the acreage is increasing rapidly. It requires different soil conditions to the other crops and low subsurface permeability is desirable. Soils relegated in the ratings for other crops because of poor profile drainage are upgraded, e.g. Habelo and Kwezi series.

Citrus. Citrus is known for its susceptibility to root diseases induced by poor drainage, so that deep and light to medium textured soils with free, or even slightly excessive drainage are given high ratings. R set is downgraded on account of its heavy texture even though all the field indicators such as colour, structure and consistence point to good drainage, and preliminary measurements have shown high infiltration rates. This stringency on texture was justified by the onset of root rot in some orchards on R set soil following the exceptionally heavy and intense rainfall during Cyclone Claude in 1966, whilst trees on nearby, morphologically similar, but lighter textured L set soils did not succumb.

Irrigated Pasture. As with dryland planted pastures, this is included for the future, as there is little or no systematically irrigated pasture in Swaziland at present. The use of irrigated pastures to 'finish off' veld-grazed stock may increase, and some estates are showing interest. It is envisaged that the irrigations would be lighter than in other systems so that the soil ratings are less stringent on permeability and drainage (I'Ons, 1968).

Soils and overhead irrigation. In addition to deficiencies in either drainage or water holding capacity, shallow soils or soils of either textural extreme are downgraded for surface irrigation because of the difficulty in applying the water in correct quantities. For light textured and shallow soils, the amount of water required to reach the end of a furrow is in excess of the water holding capacity of the rooting zone, so that efficient irrigation requires a close network of lined field distributaries. For heavy-textured soils the rate of water application required to give flow to the end of a furrow exceeds the permeability, giving rise to runoff, erosion and downslope waterlogging. These distribution difficulties are avoided by overhead, sprinkler irrigation. The quantity and rate of water application can be controlled and adjusted to suit the soil conditions. The flexibility of overhead irrigation is limited by the cost of the equipment, and very frequent, light irrigations are more expensive. The soil ratings are drawn up for surface irrigation and are rather stringent for sprinklers.

The use of overhead irrigation is increasing, especially in the sugar areas. There is an interesting, and so far successful, field scale experiment in sprinkler irrigated rice in the north of Swaziland, and this use of overhead irrigation could well increase.

The current soil series ratings. Table 3.1 gives the January 1968 ratings for the series mapped in the semi-detailed survey areas of the Usutu Basin. Many of these ratings must be regarded as tentative and open to revision.

The most recent revision followed a numerical analysis of the yields of maize, cotton, sugar-cane and planted Pinus patula and P. ellioti on some of the more widespread series. The yields were obtained for a number of harvests either from the (then) Department of Agriculture demonstration plots (for maize and cotton) or from surveyed fields or blocks on large estates (for sugar cane and pine). There were no zero treatment plots, only normal commercial management. Most of the previous series ratings were confirmed and only minor revisions were required (Murdoch, 196[illegible]).

In Table 3.1 all series are rated for all ten cropping systems. This means that several geographically impossible combinations occur. For example, pineapple is restricted to an altitude zone stretching from 1,800 to 3,200 feet. It is therefore impossible that pineapples ever be grown on Valumgwace series which is restricted to bottomlands in the Eastern Lowveld. This and similar unlikely combinations are in lower case letters and in parentheses.

Due to limited resources, it has not been possible to draw up more than two land capability maps for each of the semi-detailed survey areas. For the Central Middleveld, the Upper Mgwempisi and Siphocosini areas, the development alternatives are irrigation or intensive dryland farming. Therefore the two maps for each of these areas show the land capability for the irrigated rotation and the dryland rotation of maize and beans. The comparison of these two should be satisfactory for decisions on whether to irrigate or not.

In the Lowveld, irrigation of some sort is a pre-requisite of intensive agriculture, so here the pertinent comparisons are between widely different irrigated cropping systems. Land capability maps have been drawn for the irrigated rotation and irrigated rice. The rotation was chosen for the flexibility of its cropping sequence and its exacting soil requirements and rice because it is the most economically attractive of the monocultures, except for its heavy water requirements. The combinations of soil series and cropping system that have actually been incorporated into any of the land capability maps appear in capitals in Table 3.1. Those ratings which appear in lower case letters but not in parentheses are combinations that are geographically possible, but which have not been used for land capability mapping in this report.

Certain of the Lowveld soil sets as well as their component series have been rated for the irrigated rotation and rice. This is necessary as the original Lower Usutu Basin soil map only differentiated sets (Murdoch and Andriesse, 1964). Generally the set rating is that of the commonest component series.

Table 3.1

Capability ratings of Swaziland soil series for different cropping systems.

Series / Set	Irrigated: Rotation	Irrigated: Rice	Irrigated: Sugar-cane	Irrigated: Citrus	Irrigated: Pasture	Dryland: Maize-beans	Dryland: Cotton-sorghum	Dryland: Avacado	Dryland: Pineapple	Dryland: Pasture
l	B	b	(b)	b	b	A	(b)	c	a	b
m	B	b	(b)	b	b	A	(b)	b	a	b
t	C	a	(d)	d	c	D	(d)	d	c	c
e	A	D	b	a	a	B	a	a	a	a
o	E	E	e	c	d	E	e	c	c	e
u	C	E	c	a	b	C	c	a	b	c
B	C	E								
a	C	A	b	d	a	(b)	a	(d)	(d)	(a)
u	C	A	b	d	a	(b)	a	(d)	(d)	(a)
C(L)	C	A								
m	B	b	(a)	c	a	A	a	c	b	a
o	B	b	(a)	c	a	A	a	c	b	a
t	A	c	a	a	b	(a)	a	(a)	(a)	(a)
e	B	A	b	b	a	(a)	a	(c)	(b)	(a)
D(L)	B	A								
b	E	E	e	e	d	E	e	e	e	d
m	E	E	e	c	d	E	d	d	d	c

Series / Set	Irrigated: Rotation	Irrigated: Rice	Irrigated: Sugar-cane	Irrigated: Citrus	Irrigated: Pasture	Dryland: Maize-beans	Dryland: Cotton-sorghum	Dryland: Avacado	Dryland: Pineapple	Dryland: Pasture
Jb	C	d	(c)	c	b	D	(c)	c	c	b
Jw	C	c	(c)	c	b	D	(b)	c	c	b
Kn	D	a	(d)	e	b	B	b	e	e	b
Kt	D	A	d	e	b	(b)	b	(e)	(e)	(b)
Kz	D	A	d	e	b	(b)	b	(e)	(e)	(a)
K	D	A								
Le	A	D	a	a	a	A	a	(a)	(a)	(a)
Ld	B	D	a	a	a	B	b	(a)	(a)	(a)
Lz	B	E	a	b	a	C	c	(b)	(a)	(a)
L	A	D								
Mv	E	e	(e)	e	e	D	(d)	e	d	c
Ma	A	d	(a)	b	a	A	(a)	a	a	a
Mb	A	(d)	(a)	(b)	a	A	(a)	b	b	a
Md	A	e	(a)	a	a	A	(a)	a	a	a
Mo	A	e	(b)	(a)	a	A	(b)	a	a	a
Mz	B	d	(b)	b	a	B	(b)	b	a	a
Nh	A	D	b	b	a	(a)	a	(b)	(b)	(a)

Work?

2 landcap maps 1:50000 (semi detailed areas)

for { Central Middleveld
Upper Mgwempisi
Siphocosini

Two alternatives

for a) irrigation

b) intensive dry land farming for mais and beans

- versoil limits + cult. table 3.2. pp 132/133

Series Set	Rotation
Ek	D
E	D
Fe	B
Fr	C
Fu	A
F	B
Ge	D
Gc	D
Gn	E
Gb	D
Gz	C
G	D
Ha	D
Hl	D
H	D
I	E
Jk	C
Jv	C
J(L)	C
Jh	C
Rk	A
Ro	B
R	B
Sk	D
So	D
Sp	D
S(L)	D
Sa	C
Sv	C
Tn	C
Ts	D
T(L)	C
Tx	D
U	E
Va	E
Vm	E

Table 3.1 (Continued)

Series Set	Irrigated: Rotation	Irrigated: Rice	Irrigated: Sugar-cane	Irrigated: Citrus	Irrigated: Pasture	Dryland: Maize-beans	Dryland: Cotton-sorghum	Dryland: Avocado	Dryland: Pineapple	Dryland: Pasture
Ek	D	E	e	c	d	E	d	d	d	c
E	D	E								
Fe	B	c	b	b	a	(b)	b	(c)	(b)	(a)
Fr	C	C	(b)	c	a	C	c	d	b	b
Fu	A	C	(b)	b	a	A	(a)	b	b	a
F	B	C								
Ge	D	B	(d)	(d)	c	C	(c)	e	d	c
Gc	D	B	d	d	b	C	c	e	d	c
Gn	E	E	e	e	e	E	e	e	e	e
Gb	D	E	d	d	d	D	d	e	d	c
Gz	C	c	(c)	d	b	C	(c)	d	c	b
G	D	B								
Ha	D	A	d	e	c	D	c	e	(e)	c
Hl	D	A	d	e	c	d	c	e	(e)	c
H	D	A								
I	E	B	e	e	e	D	e	e	e	e
Jk	C	E	d	b	c	D	c	b	b	c
Jv	C	E	d	b	c	D	c	b	(b)	c
J(L)	C	E								
Jh	C	(c)	(c)	(c)	b	C	(b)	c	d	b
Rk	A	B	a	b	a	(a)	a	(b)	(c)	(a)
Ro	B	c	a	b	a	A	a	(b)	(b)	(a)
R	B	c								
Sk	D	D	c	d	c	c	c	(e)	(d)	(c)
So	D	D	c	d	c	C	c	(e)	(d)	(c)
Sp	D	d	c	d	c	C	(c)	e	e	c
S(L)	D	D								
Sa	C	B	c	c	b	B	(b)	d	c	b
Sv	C	c	c	d	b	C	(b)	d	c	b
Tm	C	B	b	d	b	(b)	b	(e)	(d)	(a)
Ts	D	A	c	d	b	(c)	c	(e)	(d)	(a)
T(L)	C	B								
Tx	D	(e)	(c)	(c)	b	D	(c)	(d)	(c)	c
U	E	E	e	e	e	E	e	e	e	e
Va	E	B	d	e	c	(d)	d	(e)	(e)	(a)
Vm	E	D	d	e	c	(d)	e	(e)	(e)	(c)

Series Set	Irrigated: Rotation	Irrigated: Rice	Irrigated: Sugar-cane	Irrigated: Citrus	Irrigated: Pasture	Dryland: Maize-beans	Dryland: Cotton-sorghum	Dryland: Avocado	Dryland: Pineapple	Dryland: Pasture
Nh	A	D	b	b	a	(a)	a	(b)	(b)	(a)
Ns	A	D	b	b	a	(a)	a	(b)	(b)	(a)
N(L)	A	D								
Nd	B	(d)	(d)	(b)	b	A	(b)	(b)	(b)	b
Nz	C	(d)	(d)	(d)	b	C	(d)	(d)	(c)	c
Ol	D	e	(d)	d	d	D	(d)	d	d	d
Om	D	E	d	d	c	(d)	d	(d)	(c)	(d)
Ok	D	e	(d)	(d)	d	D	(d)	d	d	d
Or	C	D	(c)	c	b	C	b	c	b	b
Os	D	E	d	d	c	D	d	(d)	(d)	d
Ot	D	E	d	d	d	D	d	d	d	d
O	D	E								
Pb	D	b	(d)	d	c	D	(d)	e	e	c
Pt	D	B	d	d	c	C	d	e	e	c
Po	D	A	c	d	c	C	c	e	d	c
Qu	E	E	e	e	e	(e)	e	(e)	(e)	(e)
Qo	D	d	(c)	c	c	D	(c)	c	c	c
Qb	D	d	(c)	(c)	c	D	(c)	c	c	c
Rs	B	B	b	c	a	(a)	a	(d)	(d)	(a)
Rt	A	C	a	b	a	(a)	a	(b)	(b)	(a)
Vu	D	B	(d)	e	c	D	(d)	e	e	a
V	E	B								
Wh	C	C	b	c	a	(b)	a	(c)	(c)	(a)
Wn	A	E	a	a	a	A	a	a	a	a
Ws	D	C	d	e	b	(c)	b	(e)	(e)	(b)
W	A	E								
Xu	E	E	e	e	e	E	e	e	e	e
Yo	E	E	e	e	e	(e)	e	(e)	(e)	(e)
Ze	E	C	d	e	c	(d)	d	(e)	(e)	(b)
Zn	E	D	d	e	c	(e)	e	(e)	(e)	(c)
Zl	D	B	c	e	b	c	c	(e)	(d)	(b)
Zd	E	C	d	e	b	D	d	(e)	(e)	(b)
Z(L)	E	C								
Za	C	c	(c)	(c)	b	B	(b)	d	(c)	b

Site Factors. These include rockiness, surface irregularity, vulnerability to flooding, access to water (for irrigation) and land slope. Several of these are already covered in the soil ratings. Thus rocky land, which is taken as having more than 10% of the surface covered by stones of greater than 8 inches diameter, is mapped as U set or Madevu series and these are given very low ratings. Soils which give rise to highly irregular surfaces, either by erosion or by volume changes in their clays are also downgraded in the soils ratings.

Within the semi-detailed survey areas, only X set and the very lowest B set terraces are liable to flooding, except in rare, very intense, storms. The whole of the B set terrace was flooded in the Umtilane valley during Cyclone Claude in early 1966. Accessibility to water is fairly good throughout the semi-detailed survey areas, except for occasional scarp-guarded hills, which generally have a soil cover of very low irrigability rating anyway.

Land Slope. Land slope is the only site factor which is systematically incorporated into the Land Capability classification as a separate assessment. For measurement only the gradient characteristic is considered. The other characteristics such as slope, length and form are described qualitatively under land form for the whole basin (Chapter I) and each of the semi-detailed survey areas (Chapters V - VIII).

Table 3.2 presents the complete subdivision of slope gradient used by the Swaziland Soil Survey.

Table 3.2

Slope gradient divisions used in Swaziland

Symbol	Gradient Percentage	Gradient Degrees (approx)	Description
Z	0%	0°	Zero gradient
Y	0-3%	$0-2^{\circ}$	Gentle
X	3-7%	$2-4^{\circ}$	Moderate
W	7-14%	$4-8^{\circ}$	Steep
V	14-22%	$8-12^{\circ}$	Very steep
U	22+%	$12+^{\circ}$	Excessively steep

These subdivisions are grouped into slope categories for incorporation into Land Capability units. As with the soil ratings, slope categorisation is flexible and varies with the cropping system in question. Listed below are the slope categories for each of the three farming systems for which land capability maps have been drawn.

Dryland maize - beans rotation. Slope category 1 includes subdivisions Z, Y and X, i.e. all slopes less than 7%. For these slopes only the simple mandatory conservation measures are required (Ngwenyama, Order in Council, 1953), and all agricultural machinery can be manouvred fairly easily. Slope category 2 includes slope subdivisions W and V, giving an upper limit of 22%. Land in this category requires more mechanical protection than category 1 land, and some difficulty is experienced in handling farm machinery. Above 22% gradient, land is classed as unploughable. It is realised that in many parts of the world, land considerably steeper than this is under cultivation, but any predictable increase in the pressure on arable land in Swaziland in the future can be more economically met by intensifying the agriculture on the more gently graded land than by the construction of expensive terracing. For such very stable soils that can be cultivated without recourse to terracing, the mandatory spacing of protective grass strips at no more than 4 feet vertical interval gives a panel width of less than 20 feet at 22% and this decreases rapidly as the gradient increases, so that the use of machinery is further circumscribed. Furthermore, an increasing proportion of the land is not in productive use. (Ngwenyama, C. in C., 1953). These slope categories are of the same order as those used by the S.C.S. of the U.S. D.A. (Kellogg et al., 1951; Montgomery and Klingebiel, 1961).

Rotation of irrigated annual crops. For this system, slope category 1 includes gradient subdivisions Z, Y and X so that the upper limit is 7%. The inclusion of dead flat land is problematical, because of the difficulty of surplus water disposal. However, there are practically no extensive areas of truly flat land in Swaziland (Murdoch and Andriesse, 1964) so subdivision Z has not been separated out. A gradient of 7% is thought to be the economic limit for surface irrigation, as distribution of water and protection against erosion by excessive runoff becomes complex and costly on steeper land. This limit includes both class I and most of class II arable land in the Bureau of Reclamation classification of irrigability (U.S.B.R., 1953), and it corresponds approximately with those used elsewhere in Southern Africa (Thomas and Thompson, 1959). Slope category 2 is gradient subdivision W, so that the upper limit of irrigability is set at 14%. Land in category 2 is suited only for overhead irrigation, and this requires good management to avoid wasteful and damaging runoff. As pointed out by Maletic and Hutchings (1967), the upper limit of gradient for irrigability is partially dependent on soil erodibility and several climatic factors, especially storm intensity. It can therefore vary widely from place to place and they quoted extreme values of 3% and 20% for different localities in the western United States. The Bureau of Reclamation set 14% as their upper limit for Class III irrigated arable land (U.S.B.R., 1953), and it also agrees well with the limits of Thomas and Thompson in Rhodesia (1959).

Irrigated Rice. Because of the necessity of maintaining a relatively aqueous root environment, it is necessary to consider the ease of keeping the soil very wet, if not water-logged, when setting gradient limits for this system. Therefore category 1 includes only gradient subdivisions Z and Y, setting an upper limit of 3%.

Although some through drainage is necessary to prevent the water from becoming stagnant, and also to enable the crop to be dried off for harvesting, the objections to flat land are less strong than for the irrigated rotation, because the cost of drainage is largely offset by savings in paddy construction. 3% is the absolute upper limit for paddy cultivation, because above this gradient, the quantity of material that has to be moved in building paddies is excessive, and the paddies are too narrow. Slope category 2 is gradient subdivision X, with an upper slope limit of 7%. Category 2 land can only be surface or sprinkler irrigated. The latter is still at the experimental stage for this crop, although initial results are very promisiong. If rice is to be grown as a normal annual cereal, with sprinkler irrigation, then it might be argued that the upper limit should be 14% as for the rotation. However, the only soils that would retain a moist enough root environment against the drainage gradient prevailing at slopes between 7% and 14% are the vertisolic clays such as C (Lowveld), K, and V sets, which rarely occur on such steep slopes anyway.

Land Capability Classes.

The soil series rating and the slope category are combined to give a two symbol land capability class for any area of land for particular cropping systems. As well as ranking the land, the use of a two symbol code gives a rough idea as to whether the limitations are topographically or soil imposed. As there are 5 mapped soil ratings for each farming system and 3 slope categories, 15 land capability classes emerge. However, in mapping, 7 of these coalesce by the grouping together of all land in slope category 3, no matter what rating its soil cover has, and all land covered with an E-rated soil, no matter what the slope. All this 'unusable' land (for the cropping system in question) is designated with the symbol X.

Tables 3.3 (a), (b) and (c) show the land capability classification scheme for each of the three cropping systems for which maps have been prepared.

Table 3.3(a)

Land capability classes for irrigated rotation of annual crops

Soil rating	Slope category 1 (0-7%)	2 (7-14%)	3 (14%+)
A	A1	A2	
B	B1	B2	
C	C1	C2	X
D	D1	D2	
E		X	

Table 3.3(b)

Land capability classes for dryland maize - beans rotation

Soil rating	Slope category 1 (0-7%)	2 (7-22%)	3 (22%+)
A	A1	A2	
B	B1	B2	
C	C1	C2	
D	D1	D2	X
E		X	

Table 3.3(c)

Land capability classes for irrigated rice

Soil rating	Slope category 1 (0-3%)	2 (3-7%)	3 (7%+)
A	A1	A2	X
B	B1	B2	
C	C1	C2	
D	D1	D2	
E	X		

Land capability and holding size. It has been pointed out that large estates are able to incorporate and use areas of poor land that would be uneconomic for a smaller farmer (Coulter, 1968; Swaziland Soil Survey, 1968). For example, an estate of 1,500 acres of irrigated land might be able to include 150 acres of class C or D1 land if the rest of the estate is on higher capability land, whereas 10 small holders, each farming 15 acreas of the poor land might find their position economically impossible. No allowance has been made for this variability due to holding size, but it must be considered when development decisions are made.

Land Capability and the National Soil Reconnaissance.

Those areas in the basin which do not fall into one of the semi-detailed survey areas are covered by the N.S.R. (Murdoch, 1968). The country has been mapped at a scale of 1:125,000 and the mapping units are the soil sets. There is one accompanying Land Capability map, the symbols on which indicate a rating for the soil cover and the gradient of the land slope. The soil sets have been assigned the rating of their commonest component series for the irrigated rotation of annual crops, with a few indicated exceptions where the higher sugar cane rating has been used.

Table 3.4

Soil set ratings for the N.S.R. Land Capability map

Set	Rating	Set	Rating	Set	Rating
A	B	J	C	S(H)	B
B	C	K	D	S(L)	C *
C(H)	B	L	A	T(H)	D
C(L)	B *	M	A	T(L)	B *
D(H)	E	M(H)	B	U	E
D(L)	B	M(L)	A	V	D *
E	D	O(S)+	D	W	A
F	B	O(R)+	C	X	E
G	D	P	C	Y	E
H	D	Q(H)	D	Z(H)	C
I	E	Q(L)	E	Z(L)	D *
J(H)	C	R	A *		

* Rating for irrigated sugar cane.

\+ O set has been separated into shallow (O(S)) and regular (O(R)) phases.

References

Coulter J.K., 1968; Report on a visit to Swaziland made in 1967, in preparation, mimeographed.

Dodson M.G.C., 1960; Report on the possibilities of avocado production in the Ezulwini valley, Tech. Comm. 2, Swaz. Dept. of Land Utilisation, mimeographed.

Dodson M.G.C., Stedman C.J., and I'Ons R., 1965; Pineapple growing in Swaziland, Bull. No. 12, Swaz. Dept. of Agriculture.

I'Ons J.H., 1967; 'The development of tropical pastures for the Swaziland Middleveld'; Proc. of Grassland Soc. of S. Africa, in press.

I'Ons J.H., 1968; 'Summer grown pasture grasses and legumes for the Swaziland Middleveld'; Swaziland Ministry of Agriculture. Miscellaneous Report No. 62.

I'Ons J.H. and Kidner M., 1967; Pasture and veld management in Swaziland, Bull. No. 17, Swaz. Ministry of Agriculture.

Jackson P., Quoted in Jones and Murdoch, 1965; and Murdoch, 1965.

Jones M.A., and Murdoch G., 1965; Review of soil fertility research in Swaziland, Proc. of OAU symposium on Soil Fertility, Khartoum, Sudan.

Kellog C.E. et al., 1951; Soil Survey manual, Hand book No. 18, U.S. Dept. of Agriculture.

Klingebiel A.A., and Montgomery P.H., 1961; Land capability classification, Hand book No. 210, Soil Conservation Service, U.S. Dept. of Agriculture.

Lea J.D., Murdoch G., and Dicks A.V.R., 1963; Report on a salinity survey, Swaz. Dept. of Agriculture, mimeographed.

Lea J.D., and Murdoch G., 1964; Irrigation Farming, Bulletin No. 11, Swaziland Department of Agriculture.

Lea J.D., Murdoch G., and Cornish-Bowden M., 1965; Irrigating Cotton in Swaziland, Bulletin No. 14, Swaziland Department of Agriculture.

Maletic and Hutchings, 1967; Selection and classification of irrigable lands, pp. 125 et seq. in American Soc. Agronomy Monograph No. 11, Irrigation of Agricultural lands.

Murdoch G., 1961; Report of a soil survey of Ubombo and Bar Circle in the Swaziland Lowveld, Swaziland Department of Land Utilisation, (mimeographed).

Murdoch G., 1965; Practical value of a soil series classification to agricultural research, Proc. S.A. Sugar Technologists Association.

Murdoch G., 1967; Pineapple prospects in West central Swaziland, Swaziland Department of Agriculture, mimeographed.

Murdoch G., 1968; Soils and Land Capability in Swaziland, in preparation.

Murdoch G., and Andriesse J.P., 1964;	A soil and irrigability survey of the Lower Usutu Basin (South) in the Swaziland Lowveld, Overseas Research Publication No. 3, Department of Technical Cooperation, London.
Murdoch G., and Baillie I.C., 1966;	Swaziland soil series and sets in alphabetical order, Swaziland Department of Agriculture, mimeographed.
Ngwenyama, 1953;	Ngwenyama's Order in Council No. 2, of 1953.
Richards L.A., et al., 1954,	Diagnosis and improvement of saline and alkaline soils, Handbook No. 60, U.S. Department of Agriculture.
Swaziland Dept. of Agriculture, 1966;	Annual report of the Research Division for 1964/65.
Swaziland Dept. of Agriculture, 1967;	Annual report of the Research Division for 1965/66.
Swaziland Dept. of Agriculture, 1968;	Interim annual report for Agricultural Research for 1966/67.
Swaziland Dept. of Agriculture, 1967;	Annual report of the Soil Survey for 1967.
Thomas R.G., and Thompson J.G., 195 ;	The classification and assessment of soils for irrigation in Southern Rhodesia, Proc. 3rd interafrican Soils. Conf., Dalaba, Vol. I, pp 345-50.
United States Dept. for the Interior, 1953;	Bureau of Reclamation Manual, Vol. 5, Irrigated land use.
Venn A.C., Lea J.D., and Gibbs J.D., 1962;	Production of maize under irrigation in Swaziland, Bull. No. 6, Swaziland Dept. of Agriculture.

CHAPTER IV

Survey Methods

The following remarks only apply to the author's fieldwork in the semi-detailed survey areas covered in Chapters V - VIII. For the techniques used in reconnaissance soil surveys in Swaziland, see Murdoch (1968).

The survey team consisted of the surveyor and one or two field assistants. They generally travelled by Landrover and it was rarely necessary to make foot traverses. Every possible use was made of cattle tracks, farm roads and sledge paths for access into the survey areas and only in the Eastern Lowveld was it necessary to navigate along compass traverses.

The soil was inspected with a 4 feet long, 4 inch diameter Jarrett auger, using water where necessary on hard soils. Advantage was taken of exposures in road and rail cuttings and in erosion gullies. The density of inspections varied with the type of country. In the Lowveld, one inspection was made every 50 - 100 acres, with a mean density of about one per 60 acres. This is equivalent to one field inspection per square centimetre, at the final mapping scale of 1:50,000. In the more dissected terrain of the Middleveld and Highveld, the inspections were usually closer than this.

The inspections were sited by observation of changes in landform, vegetation, and soil surface appearance. Changes not apparent on the ground, but showing up on the 1961 1:30,000 vertical black and white aerial photographs were also used in the siting of augerings. 1:20,000 colour air photography was available for the Western end of the Lowveld, North bank semi-detailed survey area. This proved to be very useful in the accurate location of certain soil boundaries, and certainly justified the higher cost. Aerial photographs thus served a threefold purpose, as they were also used as a navigational aid and as the surveyor's field sheets. The profile form revealed by the inspection was assigned to a soil series, and the field sheet marked accordingly. Only very marked soil boundaries were inserted onto the photographs in the field.

Soil boundaries were generally put onto the air photographs in the office using the 1:50,000 and 1:125,000 geological maps, and a Wild Stereoscope where necessary. These soil boundaries were transferred onto the 1:50,000 D.O.S. topographical maps by eye. The Nashton sketchmaster was available but was rarely used. It was felt that the imprecision in the original plotting of soil boundaries was such that the inaccuracies introduced by the freehand transfer of boundaries were relatively insignificant.

Many of the commoner soil series already had described profiles prior to the writer's fieldwork. About 60 profiles were described and sampled by the writer, mainly for extensive series for which descriptions were missing. The procedure and terminology laid down in the Soil Survey Manual was followed in these descriptions (Kellogg et al., 1951). These profile descriptions were incorporated into the set and series descriptions in Chapter II. It is hoped that more comprehensive profile descriptions will appear in the forthcoming inventory of Swaziland soil series.

In the preparation of the Land Capability maps, the slope gradients were measured from contour intervals on the

CHAPTER V

Lower Usutu Semi-detailed Survey Area

The mapped area covered in this Chapter was mostly surveyed by the Swaziland Soil Survey in the period from 1955 to 1964, but there are some additional areas covered by the writer in 1965-67. The Central Middleveld area (Chapter VI) has a similarly heterogeneous mapping history, but the Lower Usutu differs in that the report on the most extensive of the previous surveys has appeared in published form (Murdoch and Andriesse, 1964). Thus, printed soil and irrigability maps of all the South bank area are already available. However, in order to give a complete and consistent picture of the basin's potential, the South bank is included in the accompanying maps. During the compilation of the new combined map, the original senior author of the South Bank publication, (G. Murdoch), took the opportunity to revise a few boundaries in order to accommodate soils known to occur within the South bank area, but which were only defined as separate soil mapping units after the appearance of the original publication, i.e., J (Lowveld) and C (Lowveld) sets (Murdoch, 1968).

Although the South bank area is covered by the maps accompanying this report, it is not intended to describe it at all, and the reader is referred to the previous publication. In the previous report, many aspects of soil formation and distribution, climate, geology, landform, vegetation, land use and land capability were covered in considerable detail. Because of the strong North South geological and geographical lineation in the Lowveld that was noted in Chapter I, much of this information is also applicable to the North bank. In the following description of the North bank, much of this background information is assumed and only points peculiar to the North bank are noted.

North Bank Survey Area.

Much of the mapping previous to 1965 was undertaken at the request of the developing sugar and citrus industries, that grew up after the construction of the Big Bend canal in 1948. Other surveys were carried out for pump irrigation schemes along the Usutu and for Swazi irrigation settlement proposals and a Rural Development Area along the Myetane.

Along with the remaining areas surveyed in 1965-7, the total acreage is about 175,000 with boundaries as follows:

West: Generalised 1,000 foot contour along the base of the Bulunga hills.

North and East:

(a) Between the Bulunga hills and the Mzimpofu river - generalised 1,000 foot contour.

(b) Between the Mzimpofu and Mtindekwa rivers - cadastral boundaries at about 800 feet altitude.

(c) Between the Mtindekwa river and the Big Bend-Stegi road (new alignment) - cadastral boundary at about 900 feet altitude.

(d) The long northwards extension of the area in the east is bounded in the west by the Big Bend Stegi road, and in the east by the Myetane river, with a few exceptions.

(e) The exceptions are the areas of proposed irrigation settlement schemes at Sivunga and in the Logo trough, and the Rural Development Area at Mgcina.

South: The Usutu river.

The rather narrow 'waist' of the area formed by these boundaries resulted from the decision not to extend the semi-detailed survey over large areas underlain by the sediments of the Karroo system because of the known low potential of the soils formed from these rocks in the Lowveld. This expectation of low land capability was fulfilled by the findings of the National Soil Reconnaissance (Murdoch, 1968). Conversely, the long northwards extension in the east of the area reflects the high potential of the soils found on basic igneous rocks elsewhere in the Eastern Lowveld. The extension also accorded with Department of Agriculture policy, under which the Mgcina - Mpolonjeni area was declared a Rural Development Area. This involved detailed planning of the area by the Department (now Ministry) staff at the invitation of the Chief and local people. Soil and land capability maps were prerequisites to this planning.

Description of the Area.

Geology. The geological pattern is similar to that on the South bank, with the Karroo sediments and volcanics deposited uncomfortably on the Precambrian acid and intermediate crystalline rocks.

The Karroo system shows a strong North-South lineation, in its outcrop in Swaziland, so that the observations made on its petrology, mineralogy and pedogenetic influence in the South bank area are directly applicable to the North bank (Murdoch and Andriesse, 1964).

The main difference between the geology of the North and South bank survey areas is within the Precambrian. The main outcrop on the South bank is the Agd2, which is an intermixture of coarse grained quartz diorite and granodiorite, thought to be of synorogenic plutonic origin and dating from the second Swaziland orogenic cycle (see Chapter I). Only in the hilly region in extreme West of the South bank area does the coarse-grained porphyritic Ag5 granite outcrop. However, the contact between the two runs in a North Easterly direction, with the result that a large section of the North bank survey area is underlain by the granite. The mineral norms and chemical compositions of typical specimens of each are presented in Tables 5.1 and 5.2. Results for two of the most extensive rocks in the Karroo outcrop are included for purposes of comparison.

Table 5.1

Chemical Composition of the most extensive rocks in the Lower Usutu area

	1 Granite Agd5	2 Granodiorite Agd2	3 Ecca sandstone	4 Stormberg basalt
SiO_2	78.8	67.3	82.3	46.4
Al_2O_3	11.6	15.3	8.8	15.6
Fe_2O_3	0.6	1.3	3.2	5.9
Fe O	1.2	2.5	-	4.2
Mg O	0.1	1.8	1.6	7.7
Ca O	0.6	4,2	0.4	10.7
Na_2O	2.1	4.4	-	2.7

Table 5.1 (Continued)

	1 Granite Ag5	2 Granodiorite Agd2	3 Ecca Sandstone	4 Stormberg basalt
K_2O	4.7	1.8	3.7	0.3
TiO_2	0.1	0.5	0.3	1.4
P_2O_5	t	0.1	0.1	0.2
MnO	t	0.1	-	0.1
H_2O+	0.3	1.0	1.1	3.9
H_2O-	0.1	0.1	0.3	1.4
Total	100.4	100.2	101.8	100.4

(Analyses for samples 1 - 3 after Murdoch and Andriesse, 1964)

Origin of analyses:
1 - Kubuta (Hamilton, 1938).
2 - Otandweni, South bank survey area (Hunter, 1957).
3 - Avoca, Natal (Beater, 1957).
4 - Usutu poort, South bank survey area (Hunter, 1961).

Table 5.2

Mineral norms of the most extensive rocks in the Lower Usutu area

	1 Granite Ag5	2 Granodiorite Agd2	4 Stormberg basalt
Quartz	46.3	23.4	2.1
Orthoclase	27.8	10.5	1.7
Albite	17.8	36.8	23.1
Anorthite	3.3	16.9	29.2
Corundum	1.8	-	-
Diopside	-	2.6	18.0
Hypersthene	1.9	6.6	8.5
Magnetite	0.7	1.4	8.8
Ilmenite	0.2	1.0	2.6
Apatite	-	0.3	0.3

(After Hunter, 1961).

Associated with the extensive faulting in the Western Lowveld (see below), there is a broad outcrop of shear-zone mylonite mapped through the young Ag5 granite in the North Bank area (Swaziland Geological Survey, 1966). However, the effect of shearing is structural rather than mineralogical and chemical, and no significant pedogenetic differences were noted between the sheared rock and surrounding granite.

Landform.

The Lowveld is by no means the flat plain that it appears from the Lebombo or the Middleveld hills. Relief is low and the topography varies from rugged to gently undulating. Differences in slope form are associated with differences in geology, soils and vegetation and are described in the subdivisions of the North bank survey area (see below).

The origin of the great Lowveld trough is still a matter of controversy. One school of thought attributesit wholly to erosion. According to this view, the Middleveld-Lowveld scarp (e.g. Bulunga) is the normal connecting slope feature between the Late Tertiary Middleveld and Quaternary Lowveld surfaces, and is accordingly cut into various rocks. The Lebombo scarp, on the other hand, is thought to arise from the differential competence of the hard acid-intermediate ignimbrites and the softer basalts and Karroo sediments (King, 1962). Several objections have been made to this hypothesis. The first is that the present tributaries of the major eastwards flowing rivers do not seem to be of sufficient size and erosive power to have excavated the vast quantity of material involved within Quaternary times. (The Lowveld is 20-30 miles wide and the surface is at least 1,000 feet below a line drawn from the summit of Bulunga to the crest of the Lebombo). Another feature that some observers find inconsistent with the erosional hypothesis is the straightness and lack of indentation of the Lebombo scarp (De Blij, 1960), although this has been attributed to the lack of jointing in the rhyolite and andesite (King, 1960).

The alternative suggested mode of origin is that the Lowveld is a rift feature, with block faulting at the foot of the Lebombo (western downthrow)and in the foothills of the Middleveld (eastern downthrow) (De Blij, 1960). It is known that rifting occurred in Karroo times (Way, 1961) which explains the great thickness of shallow water sediments that were then deposited, but there is no clear evidence that it recurred in Late Tertiary or Quaternary times (Hunter, 1961). A vertical western displacement of about 700 feet was reported along the basalt-andesite contact, at the foot of the Lebombo, in Northern Swaziland (Way, 1961). However, it has been suggested that this apparent faulting was, in fact, due to interlayered lava flows, alternating in composition from basalts to andesites (Hunter, 1961). There is extensive faulting in the Precambrian and Karroo rocks in the Western Lowveld and Eastern Middleveld but these predate the formation of the present landscape and are thought to be of Karroo age (Hunter, 1961). However, there may have been refracture along the lines of weakness marked by these faults in Late Tertiary and Quaternary times, which, in combination with the putative faulting along the Lebombo, could have led to the formation of a rift valley. However, a recent aerial survey of the gravity anomalies has produced no evidence at all for faulting at the foot of the Lebombo, so it appears that the rifting hypothesis falls away (D.R. Hunter, private communication, 1968).

Whatever its mode of origin, it is generally agreed that the present land surface of the Lowveld was fashioned by Quaternary erosion (De Blij, 1959; Turner, 1967), with possible remnants of a very Late Tertiary surface capping the higher prominences (Murdoch, 1959; Turner, 1967).

Fluvial Deposits.

The Quaternary alluvial terraces, that give rise to W set and D set soils, are more continuous and extensive in the Lowveld than elsewhere.

There are no clear topographic expressions of terraces earlier than those covered with W set soils that can be compared with the series of old beach deposits found on the coast of Natal, (Maud, 196). However, pockets of rounded alluvial pebbles have been found up to 200 feet above the present river level (Murdoch and Andriesse, 1964). These are not always unambiguous as there are strata of conglomerate in the Lower and Middle Ecca beds, which weather to give layers of apparently alluvial origin. It is thought that the pebbles layer visible between the soil and weathering sandstone in the Mhuzamoya rail cutting may be an example of this type. There are, however, pebbles in other parts of the survey area which are of undoubted alluvial origin, e.g. along the bed of the Mzimneni in the granite country, and at Wisselrode in the dolerite and basalt (Murdoch and Andriesse, 1964). Similar deposits have been noted elsewhere in the Lowveld. In the North of Swaziland, the presence of rolled Stone Age artefacts, fashioned in chert, which only outcrops in the Swaziland System many miles up the Komati, points clearly to an alluvial origin.

In the North, these pebble beds are found on the crest of the very low Komati - Umbeluzi watershed, but similar deposits are not found on the Umbeluzi-Usutu or Usutu-Ngwavuma watersheds. There is, therefore, no evidence for the large North-South flowing river that might have been responsible for the excavation of the Lowveld (Rance, 1960), and the pebbles are thought to have been deposited by predecessors of the current eastwards flowing rivers.

There is a bed of rounded alluvial pebbles, including rolled artefacts from the Middle Stone Age, revealed by the railway cutting about 1 mile east of Sipofaneni. The pebble bed occurs at about 8 feet and the soil above it is mapped as red Fersiallitic loam of L set. L set is normally found on colluvial parent materials, but in this case the alluvial origin was not apparent as the fine sand and silt fractions were not high and the soil was well structured. This gradual disappearance of distinctively alluvial characteristics, especially the high fine sand fraction which weathers readily, is thought to be the normal fate of alluvial terrace material, whose deposition predates the upper (W set) Late Quaternary terrace. A similar area, also mapped as L set but thought to be derived from an old alluvial terrace rather than colluvium is found on the Komati at Balegane (Murdoch, 1963 and 196[illegible]).

In addition to the alluvial terraces along the Usutu and its major tributaries, the courses of the minor ephemeral streams are marked by thick accumulations of gully-wash material. The composition, and hence the pedogenetic effect of these materials, varies with the rock types within the catchment. The different types of gully-wash found are described for each of the subdivisions of the area (see below).

Climate.

The climate of the South bank survey area was described in some detail. The only North bank meteorological station with records covering a fairly long period, Sipofaneni, was included in the South bank description, so that the basic information is the same (Murdoch and Andriesse, 1964). Fortunately, the climatic zones follow the grain of the country and run in a generalised North-South direction. Thus the climatic gradation from semi-arid in the East to subhumid in the West is found as clearly on the North bank as on the South. The range of climates encountered is clear from the climatic summary presented in Table 5.3 for the South bank stations, Wisselrode and Kubuta, which are probably at the extremes of the range.

Table 5.3

Climatic range in Lower Usutu survey area

Station	Wisselrode	Kubuta
Mean Annual Rainfall	21 inches (530 mm)	31 inches (790 mm)
Mean Annual Temperature	72°F (22°C)	69°F (20°C)
Köppen Classification (from G. and E. Murdoch, private communication).	Bsh	Cwa
Lang's Regenfaktor	24 (arid)	39 (arid, but bordering on humid).
Thornthwaite Precipitation Effectiveness Index	22 (arid)	43 (sub-humid)

Subdivision of the North bank survey area.

For the purposes of describing the soils in relation to their parent materials and the landscape in which they occur, the area has been subdivided into seven subregions. These are separated for convenience of description only and, although they differ in topography, geology, soil and vegetation cover, and in land capability, the criteria for differentiation are nowhere strictly defined. They correspond in concept with the subregions of the South bank survey area (Murdoch and Andriesse, 1964) and any similarities between the subregions of the North and South bank will be noted. Their location is shown on Map 5.1 (see back pocket).

There is a greater degree of subdivision than in the Land Systems map of Swaziland, although some of the units do correspond (Webster, Murdoch and Lawrence, in preparation). The Land System approach is concerned with the delineation of terrain according to its appearance on air photographs under the stereoscope, without the necessity of field examination, whereas the subregions here described were only separated after the semi-detailed soil survey (Becket and Webster, 1965).

In the following sections, no details of soil profile characteristics are given. For more detailed morphological descriptions of the soils mentioned, reference should be made to Chapter II.

Subregion 1 - Ophir Lowlands.

The name comes from the old ranch that used to cover the area, but which was sold to the Lifa fund in the first quarter of the century. The South bank counterpart area to this subregion is very small and was incorporated into the Mapilonga Uplands (Murdoch and Andriesse, 1964). This is because it is essentially granite country, and the granite outcrop in the South bank survey area is of very limited extent.

As it lies at the Western end of the survey area, this subregion tends to have a moister climate than those to the East. The mean annual rainfall at Sipofaneni is 26 inches and it may be as much as 30 inches in the area just East of the Bulunga scarp.

The whole area is underlain by the coarse-grained porphyritic Ag5 granite. This gives rise to a high proportion of coarse sand and gravel particles on physical weathering. As larger grains of the non-quartzose constituents of the granite are extremely weatherable, the coarse fractions of the colluvia and soils developed from the granite are dominated by quartz. Although a relatively weatherable clay mineral, quartz is very resistant in the medium and coarser sand fractions (Jackson and Sherman, 1953). Consequently, the granite-derived soils are high in coarse sand in all positions in the landscape.

There are fairly frequent doleritic intrusions into the granite, often unmapped. They are thought to be of post-Karroo age and usually occur as dykes, although there is an extensive sheet southwest of Vikisijula hill (Swaziland Geological Survey, 1957(a)). The dolerite does not give rise to markedly positive topographic features as it does in the softer rocks further East.

The landform is distinctive of the subregion with long, gently graded straight or slightly concave slopes running up to castle-like piles of large rectangular blocks of hard, residual granite. These 'castle kopjies' are often flanked by an apron of bare hard rock, (see Plate II(a) in Murdoch and Andriesse, 1964). There are many interfluves where these residual tors are absent, especially between the southern tributaries of the Mzimnene. There is a younger erosion cycle encroaching upon the long slopes, giving steeper gradients near the watercourse, but the polycyclic nature of the landscape is less noticeable than in the Tambuti Rises and the Mtshelani Trough to the East. The watercourses have deep gully-wash deposits which are being excavated in the current erosional phase.

Soils: In the steeper parts of the landscape, the granite gives rise to the shallow sandy soils of U and O sets, generally Otandweni series. The dominant soil on the middle and lower freely drained slopes is J (Lowveld set which is a deep, reddish or pink, coarse sand. These soils are, by definition, more than 24 inches deep, but the modal depth found in the area was in the 48 - 60 inches range. The coarse texture gives high infiltration rates and there is little runoff unless the soil surface is bared. Combined with the subregion's relatively high rainfall, this means that the soils are more leached than most others in the Lowveld. This is shown by the relatively low base status and pH, and by the fairly high degree of clay segregation within the profile, which leads to increases of up to 50% in the clay content of the subsoil over that of the surface horizon.

In the bottomlands, and occasionally on almost flat elevated platforms, 'duplex' or 'two deck' soils are formed. These have an abrupt textural boundry with at least a twofold increase in clay content from the sandy topsoil to the sandy clay subsoil. The clay pan is mottled and non-calcareous, and the grey, coarse sandy topsoil also shows signs of poor drainage, with rust mottling along old root channels. The formation of the clay pan can either be attributed to enrichment by diagonal clay movement from the freely drained soils upslope, or to the moister pedoclimate prevailing in bottomland positions. Further pedological study would be required to assess the relative contributions of each.

On a national scale, or even for the whole North bank survey area, the commonest of the subsoil-mottled, non-calcareous duplex soils is H set (Murdoch, 1968). However, within the subregion so much coarse sand is developed by the weathering of the granite, that E set is more widespread. The main difference is that E set has at least 36 inches of coarse sandy topsoil over the clay pan, whereas H set has a shallow sandy surface horizon, usually less than 24 inches deep. E set may be underlain by a hard ferricrete sheet, whereas H set only has concretions. Clay pans have been found with as much as   feet of overlying sandy gully wash in some exposures along the Mzimneni.

A simplified section of the landscape and its soil cover is depicted in figure 5(a) (see back pocket).

The high ferromagnesian mineral content and consequent high clay-producing potential of the dolerite gives rise to the red clays of N set and the shallow heavy textured soils of S (Lowveld) set. As already noted, the dolerite is not markedly more competent than the country rock and is not, therefore, found exclusively in areas of greater relief. Consequently, it is not as vulnerable to erosion as it is in the areas of softer rocks to the East. Combined with the higher rainfall, this leads to a lower proportion of shallow soils than elsewhere on the North bank. The ratio of the area of N set to that of S (Lowveld) set is higher in this subregion than in any other, although the absolute areas of both are small.

Colluviation is a widespread phenomenon in the Lowveld and few truly sedentary soils are encountered (Murdoch and Andriesse, 1964). The movement of colluvium inevitably causes the mixture of materials derived from different rock types. In this subregion, mixed colluvium will have granitic and doleritic components. Soils developed on such mixed origin parent material are thought to be similar to the 'contact' soils described in Rhodesia (Thompson, 1965). In freely drained sites the commonest soils are L set, fersiallitic red loams, which are transitional between N and J (Lowveld) sets in texture, clay type, base status and other properties. The admixture of doleritic material into the gully wash deposits is indicated by the small areas of the calcareous, solonetzic duplex soils of Z (Lowveld) set. These areas are often found in streamlines below occurrence of N and S (Lowveld) set.

The only large areas of ferricrete soils in the whole North bank area occur on the higher slopes up against the Bulunga hills. This ferricrete is thought to have formed synchronously with that mapped on the South bank (Murdoch and Andriesse, 1964). The fossil character is inferred from its high position in the present landscape, well above any current groundwater influence, and from the absence of any soft and currently waxing concretions (Murdoch, 1959). The necessary mobilisation and concentration of iron may be associated with an early wet phase of the Gamblian pluvial and the dessication and induration with the subsequent interstadial. In the interstadial the atmospheric climate became more arid and there was also an assumed renewal of erosion and stream downcutting, which would have lowered the local groundwater table and led to dessication in the pedoclimate (Murdoch and Andriesse, 1964). This chronological sequence is favoured as it accords with the postulated climatic changes in Natal (De Villiers, 1962; Maud, 1968).

Vegetation and Land use: The whole subregion falls into the Lower Broad-leaved Tree Savannah (I'Ons, 1967). The bush is very distinctive as the large areas of deep sandy soils are ideal for the silver-leaved Terminalia sericea (Murdoch and Andriesse, 1964). There are areas where it grows in pure stands but it is generally mixed with species of Combretum and Dichrostachys. Pterocarpus and Erythrina spp. are also found in well drained sites. There is a more mixed bush with taller trees in and near the stream lines. Grass cover is generally poor and includes Hyparrhenias, Panicum, Urochloa, Digitaria and some Themeda (Murdoch and Andriesse, 1964) (I'Ons, 1967).

At present the area is largely devoted to cattle raising under the traditional system of communal grazing. There are some dry land maize and cotton crops grown, but the extremely poor moisture retention of the coarse textured soils more than offsets any advantage deriving from the slightly higher rainfall, so that the yields are unreliable and low.

Land Capability: The coarse texture of the dominant J (Lowveld) set soils is associated with low available water holding capacity, so that the potential for most irrigated crops is low (see Table 5.1). The most promising possibility is citrus which thrives on deep, fairly coarse textured soils. However, transmission losses would be very high in unlined distributaries and sprinkler irrigation would be necessary. There is a danger of surface capping by the impact of the sprinkler drops on soils with such poorly developed surface structure. The formation of a surface cap would lead to high runoff, which, besides being wasteful of irrigation water, could lead to erosion, as relief and slopes are moderately high. Field investigations into the irrigation management of these soils are required, and they may show that the whole subregion would be best developed for stock farming (Coulter, 1968).

2 - Vikisijula Hills.

The name of the subregion is taken from the prominent hill in the northwest of the survey area. This region is the North bank extension of the Mapilenga Uplands subregion on the South bank (Murdoch and Andriesse, 1964).

The region consists of a discontinuous belt of low hills and ridges running northwards from Sipofaneni through Vikisijula to the Dumezulu and Malinde hills, well to the North of the survey area. The rocks of the subregion are varied, with homogenous coarse-grained grandiorite in the South, and the Ag5 coarse-grained granite in the North. However, both rock types are shot through with intrusive veins of hard rock. Most of these veins are quartz, but there is one that is mapped as microgranite (Swaziland Geological Survey, 1957). These vein rocks are highly competent and have given rise to the rugged topography of the region, to which in turn can be attributed the rapid erosion, shallow soils and excessive drainage.

Soils: The dominant soils are the O set shallow sandy soils and the bare rock of U set. Within O set, the redder and slightly heavier-textured Osaguleni series is associated with the grandiorite, whereas the vein quartz and the granite both give the greyer and coarser Otandweni series. In the valley bottoms there is some thickness of accumulated colluvial material, and a heterogeneous collection of soils develops according to the dominant rock type contributing to the wash. Amongst the soils found are the deep sands of J (Lowveld) and E sets, the red loam of L set and duplex soils in M and Z (Lowveld) sets.

Vegetation and Land Use: The vegetation of the hills is dominated by succulents, notably Aloe marlothii and Euphorbia spp. There is also some stunted broad-leaved bush with Combretum spp., Dichrostachys and Maytenus prominent, but Terminalia sericea is absent from the shallower soils, and is restricted to the areas of the deeper sands of J (Lowveld) and E sets on the lower slopes. The surface of many of the soils is very stony and the grass cover is very sparse or absent. The vegetation of the valley bottoms is like the soils and very heterogeneous, but is generally dominated by the broad-leaved species.

At present, there is a little cultivation in some of the valleys, but the area is mostly given over to rough grazing.

Land Capability: Economic irrigation is precluded by the height of lift, the steep gradients and the preponderance of shallow, coarse-textured soils. The area is best left as low quality grazing.

3 - Tambuti Rises.

The name is taken from the large citrus and cattle estate within the subregion (the estate took the Afrikaans name for the tree Spirostachys Africanus). The subregion corresponds with the Central Valleys and Rises on the South bank (Murdoch and Andriesse, 1964) Geologically, it is rather heterogeneous as it is traversed by the Precambrian-Karroo contact. The western section is underlain by the Ag2 homogeneous coarse-grained granodiorite. The East is underlain by the Lower and Middle Ecca beds of the Karroo system. These are mainly medium and coarse-grained sandstones, but there are intercalated beds of shale and, less commonly, gritstone and conglomerate. Both the granodiorite and the sediments are intruded by post-Karroo dolerite (Swaziland Geological Survey 1957). The relatively horizontal bedding of the Ecca facilitates the emplacement of sills, whereas most of the dolerite outcrops in the granodiorite are dykes.

The topography is gently undulating, with generally convex slopes leading up to wide and relatively flat interfluves. The platform-type of country so formed is not as pronounced as in the Lenono platform subregion on the South bank (Murdoch and Andriesse, 1964). The flatter interfluves are the result of a previous Quaternary erosion subcycle. The absence of a scarp face and accompanying talus slope between the older, higher surface and the younger, encroaching lower slopes is explained by the relatively small vertical difference in base levels and the low competence of the rock (King, 1962). North of Mukwane hill there are discontinuous outcrops of sandstone along the break of slope, although no actual scarp is formed. In this area the Mtindekwa is flowing East-West, so that the interfluves between its tributaries are running North-South. The rock outcrops are commoner on the western flanks of the interfluves, due to the eastwards dip of the sediments.

The dolerite is harder than the surrounding Ecca sediments and gives rise to positive relief features. Sills give lithomorphic platforms, such as that west of Phuzamoya, and the dykes give ridges. These ridges are mostly North-South oriented but are seen to be secondary lines of weakness running NE-SW, and NW-SE, especially in the grandiorite (Brink and Partridge, 1966), which are marked by dykes and ridges. The dolerite makes less conspicuous relief features in the granodiorite, as the difference in competence between the two rock types is not as great.

Soils: The intermediate nature of the granodiorite is revealed by comparing its soils with those formed on the granite in the Ophir Lowlands. The difference is slightly reinforced by the marginally lower rainfall of the Tambuti subregion. In the areas of broken topography, U and O sets are again dominant but, within O set, Osagulemi series is much commoner. It is redder and of heavier texture than Otandweni series which is the dominant lithosol on granite. On the gentler mid- and lower slopes, L set soils are formed in well drained colluvium. These are red fersiallitic loams and the most widespread is Mesibovu series, which is at least 60 inches deep to weathering rock. Lutsi series is shallower and contains more coarse rock fragments and is thought to be transitional to Osagulemi series. Ludomba series is rare and is formed by the deposition of grey sandy material on top of an L set profile. In the bottomlands, duplex soils are found, with the mottled, non-calcareous H set and the dark coloured calcareous solonetzic Z (Lowveld) set both widespread. The granodiorite is not quartziferous enough to produce the large quantities of coarse sand necessary for the formation of M set.

Because of the softness of the rocks, U and O sets are of limited extent on the Ecca sediments, but where the soils are shallow, then grey, coarse sandy Otandweni series predominates within O set. On these rocks duplex soils are not restricted to sites of poor drainage, but are the dominant soils in the landscape. On the whole, the ratio of areas of Z (Lowveld) set to H set is higher on the North bank than it is on the South bank or in the country as a whole (Murdoch and Andriesse, 1964; Murdoch, 1968). Within this subregion, H set is only of scattered distribution, whilst Z (Lowveld) set is very extensive.

On the wide flatter crests of the interfluves, the reduced erosion and greater age have given the deeper and more developed profiles of Zwide series, although there are some areas of Zwakela series, which is shallower and lacks the lime-rich olive brown horizon of Zwide series. Zwakela series is the most extensive soil on the steeper connecting slopes and is found over sandstones as well as shales. On the South bank it was restricted to the thicker beds of shale in the Upper Ecca (Murdoch and Andriesse, 1964). These steeper slopes are also covered by some areas of Pofane series, in which the sandy topsoil grades into clay-enriched weathering rock without the intervening horizon of dark-coloured sandy clay. P set soils are commoner in the Lower Middleveld (see Chapter VII and Murdoch, 1968) but there was some Petronella series reported on the South bank (Murdoch and Andriesse, 1964).

Zikane series is the commonest soil formed in the deep gully wash deposits. Because of its low-lying site it is generally more sodic and calcareous than the other series in the set. It is also a rather heterogeneous mapping unit, because it may show layering which derives from its sedimentation history rather than from pedological processes. The grey sand top may be thin or absent.

Figure 5(b) (see back pocket), shows the distribution of soils in an idealised landscape on Ecca sediments.

The mode of origin of the local duplex soils is uncertain. Large areas of similar soils occur elsewhere in Southern Africa, and it is agreed that the classical solonchak-solonetz-solod chronological sequence does not explain their distribution (Vilenski, 1960; Thompson, 1957 and 1965; De Villiers 1962 and 1965). The sequence is rejected because of the almost complete absence of solonchaks or solods, so that the solonetzes appear to be the zonal soil rather than a transitional type.

Two types of process could feasibly account for the formation of such sharply differentiated textural horizons. The alternatives are:

1 - That the sandy topsoil and the sandy clay subsoil originate from different parent materials. The profile is formed by the deposition of a mobile sandy wash, probably wholly derived from sandstone, on top of the relatively stable sandy clay subsoil, which is partially or wholly derived from the shales or which may have a doleritic component.

This mode of origin is thought to be dominant in the Swaziland duplex soils (Murdoch, 1959; Murdoch and Andriesse, 1964). The high mobility of the topsoil is evident in areas where the whole horizon has been stripped by sheet erosion initiated by stock trampling or overgrazing. The abundance of grass- and stone-capped sand columns in areas of poor grass cover indicate the vulnerability of the sandy topsoil to raindrop impact when bare. The subsoil is relatively stable to sheet erosion but once gullies are initiated they grow rapidly (Murdoch and Andriesse, 1964).

The presence of occasional discontinuous sheets of angular coarser sand or gravel at the textural boundary also indicates that the profile is of compound origin. Stone lines at the base of the heavier textured subsoil and above the weathering rock have been noted elsewhere in Swaziland, as well as in this subregion (Murdoch and Andriesse, 1964; E.D. Coles, private communication). These suggest that the subsoil is also colluvial and not sedentary, although it is thought that its rate of downslope movement is slower than that of the topsoil. The colluvial origin of the subsoil horizons explains how such relatively clay-rich material is often found over sandstones, in which shale partings are thin or absent.

In Rhodesia the topsoil of calcareous duplex soils derived from granite was found to be highly erodible (Thompson, 1965). This is in contrast to findings in Natal where the sandy topsoil is relatively stable in the duplex soils of the Estcourt group. These soils erode by the formation of dongas which encroach rapidly into the sodium deflocculated sandy clay subsoils. The dongas so ~~formed often~~ have a jutting lip of relatively stable sandy topsoil overhanging the steeply sloping wall (Sumner, 1957; De Villiers, 1962). In Swaziland this type of donga formation is found only in Zikane series, the subsoil of which has a higher exchangeable sodium percentage than the other series in Z (Lowveld) set.

2 - The alternative mode of origin is that the whole profile develops in relatively homogeneous parent material by the eluviation of the clay fraction from the topsoil. The clay could either be illuviated vertically into the subsoil, thus reinforcing the textural difference or it could move diagonally downslope (Murdoch, 1959). Eluviation is thought to be the dominant formation process in duplex calcareous

soils in Rhodesia, where the drainage water moving laterally across the top of the low permeability subsoil was found to be heavily charged with deflocculated clay (Thompson, 1965).

In the Tall Grassveld region of Natal, sodic and non-sodic duplex soils occur as a complex pattern in the landscape. It was postulated that all the soils had been subject to argillisation and planosolisation in a moister phase of the Quaternary. Only after the texturally differentiated profiles had already been formed, were some of them subject to sodium-rich groundwater, causing them to absorb sodium onto their colloids (De Villiers, 1962). A superficially similar, complex pattern of slightly sodic (Z (Lowveld)) and non-sodic (H set) duplex soils is found on the Ecca sediments in Swaziland. However, the more acid, non-sodic, H set soils are found on steeper connecting slopes and are therefore thought to be better drained and leached than the calcareous, slightly sodic Z (Lowveld) set soils. These are commoner on the flatter, less well drained erosion platforms (Murdoch, 1959; Murdoch and Andriesse, 1964). The North bank survey area is rather anomalous in Swaziland in that its area of H set soils mapped is very low (Murdoch, 1968).

In areas of similar climate on the granite and granodiorite the duplex soils are restricted to low lying sites, which are enriched by the illuviation of bases from the surrounding higher areas. The dominance of these soils, especially the solonetzic type, on the Ecca sediments, is not attributed to the high absolute values for the contents of these elements which are less revealing than their ratio to the calcium level. No figures are available for the levels in any Swaziland samples of Ecca rocks, but no sodium was recorded in the Natal example in Table 5.1, and in view of their fresh water origin, sodium contents of these rocks are unlikely to be high. Magnesium is thought to have a similar but lesser affect on soil structure and profile development to that of sodium (Whittig, 1959). Table 5.1 reveals that the Ecca sandstone has a high level of magnesium, especially in relation to the calcium content. Table 5.4 gives the Mg:Ca ratios for the commoner rocks within the survey area.

Table 5.4

Magnesium : Calcium Ratios of the most extensive rocks within the Lower Usutu area.

	1 Granite Ag5	2 Granodiorite Agd2	3 Ecca sandstone	4 Stormberg basalt
Mg O : Ca O	0.2	0.4	4.0	0.7

Origin of samples as in Tables 5.1 and 5.2

Thus the occurrence of the Swaziland solonetzes seems to be associated with high Mg : Ca ratios in the Ecca rocks rather than high sodium levels but detailed pedological studies are required to verify this. However, opinion is by no means unanimous that magnesium alone can lead to solonetz formation (e.g. Smith et al., 1949; Thompson, 1965).

Because it is a more competent rock and forms upstanding relief, drainage tends to be centrifugal off dolerite outcrops, and soils characteristic of the middle and upper slopes predominate. Thus dyke outcrops are generally covered with the heavy-textured lithosols of A (Lowveld) set or rocky ground (U set). Sill outcrops also give elevated topography, but this usually has a platform-type of structure, which gives much gentler slopes than on the dyke-formed ridges. The gentler slopes make for deeper and less well drained soils and the largest of these lithomorphic platforms, west of Phuzamoya railway station, is partly covered by an extensive area of K set black lithomorphic vertisols. This area also includes the subregion's only mapped V set, which is a deep topomorphic vertisol formed in colluvium or gully wash wholly derived from basic rocks. Other sills are generally thinner and outcrop over smaller areas. The dominant soils found on them are U, S(Lowveld) and K sets. Several cases were noted where the thinness of the sill was revealed by stream-lines which had cut right through to the Ecca sediments beneath. This has the effect of giving bottomland parent material of mixed origin, rather than being wholly dolerite, so that soils of Zikane series, rather than V set, are formed.

The 'contact' soils of the subregion, i.e. those developed on colluvium of mixed dolerite and sandstone derivation, are occassionally of the L set Red Fersiallitic loam type Generally, however, they fall into Z (Lowveld) set and the dolerite is thought to contribute to the clay fraction of the heavy subsoil, especially in Zwakela and Zikane series.

Vegetation and Land use: The subregion falls into two vegetation zones on the accompanying map (I'Ons, 1967). The western section, roughly corresponding with the outcrop of the granodiorite and with the Lset red loams, is mapped as Lower Broad-leaved Tree Savannah and such genera as Combretum, Erythrina and Pterocarpus are common. Compared with the Ophir Lowlands, however, Terminalia sericea is very rare. The eastern section falls into the Acacia Savannah. On the S (Lowveld) set and K set soils derived from the dolerites, Acacia nigrescens and Sclerocarya birrea are common, although Aloes are found on the shallower S (Louveld) set soils as well as on areas as U set. The vegetation on the duplex soils is heterogeneous with Combretums, Acacia nilotica, A. senegal, Spirostachys africanus and Dichrostachys cinerea and thickets of A. heteracantha and A. gillettiae on lower slopes. Grass cover varies widely but the veld is usually sweet grazing (Murdoch and Andriesse, 1964).

At present most of the area is given over to extensive cattle raising, both on Swazi Nation Land and individual tenure land. There is some citrus and cane grown on two estates, both irrigated by water pumped from the Usutu.

Land Capability: The large area of K set west of Phuzamoya and the areas of Z set on the Ecca sediments make the eastern part of this subregion the most extensive area of high rice potential on the North bank. As it is of low capability for other cropping systems (see Table 3.1), it would be the obvious choice for any large scale rice development, should there be sufficient water available.

The area of L set round Sipofaneni is land of high irrigable potential for all crops except rice, and the height of lift necessary to reach much of it with water pumped out of the Usutu is not excessive.

4 - Stratford Heights.

The name is taken from the cattle ranch in the subregion. This subregion corresponds with the Incandu Heights on the South bank (Murdoch and Andriesse, 1964).

Topographically it is broken country with a series of North-South aligned ridges. In the west there is a distinct, but discontinuous, west-facing low scarp. The rock forming this scarp is the thin quartzite band in the Lower Stormberg, which has been tentatively correlated with the Molteno quartzite (Murdoch and Andriesse, 1964). To the east the country rock is the Cave sandstone, followed by the basalts of the Stormberg series. The cave sandstone is the final sedimentary deposit in the Karroo System and marks a return to terrestial conditions. It is an aeolian deposit and consequently has a high content of fine sand. It lacks marked stratification and its outcrops weather to give a pitted surface. The relief in the subregion is nowhere sufficient to give any of the rock shelters for which the beds are known and named (Scogings and Lenz, 1961; Davies, 1961). The basalt has been subdivided on mineralogical grounds (Urie and Hunter, 1963), but only one type - the Lubuli basalt - is of importance on the North bank. Besides, it was found on the South bank that these subdivisions within the basalt are not pedologically significant (Murdoch and Andriesse, 1964). Both the Cave sandstone and the basalt are intruded by a swarm of dolerite dykes and it is these that give the North-South ridges and consequent broken country. The swarm peters out further North and this subregion does not run up to the northern watershed.

Soils: The steep slopes and the low rainfall lead to a preponderance of bare rock and shallow soils. The shallow lithosols developed on each of the major rocks are distinctive, although colluviation precludes an exact correspondence. The quartzite gives Otandweni series which is grey in colour and has a high coarse sand content. The Cave sandstone gives Ozhlandlu series which has a far higher fine sand content than other series in C set. The gentle brownish grey to pinkish grey colours are also distinctive. The dominant soils on the dolerite ridges and their basalt flanks are the heavy textured lithosols of S (Lowveld) set and U set, rocky ground.

In the narrow valleys there is sufficient accumulation of colluvium for deeper soils to develop. The type of soil formed depends on whether the dominant contributions to the colluvial parent material comes from the arenaceous sediments or the basic igneous rocks. In the bottomlands of the short valleys that drain westwards into the Mtendekwa and the Usutu, they are mostly the solonetzic duplex soils of Z (Lowveld, set, often Zikane series, which indicates the sedimentary origin of thoparent material. The basic colluvium in the valleys running south and east is much more widespread and gives narrow strips of R, C (Lowveld), K, and rarely, V sets. It is possible, in these valleys, to find the whole gamut of basic rock Lowveld soils, running from S (Lowveld) set (deeper, red clays), C (Lowveld) set (dark brown clays), K set (black lithomorphic vertisols) to V set (deep, topomorphic vertisols) within a few tens of yards. Naturally, it is impossible to map them all at a scale of 1:50,000, and only the most extensive of the series present is recorded. A commonly mapped sequence from ridge crest to stream line in the upper ends of the valleys is U set Somerling series - Cantebury series.

Vegetation and Land use: On the U, O and S (Lowveld) sets of most of the area Aloes and scrubby Acacia nigrescens are dominant. The grass cover is poor and the main genera present are Panicum, Urochloa, Digitaria and some Themeda (Murdoch and Andriesse, 1964; I'Ons, 1967). In the western valleys, the Z (Lowveld) set soils often have thickets of A. heteracantha and A. gillettiae. The deeper soils on basic colluvium support thin strips of parkland, made up of Sclerocarya birrea and larger specimens of A. nigriscens (Compton, 1966). In the lower reaches, the black clays of K and V sets may be marked by scattered fever trees (A. xanthoplea). The grass cover in the valleys is better than on the ridges, but it is of similar botanical composition (Murdoch and Andriesse, 1964).

At present there is no cultivation in this region and the whole area is used for extensive cattle farming.

Land Capability: The steep slopes and preponderance of shallow soils preclude economic irrigation, and the area is probably best left as cattle ranching country.

5 - Mtshelani Trough.

The name is taken from another ranch which is now the property of the Lifa fund. The subregion corresponds with the Umfulangwenya Trough on the South bank (Murdoch and Andriesse, 1964).

The whole area is underlain by the Stormberg basalt. This is mainly of the Lubuli type but, as was noted, there does not seem to be any significant pedogenetic difference between the various types. The basalt is intruded by dolerite dykes, but these are much more scattered than in the Stratford heights subregion and are more conspicuous in stream beds than as outcrops on the interfluves (Swaziland Geological Survey, 1957). The topography is gently undulating and reflects the relative absence of ridge-making dykes. The basalt is of low competence and does not hold sharp break-of-slope features. Nonetheless, the wide, flattened interfluves clearly represent the work of a Quaternary erosion subcycle previous to that responsible for the steeper valley slopes. This encroachment by rejuvenating valleys is shown in the Frontispiece of the South bank report (Murdoch and Andriesse, 1964).

Soils: The climate of this subregion is more arid than elsewhere in the survey area, and this results in a high proportion of shallow soils, despite the gentle topography. However, there are extensive areas of deep soils which are developed on colluvium wholly derived from basic igneous rocks. Because of the homogeneity of the parent material, the very distinct differences in the soils can be attributed to differences in topographic position and hence in the soil moisture regime. As well as receiving water from higher land, the bottomland soils are also enriched with bases and salts.

The distribution of soils within the landscape is clearly shown in the Frontispiece of Murdoch and Andriesse (1964). The only modification necessary in the light of the North bank surveys is at the break of slope between the older interfluve surface and the rejuvenating valley. The break of slope is rarely sharp enough to give an outcrop of U set bare rock, although there is often a strip of shallow soils (S (Lowveld) set) in this position. The diagram represents an idealised landscape section and, as we stressed in the original publication, it is quite possible that one or more members of the U set - S (Lowveld) set - R set - C (Lowveld) set - K set - V set sequence be elided, or be of such small extent as to be unmappable.

In the northern part of the subregion, the narrow strips of gully wash along the tributaries of the Myetane and Mkutshane develop to the deep black, calcareous clays of Valumgwaco series. In the South, however, the deposits are wider and where site drainage is poor, the naturally slightly saline Vimy series is formed. It is such sites that are liable to become very saline, and eventually alkaline, when over-irrigated. The largest areas, where man-made saline soils were found, are mapped as Youngsvlei series (Murdoch, 1961). It is now known that this salinity is not as permanent as was originally feared (Lea, Murdoch and Dicks, 1963). Leaching has redeemed many saline spots on Ubombo Ranches, without any need for chemical amendment.

Vegetation and Land use. The northern part of the subregion falls in the Acacia Savannah Zone and the southern part in the Dry Acacia Savannah zone (I'Ons, 1967). The vegetation on the middle and upper slopes of both regions is parkland with Acacia nigrescens and Sclerocarya birrea dominant. The grass cover is generally good and contains the genera Panicum, Digitaria, Urochloa and Themeda.

The Acacia Savannah zone corresponds roughly with the area where the bottomlands consists of long thin strips of the black clays of K set and Valumgwaco series. The stream lines are marked by scattered Acacia xanthoplea ('fever tree') and a thick grass cover.

In the Dry Acacia Savannah zone to the South, the bottomlands consist of wider expanses of V set soils, which includes a considerable proportion of Vimy series. The vegetation is distinctive with very dense thicket of Acacia gillettiae, with A. heteracantha and Euclea divinorum also present. The grass cover is very poor and occasionally absent, being replaced by ground succulents such as Aloe saponaria, (Murdoch and Andriesse, 1964).

This subregion is the most cultivated in the survey area. Along the Usutu and in the Lower Myetane there are large areas of canal-supplied sugar cane, serving the mill at Ubombo. There is also some irrigated citrus grown along the Usutu. On the Swazi Nation Land in the Upper Mkutshane and Myetane maize, cotton and sorghum are grown under dryland conditions. The remainder of the region is devoted to cattle ranching.

Land capability. The predominance of heavy-textured soils means that generally the limits on irrigability are imposed by low permeability and poor drainage rather than low available moisture holding capacity. C (Lowveld), K, and V sets are successively downgraded for the irrigated rotation as the proportion of 2:1 lattice clay minerals increases and reduces the permeabilities and infiltration rates. Most of these bottomland soils make excellent rice soils, except that the higher sodium levels in Vimy series makes it a risky proposition for the irrigation of any crop.

The irrigability of S (Lowveld) soils is problematical. They are very shallow, but have given good yields of cane on Ubombo (Murdoch, 1968). However, during the exceptionally dry period in January 1968, the cane on Somerling series at Harmony, on the South bank, appeared to be wilting severely. As irrigation water, rather than good irrigable land, will eventually limit the expansion of irrigated farming in

Swaziland, it would seem wisest to concentrate on the deeper soils such as R and C (Lowveld) sets and ignore the shallow soils. However, any extensive irrigation development in the Lowveld would undoubtedly command large areas of S (Lowveld) soils and it might prove uneconomic to leave this land unused. To meet this eventuality, the Ministry of Agriculture Research Division has laid down irrigation management experiments on these soils at the Lowveld Experiment Station, Wisselrode (J. A. Coulter, 1968).

6 - Cislebombo Ridges.

This subregion is a northwards continuation of the South bank subregion of the same name. The coined name has been retained as it is very apt in describing the geographical location (Murdoch and Andriesse, 1964).

The underlying rocks consist of alternating bands of andesite and basalt. There was obviously no long hiatus in volcanic activity between the extrusion of the basaltic and andesitic lavas, and there was a period of alternating lava types during the transition (Urie and Hunter, 1963; Hunter, 1961). The greater hardness of the andesites gives rise to marked positive relief features, the form of thin but persistent ridges running parallel to the main Lebombo escarpment. The form of these ridges depends on the local angle of dip in the rocks. Shallow dips (less than 20°) give cuesta features with a steep, West facing scarp and a gentle eastern dip slope, but steeper angles of dip give more symmetrical hogback ridges. The intervening valley floors are underlain by the easily weathered basalt (Murdoch and Andriesse, 1964).

Soils: There is much bare andesite outcropping on the ridges and the rest of their ground surface is very stony. The steeper flanks of the ridges are covered with medium-heavy textured lithosols in S (Lowveld) set. In the valleys deeper soils are formed on colluvial parent material. If the andesitic component of the colluvium is significant, D (Lowveld) set soils are found. These are lighter in texture and colour than soils derived wholly from basalt. They generally grade to redder colours and heavier texture with increasing depth, reflecting the increasing influence of the underlying basalt. Where the effect of the andesite is small or absent, the same toposequence of R set - C (Lowveld) set - K set - and, possibly, V set as occurred on basaltic parent material in the Mtshelani trough is found.

Vegetation and Land Use: The ridges are covered with Aloes and scrubby Acacia nigrescens and the grass cover is poor on the rocky ground. The valleys are covered with an A. nigrescens - Sclerocarya birrea parkland and have a good cover of 'sweet' veld.

On the South bank, some of the valleys are under irrigated sugar cane, but on the North bank, apart from the dryland cotton, maize and sorghum, there is no cultivation and the area is used for extensive cattle rearing.

Land Capability: The poor soils and steep slopes of the ridges restrict their use to extensive grazing. The valleys are rather narrow and steep sided but, where gradients permit, the reasonably drained soils of the middle slopes (R and C (Lowveld) sets) are fairly irrigable (see Table 3.1). The andesitic influence is beneficial and D (Lowveld) set soils are more permeable and, hence, flexible than those of R set.

7. - Mkiwane Terraces.

The name is taken from the citrus and sugar cane estate on the Usutu, south of Big Bend. It is also the siswati name for trees in the genus Ficus, and these are common in the gallery forest of the subregion (Murdoch and Andriesse, 1964). The subregion consists of the river terraces, and therefore stretches as a thin strip right through the survey area. These riverine areas have been separated from their hinterlands because they have more in common with other terrace areas than with the land at their backs. This separation is also found in the Land Systems Map of Swaziland (Webster et al., in preparation).

The terrace topography is quite pronounced with distinct bluffs between them, especially in the lower and younger deposits. There are places where the terraces show quite distinct levée features on the outer edges of the terrace tops. The terraces slope back from these levées to give troughs of interior surface drainage. A good example of levée in the upper (W set) terrace is found on Ubombo, East of Big Bend. On Bar J ranch, North of the Big Bend canal take off point, the levée on the lower (B set) terrace is about 20 feet high and has been breached by some ephemeral streams draining off the Stratford Heights, to give minature 'poort' (Afrikaans - gorge) features.

The soils formed on the alluvial parent materials of the terraces are quite young. As noted in Chapter I, the material of the upper terraces appears to have been subject to a period of humid tropical weathering in the Quaternary. This significantly weathered material gives the red fine sandy loams of W set. The most extensive soils is Winn series, which is well drained and shows incipient horizonation. Visselrode series occurs in the troughs of poor surface drainage at the back of some levée terraces. Poor drainage and the illuviation of weathering products from surrounding areas of higher elevation has led to the formation of some vertisolic characteristics, such as darker colours and a coarse blocky structure. However, the clay content is not sufficient to give slicken-sides.

The material laid down as the lower terraces was not subject to the tropical weathering. It is much more heterogenous than the upper terrace material and can have wide textural variation within short vertical distances. The commonest series within B set is Bushbaby which is mostly a pale brown loamy sand, but areas of Setusile, with a higher silt content, and Bona series, which has more coarse sand and gravel, are also found.

L (Lowveld) set soils are formed by the deposition of a thin alluvial cover onto a red clay profile of R set, which may or may not have been truncated by fluvial erosion. There are fairly extensive areas of Mhlova series on the South bank, but only one small occurrence of Msoko series was mapped on the North bank.

The low lying sand and gravel banks subject to current river action are all grouped as Xulwane series.

Vegetation and Land Use: The sharp breaks of slope bounding the terraces are marked by thin strips of gallery forest. These contain some of the largest trees in the survey area and these are of genera such as Ficus, Trichilia, and Syzigium. The flat surfaces of the upper(W set) terrace are covered by a non-distinctive bush with such components as Acacia spp., Euclea divinorum, Maytenus and scattered Ficus. The lower terraces in B set may have been beds of reeds and sedges which are predominantly Phragmites spp., but which may also contain Cyperus sp. and Pycreus sp. (Murdoch and Andriesse, 1964).

The upper terrace (W set) soils are favoured for irrigated sugar cane and especially citrus. In Swazi area, the Middleveld and Highveld practise of growing some of the crops on the lower, B set, terraces as an insurance against a dry year, is not followed in the Lowveld. Presumably a drier than average year in the Lowveld means a complete failure of crops anyway, no matter where they are grown.

Land Capability: The soils of Winn series have excellent irrigability characteristics for all crops except rice. They give the highest yields of all soils commonly used for sugar cane (Murdoch, 1968). Citrus especially will do very well on Winn series. The limited areas of Wisselrode series are not of such high potential and, although rice and sugar cane may do reasonably well, such drainage-sensitive crops as citrus and vegetables are not recommended (see Table 3.1).

The soils of B set on the lower terraces have excessive drainage for the economic irrigation of any crop except, possibly, citrus. However, even for citrus there are topographical hazards. One is the danger of inundation in very high floods and another is the night frost hazard, which can be severe in winter.

Areas of Soils and Land Capability classes.

The survey area is not broken down into subregions for purposes of areal measurement, because the boundaries of the subregions are not sufficiently precise. The soil mapping units used in the accompanying maps are listed alphabetically in Table 5.4 and the area mapped of each is given, the North and South bank figures are given separately as well as their combined total. As some of the North bank was only mapped at set level, the figure for the set can be greater than the sum of the areas of the differentiated component sets. The South bank soil map was only published with differentiation at set level, but series differences were noted in the field, enabling the authors to estimate the area of each series. This was not possible for series that were not defined as separate mapping units until after the time of the original publication (Murdoch and Andriesse, 1964).

Table 5.5

Areas of Soil mapping units in the Lower Usutu area

Series	Set	North bank	South bank	Total
		(In hundreds	of	acres).
Be		1	2	3
Bo			10	10
Bu		21	40	61
	B	23	52	75
Ca		113		113
	C(Lv)	156 *	83	239
Dt			2	2
De		t		t
	D(Lv)	5 *	2	7

Table 5.5 (Cont.)

Series	Set	North Bank	South bank	Total
		(In	hundreds of	acres)
Ek		21	12	33
Em			2	2
	E	21	14	35
Fc		2	10	12
	F	2	10	12
Gc		5	25	30
Gn			6	6
Gb			4	4
	G	5	35	40
Ha		30	30	60
Hl		t	240	240
	H	33 *	270	303
Jv		86		86
	J(Lv)	86	16 *	
Kz		72	60	132
Kt			5	5
	K	95 *	65	160
Lc		21	46	67
Ld		t	7	7
Lz		8	3	11
	L	30	56	86
Nh			26	26
Ns		1		1
	N	1	26	27
Ot		67	167	234
Om		20	120	140
Os		38	10	48
	O	124	297	421
Po		8		8
Pt			30	30
	P	8	30	38
Ro		109	214	323
Rt		5	40	45
Rs		1	15	16
Rk		9		9
Rd			2	2
	R	167 *	271	438

Table 5.5 (Cont.)

Series	Set	North Bank	South Bank	Total
		(In	hundreds of	acres)
So		324	385	709
Sh			53	53
Sk		20	50	70
	S(Lv)	566 *	488	1,054
Tn		1		1
	T(Lv)	11 *		11
	U	225	379	604
Va		21	29	50
Vm		17	8	25
	V	42 *	37	79
Wn		25	17	42
Wa			2	2
Ws		1		1
	W	26	19	45
Yo		1	t	1
	Y	1	t	1
Zd		83	81	164
Zl		32	8	40
Ze		1		1
Zn		7	20	27
	Z(Lv)	123	109	232
TOTAL		1,750	2,250	4,000

Notes: 1) t - denotes areas of <50 acres.
2) * - set figure includes areas not differentiated into series.

The percentages of the survey area covered by the most extensive soil sets are given in Table 5.6. These are compared with similar percentages for the whole of the Swaziland Lowveld and the Lowveld within the bounds of the Usutu basin (both from Murdoch, 1968).

Table 5.6

Percentage Distribution of commonest Soil sets in Lower Usutu area

Soil set	% of N. bank Survey Area	% of S. bank Survey Area	% of Whole area	% of Lv. within Usutu basin	% of Swaziland Lv.
S (Lv)	32	22	26	19	15
U	13	17	15	14	12
R	10	12	11	9	8
O	7	13	10	12	12
H	2	12	8	12	13
C (Lv)	9	4	6	6	6
Z (Lv)	7	5	6	11	12
K	5	3	4	4	4
J	5	1	3	2	2
L	2	2	2	3	3
V	2	2	2	2	2
B	1	2	2	2	2
W	2	1	1	1	1

The basis for assessing Land Capability on grounds of slope gradient and soil cover is outlined in Chapter III. The accompanying Land Capability maps for this area are for the surface irrigated rotation and paddy rice cropping systems. The low and unreliable rainfall precludes intensive dryland farming and the two irrigated systems are chosen to be as diverse as possible. The areas of the Land Capability classes are given in Tables 5.7 and 5.8.

Table 5.7

Areas of Irrigated Rotation Land Capability Classes in Lower Usutu Area

Class	North bank	South bank	Whole area
	Areas in hundreds of acres; (percentages of survey area in parentheses.)		
A1	55 (3.1)	98 (4.4)	153 (3.8)
A2	11 (0.7)	17 (0.8)	28 (0.7)
B1	150 (8.6)	280 (12.4)	430 (10.8)
B2	12 (0.6)	13 (0.6)	24 (0.6)
C1	199 (11.4)	139 (6.2)	337 (8.4)
C2	12 (0.7)	15 (0.7)	27 (0.7)
D1	728 (41.6)	899 (40.0)	1,627 (40.7)
D2	178 (10.2)	242 (10.[illegible])	420 (10.5)
X	405 (23.2)	547 (24.3)	952 (23.8)
Total	1,750(100.0)	2,250 (100.0)	4,000(100.0)

Table 5.8

Areas of Irrigated Rice Land Capability Classes in Lower Usutu area

Class	North bank	South bank	Whole area
	Areas in hundreds of acres; (percentage of survey area in parentheses).		
A1	146 (8.4)	230 (10.2)	376 (9.3)
A2	126 (7.2)	178 (7.8)	305 (7.6)
B1	49 (2.8)	16 (0.7)	66 (1.6)
B2	48 (2.7)	15 (0.7)	63 (1.6)
C1	118 (6.7)	212 (9.4)	330 (8.1)
C2	133 (7.6)	163 (7.2)	296 (7.4)
D1	245 (14.0)	196 (8.6)	440 (11.0)
E2	284 (16.2)	314 (14.0)	598 (15.0)
X	600 (34.3)	936 (41.5)	1,536 (38.4)
Total	1,750 (99.9)	2,250 (100.1)	4,000 (100.0)

References

Beater B.E., 1957; Soils of the Sugar Belt, Part I, Natal North coast, O.U.P., Cape Town.

Beckett P.H.T., and Webster R., 1965; A classification system for terrain, MEXE Report No. 872, Christchurch, England.

Brink A.B.A., and Partridge T.C., 1966; Sipofaneni Joint Soils Mapping project, Swaziland, unpublished.

Compton R.H., 1966; An annotated Check List of the Flora of Swaziland, J.S. Afr. Bot. Supp. Vol. No. VI.

Coulter J.K., 1968; Report on a visit to Swaziland made in 1967 (in preparation).

Davies D.N., 1961; The sedimentation features of the Karroo system in Swaziland, Bull. No. 1., 14 - 22, Swaziland Geological Survey and Mines Dept.

De Blij H.J., 1959; The Geomorphology of Swaziland, unpublished thesis, Northwestern University, Evanston, Ill., U.S.A.

De Blij H.J., 1960; A note on the relationship between the Swaziland Lowveld and its adjoining areas, Trans. Geol, Soc. S. Afr. Vol. 63, 175 et seq

De Villiers J.M., 1962; A study of soil formation in Natal, unpublished thesis, Univ. of Natal.

De Villiers J.M., 1965; The genesis of some Natal soils, II Estcourt series, S. Afr. J. Agri. Sci., 8, 507 et seq.

Hamilton G.N.G., 1938; Geology of the country round Kubuta, Swaziland, Trans. Geol. Soc. S. Afr., 41, 41 et seq.

Hunter D.R., 1957; Geology, petrology and classification of Swaziland granites and genisses, Trans. Geol. Soc. S. Afr. 60, 85 - 125.

Hunter D.R., 1961; The geology of Swaziland, Swaz. Geol. Survey and Mines Dept.

Hunter D.R., 1968; The granitic rocks of the Swaziland Precambrian (in preparation.)

I'Ons J.H., 1967; Veld types of Swaziland, Bull. No. 18, Swaz. Min. of Agriculture.

Jackson M.L., and Sherman D.G., 1953; Chemical weathering in soils; Advances in Agronomy 5, 219 et seq.

King L.C., 1960; Appendage to De Blij, 1960.

King L.C., 1962; The morphology of the earth, Oliver and Boyd, Edinburgh.

Lea J.D., Murdoch G., and Dicks A.V.M., 1963; Report on a salinity survey, Swaziland Lowveld, Swaz. Dept. of Agriculture, mimeographed.

Maud R.R., 1968; Quaternary geomorphology and soil formation in coastal Natal, in preparatbion.

Murdoch G., 1957; Report on a Reconnaissance of the Logo Trough, Sivunga, Swaz. Dept. of Land Utilisation, mimeographed.

Murdoch G., 1957; Reconnaissance of Sivunga Crown Land, Swaz. Dept. of Land Utilisation, mimeograpged.

Murdoch G., 1959; Note on the range of soils occurring in the western Lowveld of Swaziland, Proc. 3rd. interafr. Soils Conf., Dalaba, 1, 395-403.

Murdoch G., 1960; Soils of part of Tindekwa, Swaziland Dept. of Land Utilisation, manuscript.

References (Continued)

Murdoch G., 1961; Report on a Soil Survey of Ubombo and Bar Circle in the Swaziland Lowveld, Swaz. Dept. of Land Utilisation, mimeographed.

Murdoch G., 1962; Soils of Tambuti (South East Corner), Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1962; Soils of part of Big Bend Estate, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Soils of Tambuti (South Western Corner), Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Soils of Balegane Ranch, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Soil Survey of Bar Circle Ranch, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1966; Soils and land capability of the Ngcina R.D.A., Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1968; Soils and Land Capability of Swaziland, in preparation.

Murdoch G., and Andriesse J.P., 1964; A soil and irrigability survey of the Lower Usutu Basin (South) in the Swaziland Lowveld, Overseas Research Publication No. 3, Dept. Technical Cooperation, London.

Murdoch G., and Jackson P., 1964; Soils Survey of Diamond C. estate, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., and Jackson P., 1964; Soil Survey of Bar J estate, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., and Jackson P., 1964; Soils Survey of Riverbank Estate, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., and Murdoch E., 1958; Swaziland Meteorological data, Swaz. Dept. of Land Utilisation, mimeographed.

Scogings J.L., and Lenz C.J., 1961; The Karroo System of Sediments in Eastern Swaziland Bull. No.1, 84-91, Swaz. Geol. Survey and Mines Dept.

Smith, Beuhrer and Wickstrom, 1949; The effect of exchangeable magnesium on the chemical and physical properties of some Arizona soils, Soil Science, 68, 451 et seq.

Sumner M.E., 1957; Physical and chemical properties of Tall Grassveld soils of Natal in relation to their erodibility, unpublished thesis, University of Natal.

Swaziland Geological Survey, 1957; Geological Survey of Swaziland at the scale of 1:50,000.
(a) Sheet 2631 DA
(b) Sheet 2631 DB
(c) Sheet 2631 DD
Swaziland Geol. Survey and Mines Dept.

Swaziland Geological Survey, 1966; 1:125,000 Geological map of Swaziland, Swaziland Geol. Survey and Mines Dept.

Thompson J.G., 1957:, Granite soils in Southern Rhodesia, Rhod. Agric. Jnl., 54, 121 et seq.

Thompson J.G., 1965; The soils of Rhodesia and their classification, Govt. Printer, Salisbury.

Turner J.L., 1967; The mapping and study of certain geomorphological features of Natal and its adjacent regions, unpublished thesis, University of Natal.

<u>References</u> (Continued)

Urie J.G., and Hunter D.R., 1963;	The geology of Stormberg volcanics in Swaziland, Bull. 3, 28-44, Swaz. Geol. Survey and Mines Dept.
Vilenski D.G., 1960;	Soil Science, translated from the Russian by the Israel Programme of Scientific Translation, Jerusalem.
Way H.J.R., 1961;	Major Swaziland structures, Bull. No.1, 94-95, Swaz. Geol. Survey and Mines Dept.
Webster R., Murdoch G., and Lawrence C.;	Atlas of Land Systems in Swaziland, in preparation.
Whittig, 1959;	Characteristics and genesis of a solodised-solonetz of California, Pro. Soil. Sci. Soc. of America, 23, 469 et seq.

CHAPTER VI

Central Middleveld semi-detailed survey area.

The slope gradient map of the whole basin shows a large, relatively flat area in the Upper Middleveld, stretching on either side of the Mbabane - Manzini road. To the casual observer on the ground, the gentle relief of this area is enhanced by the contrast with the rugged Highveld mountains in the background. The Central Middleveld semi-detailed survey area included all of this tract of flattish land, and some of the hillier country in the Lower Middleveld downstream. This area was not all surveyed as one piece of field work, and the whole is made up of several projects of the Swaziland Soil Survey, carried out since 1956. A list of the locations and extents of these surveys is to be found in the Introduction. Of these component surveys, only that of parts of the Mdutshane Research Station has been formally published (Murdoch, 1965(a)) and the remainder are filed in the Ministry of Agriculture. These surveys were carried out in connection with such various projects as irrigation schemes, the selection of an area for industrial development, and railway land compensation. The ad hoc basis of these surveys resulted in rather awkward and irrational boundaries for their composite area. The field work of the writer in 1965-7 was aimed at filling in the largest of the gaps and extending some of the survey area to its obvious topographical boundaries.

The final boundaries along the feet of the Mdimba, Lupohlo, Nyonyane, Mtondozi and Makungutsha hill masses are so marked topographically that they choose themselves. The crest of the Skombeni - Njingo block of lower hills is also a fairly distinct topographical boundary. The eastern boundary of Usutu Forest and estate boundaries in the Tubunga area are the most prominent cadastral limits taken. The boundaries in the Peebles - Mkonyeni section at the lower end of the area are rather arbitary, but in general they are topographically determined to include the main areas of flatter land.

Description of the Area.

Geology.

The whole area is underlain by crystalline rocks of great age. These were originally classed as the infrastructural gneisses and synorogenic granites of one orogenic cycle, but they are now thought to result from two separate cycles. (Hunter, 1957; and private communication, 1968).

The rocks dating from the earlier cycle have since been subject to so much metemorphic activity that it is difficult to distinguish the remnants of the different phases of the cycle. However, it is now thought that the geosynclinal phase is represented by a wide range of rocks known as the Ancient Gneiss Complex. The most extensive of these rocks are the biotite and biotite-hornblende gneisses, but the Complex also includes metaquartzites, granulites, amphibolites, serpentinites and talc-chlorite schists (Hunter, 1961). Of these, only the metaquartzite does not occur as mappable outcrops within the survey area (Swaziland Geological Survey, 1957 and 1959).

The synorogenic granitisation cycle of the early orogeny gave rise to the more homogeneous granodiorite gneisses, which are intimately interdigitated with the geosynclinal rocks of the Complex. This intermixture has made it impossible to to separate these rocks at the 1:250,000 scale of the recent national geological map (Swaziland Geological Survey, 1966), but earleir and larger scale maps did differentiate the larger bodies of the amphibolite and the meta-sediments from the mass of gneisse rocks (Swaziland Geological Survey, 1957 and 1959).

Thus the two most extensive rock types within the Ancient Gneiss Complex outcrop are the biotite-hornblende gneisses, which contain quartz and oligoclase feldspar in addition to the named minerals, and the granodioritic gneisses which contain quartz, biotite, plagioclase and variable amounts of microcline (Hunter, 1968).

The granodiorites and quartz diorites underlying most of the western section of the area date from the synorogenic granitic cycle of the second orogeny (Hunter, 1968). The area is poor in outcrops because of the great depth of weathering, widespread colluviation and the gentle topography, but it is clear from the legends of the larger scale maps (Swaziland Geological Survey, 1959; Hunter 1961), that a variety of rocks are encountered. They are mostly pegmatised or charnockitic variants of granodiorite. These rocks are very rich in xenoliths of amphibolite and serpentite, both of which contain abundant hornblende. Common minerals in the granodiorite itself are quartz, plagioclase, biotite and hornblende (Hunter, 1961).

Both the granodiorites and the older rocks of the Ancient Gneiss Complex contain abundant pegmatites. These have been subdivided into two groups: the diffuse and the dyke pegmatites. The dyke structure indicates later emplacement, but this evidently took place over a long period, as it is possible to find outcrops showing dykes pegmatites of two obviously different ages (Hunter, 1957). The areas where the pegmatites are particularly abundant are mapped as the Pegmatite Complex in the large scale national geological map of 1959. The rocks so mapped are noticeably more competent than those surrounding and give rise to the hill masses of Sitshegu, Mokwane, and Sopanga kop (Swaziland Geological Survey, 1959).

In addition to the pegmatites, both the granodiorites and the Ancient Gneiss Complex are shot through with quartz veins and basic intrusions. The thicker quartz veins give positive relief features, but even the thin ones are disproportionately important in soil formation. The earlier basic intrusions are of diabasic composition and predate the deposition of the Karroo System. There are also post-Karroo doleritic intrusions. Both these rocks give rise to positive relief features such as Lupondo (diabase and Njingo (dolerite).

The Ag3 late-orogenic coarse granite only outcrops in the survey area as a very thin strip along the South-western boundary of the Ezulwini valley Its main effect derives from the zone of mineralisation along its contact with the older granodiorites. The occurrence of cassiterite in workable quantities gave rise to a small tin-mining industry in the early part of the century. The primitive washing methods used initiated severe erosion and some of the deepest and most extensive gullies in Swaziland are found in this area (Hunter, 1961).

The Ag5 prophyritic granite pluton that forms the Mdimba is post-orogenic and was emplaced after the sedond Swaziland orogenic cycle. The form of the scarp on the north eastern side of the Ezulwini valley appears to be largely controlled by the structure of the pluton but, in fact, it no longer marks the contact between the granite and the Ancient Gneiss Complex.

Scarp retreat since the Late Tertiary (Turner, 1967) has planed part of the granite outcrop, and the north eastern strip of the Ezulwini valley floor is underlain by the granite. The granite is riddled with quartz veins but is noticeably less intruded by basic rocks than the rest of the area.

Despite the great heterogeneity of the underlying rocks the soils of the area West of the main Ancient Gneiss Complex - Granodiorite contact, to the East of Sitshegu - Lupondo, seem to be developed on a relatively homogeneous intermediate (in the geological sense) parent material. Several factors tend to mask the differences inherited from the rocks. The land surface is thought to have been fashioned by Late Tertiary erosion, so that the regolith has been exposed to atmospheric weathering for a long period (Turner, 1967). The present climate is fairly humid and gives quite high leaching (see Table 1.5 for Ndutshane estimated leaching). It is thought that the climate may have been even more humid and tropical in Late Tertiary times than at present (De Villiers, 1962), so that the soils and their parent materials have been subject to the homogenising effect of a moist climate over a considerable period. In addition to the geomorphological age and the high leaching, homogeneity is increased by the widespread and deep-reaching effects of colluviation. The rock type can vary widely over short distances due to its age, complex metamorphism and long history of intrusion. Judging from the distance travelled by quartz gravel from the original verins, colluviation has moved material through considerable distances (possibly measurable in miles) in this landscape, so that the final parent material is of highly composite geological origin.

The parent material derived from the rocks of the Ancient Gneiss Complex to the East of the main contact is thought to be more acid (Murdoch, 1968). It is difficult to isolate the effect of the parent material on the type of soil developed because the eastern part of the survey area is also younger geomorphologically, more dissected topographically, experiences a drier climate at present and was not subject to the intense weathering in the Late Tertiary. However, the assumption that the rocks of the East are more acid is partly substantiated by the analyses in Table 7.1. By taking the main granodiorite - Ancient Gneiss Complex contact as the boundary between the intermediate and acid parent material zones, the Ancient Gneiss Complex rocks and the young porphyritic granite that floor the Ezulwini valley are included in the western, intermediate zone. The distribution of soils fully justifies this as the Ezulwini, Umtilane and Malkerns 'valleys' are of one pedo-landscape (Lobamba Land System of Webster et al., Murdoch and Lawrence). The chemical analysis shows of the A.G.C. biotite gneiss (Sample No.1) in Table 7.1 shows that the Ezulwini rocks are more intermediate than those of the larger outcrop to the East.

However, the inclusion of the granite (sample 5) and the rather siliceous granodiorite (sample 4 in the western zone suggests that the difference between the zones may be attributed to a greater density of basic intrusions, rather than to chemical differences between the matrix rock types. Alternatively, the parent material contribution to the variation in the soil distribution pattern may be negligible in comparison with those of the topographic and climatic differences.

Table 6.1

Chemical composition of some major rock types of Central Middleveld area

Sample No.	1 (West)	2	3	4	5	6 (East)	7
Rock Type / Composition	Ancient Gneiss Complex Biotite gneiss	Synorogenic Quartz Diorite		Synorogenic Granodiorite	Post orogenic Porphyritic Ag5 granite	Ancient Gneiss Complex Granodioritic gneiss	
SiO_2	59.21	55.53	56.91	71.51	70.03	70.56	70.85
Al_2O_3	16.67	20.43	19.04	14.40	13.97	14.35	15.32
Fe_2O_3	1.79	1.97	2.08	1.07	0.84	1.02	0.50
FeO	4.80	3.58	4.39	1.57	2.63	1.72	1.22
MgO	1.39	2.32	2.70	0.65	0.70	1.29	0.67
CaO	3.72	5.79	5.01	2.33	2.38	3.11	2.46
Na_2O	4.73	5.47	5.06	4.55	3.51	4.35	5.13
K_2O	5.47	3.26	2.27	2.40	4.85	1.98	2.83
H_2O+	0.96	0.60	1.58	0.86	0.46	1.08	0.73
H_2O-	0.12	0.06	0.13	0.12	0.11	0.05	0.05
TiO_2	0.93	0.72	0.88	0.27	0.50	0.29	0.39
P_2O_5	0.41	0.36	0.31	0.09	0.14	0.15	0.17
MnO	0.13	0.11	0.09	0.04	0.06	0.01	0.02

Origin of samples:

1 Ezulwini valley, 12 miles S.E. of Mbabane
2 Lozita-Avolitchi area, 5 miles W. of Manzini
3 Calaisvale area, 6 miles, W.S.W of Manzini
4 Umtilane valley, 10 miles N.W. of Manzini
5 Mdimba pluton, 1 mile N. of Mbabane
6 Mhlamanti area, 10 miles S.E. of Manzini
7 Mzimpofu area, 13 miles E. of Manzini

Samples 5 - 7 come from outside the survey area but, have been included for comparison.

Geomorphology.

The survey area consists of the remnants of an elevated well-planed erosion surface which is increasingly dissected towards the East. A discontinuous line of prominent, but not particularly high, hills marks a convenient boundary between the relatively undissected West and the more dissected East. The topographic zones so formed are:-

(i) The Western section:- rolling country, with wide interfluves of Late Tertiary (Turner, 1967) or, possibly, Early Quaternary (De Blij, 1959; Andriesse, 1960), age.

(ii) The eastern section:- rugged, broken country, summits concordant with the Western Middleveld Late Tertiary surface.

(iii) The Transition zone:- a line of hills stretching from Sitshegu, through Lupondo-Mokwane, across to the Mjingo-Skombeni watershed. The zone is considered to run northeastwards from Lupondo to Mjingo, rather than directly northwards to the Mdimba, in order that the Umtilane valley be included in the Western Section.

The boundary between West and East formed by these hills almost coincides with the major Granodiorite - Ancient Gneiss Complex geological boundary. As a younger erosion cycle encroaches upon an older surface from downstream (King, 1962), it is to be expected that the early stages of dissection of the Late Tertiary Middleveld surface should affect the Eastern Middleveld more than the West. However, the coincidence of the topographical transition with the geological boundary, especially across the Usushwane valley from Lupondo to Mjingo, hints at a degree of lithological control. The only large outlier of granodiorite in the eastern section forms part of the prominent Mendisa hill-mass, which is also evidence that the gneissic rocks of the East are less competent than the granodiorites. However, the converse is not found, and the gneissic rocks in the Ezulweni valley do not give noticeably more dissected country than the surrounding granite or granodiorites.

Fluvial Deposits.

Of the two groups of recognisable Quaternary terraces described in Chapter I, the upper (W set) terraces only occur extensively in the Peebles-Mkonyeni area, which is regarded as Lowveld rather than Eastern Middleveld. Traces of alluvial deposits that predate the W set terraces are also restricted to the bottom end of the survey area. They occur as patches and discontinuous beds of rounded pebbles and boulders. There is no suggestion of terracing in the slope form and all the fine earth material that may have been deposited has since disappeared. The material interstitial between the boulders is mostly angular coarse quartzose sand, colluvially derived from upslope. These deposits are commonest along the lower reaches of the Ngwempisi and Mkondo (Baillie, 1966).

The lower (B set) Quaternary terraces are found throughout the area but they rarely form continuous strips along the river. They were deposited in the meander bends of the course previous to the recent entrenchment, so that they occur as discontinuous pockets along the streams on the accompanying soil map.

Climate.

Details of the Basin's climate are to be found in another Appendix to the Consultant's Report. From this, it is clear that the climate of the East is considerably more arid than that of the West. The magnitude of the difference is shown in Table 6.2, which lists various climatic parameters and indices for stations typical of the two regions. The stations cited for the Eastern section - i.e. Mpisi is not actually in the Usutu basin but it is close to the northern watershed.

Table 6.2

Central Middleveld Climate

Station	Mdutshane (Western section)	Moisi (Eastern section)
Altitude - feet	2,500	1,300
Mean annual rainfall - inches (after Murdoch and Murdoch, 1958)	38.7	27.6
Mean annual temperature - °F. (after Murdoch, 1967 (a)).	66.9	68.1
Köppen classification (G. & E. Murdoch, private communication).	Cwb (Cfb)	Cwa (Cfa)
Lang's Regenfaktor	51 (humid)	35 (arid)
Thornthwaite Precipitation Effectiveness Index.	54 (semi-arid)	32 (arid-semi-arid)
N - value (see Chapter I)	1.1	2.5
Drought hazard i.e. percentage of years with less than 30 inches rainfall (after Murdoch and Murdoch, 1958).	12%	67%

The climatic transition from West to East is more gradual than the geological and topographical changes, but Table 6.2 indicates that the difference is considerable.

Subdivision of the Survey area.

The combination of differences in parent materials, landform and climate has given rise to distinct soil and vegetation patterns in the Western and Eastern sections, which are described separately below.

Western Section.

The landscape of this section consists of wide and relatively flat interfluves, which are connected to the valleys of the currently downcutting streams by gentle, convex slopes. The interfluves are remnants of a highly planed surface, thought to be of late Tertiary age (Turner, 1967). The dissection of this surface by stream incision took place in the Quaternary. The absence of scarp features and very steep slopes in the areas of dissection is attributed to the low competence of the deeply weathered underlying rocks. The depth of this intense weathering is shown by borehole drilling, which, in the Malkerns area, has gone through more than 100 feet of soft weathered material before striking fairly hard rock. The deep man-made gullies in the tin mining zone along the South-western side of the Ezulwini valley reveal up to 50 feet of very soft, highly weathered material. Of the rock types underlying the section, only the quartz veins have not weathered appreciably, and they extend to the present land surface as ribs of hard rock in otherwise soft material. The depth of weathering decreases near streams where recent erosion has stripped the soft material, and is greatest on the interfluve crests. The great depth of weathering is similar to that described in the Highland Sourveld region of Natal, which was attributed to a prolonged humid, tropical climatic phase in the Late Tertiary (De Villiers, 1962). If the same tropical climate is held responsible for the deep weathering in the Western Middleveld, then Turner's Late Tertiary (1967) age for the surface is preferable to De Blij's Early Quaternary dating (1959).

Quartz stone-lines are common in this section and the evidence of road-cuttings, where quartz veins are seen transformed into downslope stone lines as they approach the surface, suggests that they are of mainly colluvial origin. Anthills are common in the area but are of modest size compared with some of the termitaria of tropical Africa (Nye, 1955). Faunal segregation of the stones and gravel from the finer-textured material of the soil is thought to be subsidiary to the physical separation process during colluviation, as outlined by Murdoch and Andriesse (1964).

The distances travelled by the hard, angular quartz stones and gravel from their parent veins indicate that colluviation is very widespread and that there are virtually no soils in the area that are wholly residual (Murdoch, 1968). Even sites that are now the crests of interfluves have, at some stage, been recipients of colluvial drift. In the later stages of the planation of the Late Tertiary surface, and prior to the current dissection and stream entrenchment, the landscape must have presented a mature or senile appearance. In such a landscape it is possible for stream - and crest - lines to wander considerably, so that the streams need not always have followed their present courses. However, if the stream lines did wander in this way, it is surprising that no recognisably fluvial deposits are found above the level of the higher (W set) Quaternary terrace.

Where the area abuts against the Highveld scarp, e.g. the Mdimba, cones of unsorted hill-wash material have been deposited. This material contains a high proportion of fine earth, presumably derived from pre-weathering in the Highveld, but large boulders are also common. The present streams do not run over the faces of these fans, but rather down their margins, against the rock face of the scarp. The steep slopes up against the scarp, where there is no fan, give rise to shallower soils than are common elsewhere in the Western section.

There are discontinuous, relatively soft remnants of a ferricrete sheet on the Late Tertiary interfluves. These remnants are most extensive in the Umtilane valley, but have also revealed by building excavations at Lobamba in the Ezulwini valley. In addition, there are many mapped areas of ferricrete soils (G set) in the Malkerns area that do not occur on the flat interfluves. They often flank the truly hydromorphic soils (I set) in the present valley bottoms. These 'valley ferricretes' are thought to be of more recent formation than those on the crests, and caused by seasonal fluctuations in the local water-table.

The thick indurated sheet of ferricrete in the Ntondozi area to the south of the river is too extensive and massive to be caused by the fringe effects of minor streams.

Whole interfluves are mantled by this sheet and it is attributed to a hiatus in the general downward movement of base level in Quaternary times. There is no sheet of comparable extent in the Eastern Middleveld downstream, and the long Mtondozi hiatus may have been localised rather than basin - or country - wide. It is thought that the standstill in groundwater table movement was confined to, or very much protracted in, the area because of a lithological barrier to river downcutting immediately downstream of Mtondozi. There is a band of very mixed rock types, but mainly comprised of the Pegmatite Complex and pre-Karroo diabase intrusions, which are harder and more competent than the surrounding granodiorites. The resistance of these mixed rocks to sub-aerial erosion is shown by the upstanding relief of the Sitshegu - Lupondo ridge. The rocks are also more durable to fluvial abrasion, as is shown by the rapids in the river-gap between Sitshegu and Lupondo. They could well have constituted a barrier to the upstream movement of a nick-point (King, 1951), so that the area upstream was subjected to a period of stable river and groundwater levels. This period was long enough for a thick bed of iron concretions to form and coalesce in the zone of seasonally fluctuating wetness. The induration of the resulting ferricrete sheet was probably not synchronous with its formation but occurred in an ensuing period of soil dessication. The dessication followed a drop in the groundwater table once the barrier of very hard rock was eventually breached.

The areas of 'crest ferricretes' in the Ezulwini and Umtilane valleys are in the catchment of the Usushwane, which flows into the Usutu well below the Sitshegu - Lupondo rapids. These ferricretes are therefore not in the zone of influence of the postulated rock bar. This makes it difficult to establish any temporal or causal relationship between the Mtondozi and Umtilane ferricretes, but they may be of similar age, judging from their approximate concordance in altitude.

Soils.

The dominant soils of the Western section are deep, leached red loams and clay loams. The leaching intensity of the present atmospheric climate is high, as is shown by the figures for the Mdutshane Research Station in Table 1.5.

In the S.F.I. classification, most of these soils are ferrallitic, but the base status in some of the subsurface argillic horizons is possibly too high and they may grade towards fersiallitics (D'Hoore, 1964). In the current South African classification, the criteria for differentiation between fersiallitics and ferrallitics are not defined, but most of these Middleveld soils fall in the ferrallitic end of the Doveton Suite range, i.e. in the Farningham and Vimy families (Loxton et al., 1967). The general characteristics of the Swaziland soils are weak or apedal structures, friable consistence, low pH and base status, and clay fractions that are predominantly kaolinites and sesquioxides. They are infertile soils, and in addition, to the major plant nutrients, field and pot experiments have revealed multiple trace element deficiencies (Jackson, Venn and M'Ons, 1965).

These leached red soils are differentiated into sets largely on the presence or absence of layers liable to impede root growth. The most extensive is M set, which has no significant mechanical impediments. Gudzeni series (of G set) has a continuous, hard iron pan within rooting (and auger) depth. F set is characterised by a thick layer of iron concretions which are not coalesced into an indurated sheet. In J (Highveld) set there is a thick, compact stone line, usually within two feet of the soils surface. The stones are mostly quartz, but occassional pieces of granodiorite and other rocks also occur.

The soil sets have been built up by grouping similar series with minor textural, colour, or morphological differences. Thus the two most extensive series in the Western section are Malkerns and Mtilane, which are separated on the occurrence of a thin, sometimes discontinuous, quartz gravel layer in the latter. Although of minor importance in itself, the quartz gravel in Mtilane series often indicates a more acidic parent material for the topsoil and this difference leads to lower soil reaction and base status (see Chapter II). The differentiae for the other series are to be found in Chapter II.

The red soils of M, F, J (Highveld) sets and Gudzeni series cover the flatter interfluves almost entirely and also mantle a major part of the gentler of the convex slopes and the hill wash fans. It is in these sites that the homogenising effects of deep weathering and colluviation are strongest. The influence of differences underlying rock type on soil formation is weak and diffuse.

In areas of steeper slopes, erosion has stripped much of the colluvial and highly weathered material, so that the effects of underlying rocks are not so marked. Soils in these areas show greater variation than those formed in the areas of gentler gradient because of the greater heterogeneity of the parent materials. Most of the steeper gradients in the Western section occur in the areas close to the Highveld scarp or in the steeper areas of quaternary dissection. There are also scattered rock outcrops on the interfluves, where hard rock has resisted erosion and weathering, and these are also flanked by shallower soils.

In the areas up against the scarp, hard or only slightly softened rock is encountered within auger depth. The soils found fall mainly into O set (grey sandy loams), Z (Highveld) set, (red or yellow loams), or S (Highveld) set, (brown or dark red clay loams or clays). The soil type strongly reflects the acid, intermediate or basic nature of the rock.

In the more steeply dissected valleys a similar textural range is found. However, the soils are generally deeper, although still strongly influenced by the underlying rock type. On basic rocks the deeper clays of C (Highveld) set are found, although there are also patches of S (Highveld) set. The more acid rocks give soils of O set but Orrin series is much more extensive in the valley areas than it is up against the Highveld scarp. In this series the grey sandy loam overlies rather soft ferruginised, weathered rock rather than hard rock as in Otandweni series. Acid rocks also give P set, in which the weathering rock beneath a grey, sandy topsoil is clay enriched and imperfectly drained.

There is a considerable area of Q (Highveld) set soils beneath the western end of the Mtondozi massif. These soils contain abundant quartz gravel, which is spread diffusely throughout the profile rather than concentrated in a stone line as in J (Highveld) set. These soils derive from a parent rock rich in coarse quartz crystals and are often associated with pegmatites (Murdoch, 1968). In the Mtondozi area, however, it is thought that the quartz is derived from a particularly coarse phase of the porphyritic Ag5 granite.

Narrow gully wash deposits are found in the valley bottoms throughout the Western section, although they are currently being eroded out. The streams are perennial and the soils developed in the gully wash materials are truly hydromorphic and are mapped as I set. They are sometimes divided into series on textural grounds (e.g. Andriesse, 1960) but are not differentiated on the accompanying soil maps. Flanking the valley bottom strips of I set there are soils with characteristics of intermittent waterlogging, notably Atondozi series and G set.

The soils in the Atondozi area to the South of the river are somewhat anomalous. As noted above, this area is thought to have been subject to a prolonged period of water-logging due to a rock bar in the river downstream. The commonest soils are C and E sets, in which a coarse sandy surface horizon overlies an indurated and relatively continuous sheet of ferricrete. The sandy and quartzose of the surface horizon is not thought to be due to particularly quartziferous parent material. The thickness and extent of the ferricrete sheet indicate an abundant source of iron. Where gullies have exposed the underlying rocks, they appear to be granodioritic or gneissic and similar to those North of the river. The occurrence of C (Highveld) set in areas of recent dissection along the Usutu show that basic as well as intermediate and acid rocks are present. The quartzose surface horizon is attributed to the decomposition of eluviation of the alumino-silicate clay minerals and the high degree of segregation and concentration of the iron oxides in the ferricrete sheet.

An idealised section of the landscape of the Western section and its soil cover is shown in Figure 6 (a), (page 175).

Vegetation and Land-use.

The Western section of the area has a long history of settlement and has been the geographical centre of the Swazi nation since the move from Shiselweni in the early 19th century, except for a break when the capital was at Hoho (Murdoch, 196). This, combined with the present high desity of population (Jones, 1968) means that the 'natural' vegetation is very disturbed. This disturbance blurs ecological boundaries, but I'Ons mapped two distinct types (1967).

The Moist Tall Grassveld is mapped in the Ezulweni and upper Umtilane valleys, and in the higher parts of the Malkerns area. Common grasses are Hyparrhenia filipendula, Rendlia altera, Loudetia simplex and others, with Erogrostis spp, Sporobolus spp and Cynodon dactylon coming into the widespread areas of overgrazing. It is generally fairly open grassland but there are patches of scrub, with Acacia karroo, A. ataxacantha and Syzygium cordatum amongst the commonest species.

The rest of the area is mapped as Tall Grassveld. This is also fairly open grassland with Hyparrhenia filipendula, H. dissoluta, Eragrostis racemosa, Heteropogon contortus, and Cymbopogon excavatus amongst the commonest grass species. In the odd patches of bush, Euclea crispa and Dichrostachys cinerea are common.

Land use is intensive in this section but ther is no staple crop corresponding to sugar cane in the developed areas of the Lowveld. Pineapples are a promising crop but the acreage is limited by the capacity of the present cannery, which may not be expanded or replaced as soon as was hoped.

Avocadoes are difficult to market in large quantities and there are agronomic problems due to the crops' susceptibility to root diseases in soils of suspect drainage (Dodson, 1960). The quality of fruit from the citrus orchards in the Western section has been severely reduced by the virus disease 'greening'. Further plantings are discouraged by the Ministry of Agriculture (1967). There was a small but flourishing tung oil enterprise, but the slump in world prices following the reentry of China into the market in the 1950's caused the plant to close. There is some rice grown, which is irrigated by uncontrolled slope flooding. On the permeable soils of the area this method has an extremely heavy water requirement and is not officially encouraged.

On the Swazi Nation land, maize is the most important crop, and pumpkins, beans and a few other vegetables are also grown. The Ministry of Agriculture is encouraging the expansion of cotton into the Upper Middleveld. The King's Field, near Mahlanya, is used for demonstration purposes by the Ministry and it is now growing crops of maize, cotton and groundnuts.

Land Capability.

The combination of relatively gentle slopes, good depth, good drainage, high water-holding capacities and high permeability means that the red loams and clay loams are highly irrigable. They form one of the largest continuous areas of highly irrigable land in the whole country, and certainly the largest in the basin (see Murdoch, 1968). However, it is clear from Table 6.2 that the rainfall is of sufficient quantity and reliability for intensive dryland farming, although supplementary irrigation will always be useful. This coincidence of the largest area of highly irrigable soils and a climate that can support dryland farming poses one of the fundamental problems in the development of the basin's resources, i.e. should the limited water resource be used on land of low irrigability in the drier areas where the climate makes irrigation indispensable, or on better land receiving more rain where its effect is marginal and supplementary?

Whether they are irrigated or not, these red soils require heavy lime and fertiliser applications for successful intensive farming. As well as requiring N, P Ca, Mg and, to a lesser extent K, these soils are also deficient in some trace elements, notably zinc and molybdenum (Jackson, Venn and I'Ons, 1965; Jones and Murdoch, 1965).

The slopes in the riparian stetch at Ntondozi are the gentlest in the whole section, but the underlying indurated ferricrete sheet precludes intensive agriculture, and the area is best left as it is i.e. poor quality grazing.

The Transition Zone.

The line of hills that form the topographic transition from the planed West to the more dissected East are formed from rocks that have hardiness in common but which are very diverse chemically and mineralogically. Sitshegu and Lupondo are mixtures of the Pegmatite Complex and pre-Karroo diabasic intrusives. Mokwane is made up wholly of rocks of the Pegmatite Complex. The rocks of the Mjingo - Skonbeni ridge are mostly dolerites, of post-Karroo age in the South and pegmatised hornblende granites further North (Swaziland Geological Survey, 1957 and 1959).

Because of the steep slopes, erosion is rapid and shallow soils are common. These strongly reflect the chemical and mineralogical nature of the underlying rocks. There are large areas where bare rock outcrops at the surface and these are mapped as U set. On Sitshegu and Lupondo, the diabase gives rise to the fairly shallow clays of S (Highveld) set, mostly Sangweni series. The more acid rocks of Mokwane give rise to areas of the shallow sandy soils of O and P sets. The dolerites of Njingo are marked by areas of S (Highveld) and C (Highveld) sets. Towards Skomboni the rocks are more intermediate, and the, shallower soils formed fall into the medium textured Z (Highveld) set. However, there are large areas of deeper soils and these are mostly mapped as H and J (Highveld) sets, the latter being more common because of the abundant supply of coarse quartz derived from the pegmatites.

The slopes in this zone are too steep for irrigation and the lighter textured soils are too shallow. However, the heavy textured soils of C (Highveld) and, especially, S (Highveld) sets have given excellent results, under dryland farming. A numerical study of raingrown maize yields on Department of Agriculture demonstration plots revealed Sangweni to be the highest yielding of all Swaziland soils (Murdoch, 1968).

Eastern Section.

The landscape of this section is fairly broken and the streams have incised deeply into Middleveld Late Tertiary surface. Where the hills are capped by remnants of this surface, the country is rolling, with convex slopes. These summit remnants are characterised by very deep weathering. There are areas where this deeply weathered material has been removed entirely, and the hills have sharper crests and straighter slopes. There are areas of flatter land in the lowest part of the section, especially in the Nkonyeni - Mbiza area, which are thought to be planed by Quaternary erosion. They are, therefore, isolated inliers of the erosion bevel of the Western Lowveld.

The frequent occurrence of quartz stonelines is taken to show that colluviation is widespread. However, there is not the great depth of colluvial material that is found in the western section. The stone lines are generally shallow and they often grade directly into soft, slightly weathered rock, which still retains its gneissic structure. Greater depths of transported material accumulate in the valley bottoms as gully wash deposits.

There are areas of indurated ferricrete along both the Usutu and the Usushwana rivers. They may be contemporaneous with the Mtondozi sheet but they are not as thick or as extensive. This is because the hiatus in the downward movement of the ground water table was not prolonged by bands of hard rock, as is thought to have been the case in the Mtondozi area.

Soils.

The soils' parent material in the Eastern section is not nearly as weathered as that in the West. As well as experiencing a more arid climate at present, most of the landscape did not experience the Late Tertiary period of intense weathering (De Villiers)(1962). Only the summit romanants of the old Middleveld surface carry weathered mantles of depths comparable with those in the Western Middleveld. The greater dissection and steeper slopes mean that chemically weathered but physically detached material is more rapidly eroded than in the more gently sloping west, and does not accumulate in any depth except in the bottomlands.

U set bare rock is much commoner than in the Western section. The commonest soils on the steep middle and upper slopes are O and P sets. O set soils consist of a shallow coarse sandy surface horizon overlying hard rock (Otandweni series) or well drained slightly weathered rock (Orrin series). Road cuttings reveal that soils mapped at Otandweni are in fact more weathered at depth, but the immediate subsurface horizon is a quartz stone layer of such thickness (often more than 1 foot), that it is a completely effective mechanical barrier to plant roots or surveyor's auger. In P set the surface horizon is a grey sandy loam, which overlies weathering rock which has mottled grey-brown and rust colours and appears to be imperfectly drained. The upper parts of the weathering zone have a higher clay content than the horizons above or below it. The persistence of the original rock structure in this zone suggests that the clay is derived in situ by weathering rather than from illuviation. Where the sandy topsoil is deeper than 3 feet (90cms), P set grades into E set.

The basic and ultrabasic intrusions and xenoliths of the area give rise to soils with high clay contents. The deeper soils grade from C (Highveld) set in the higher and moister parts of the section to R set in the Lowveld areas around Mkonyeni. The shallower (generally less than 2 feet - see Chapter II) soils are mapped as S (Highveld) set in the higher areas, with S (Lowveld) set becoming more common as altitude and rainfall decrease.

Parent material derived from mixed acid and basic rocks or from intermediate rocks gives the red loams of M and L sets. M set tends to be confined to the Late Tertiary summit remnants in the higher and western part of the section. L set is more strongly structured and has a higher base status and pH than M set, bu the criteria for differentiation are not rigidly defined. Fortunately, in the zone where the transition occurs, i.e. between the upper fringes of the Eastern section and the inliers of the Lowveld, such as Mkonyeni, there are few occurrences of deep, red loams. Thus the sets form two distinct natural communities and an arbitrary division is not necessary.

The soils on the indurated ferricrete sheets are similar to those in the Ntondozi area and are differentiated into G and E sets. E set are defined as having at least 36 inches of grey coarse sand or gravel above the iron pan horizon whilst G set soils are shallower. The depth of coarse textured poorly drained material is thought to be the most important characteristic of the soil, and both clay pan and iron pan profiles are mapped as E set; hence the gradation into either G or P sets.

The streams in the higher part of the Eastern section are generally perennially wet, if not actually flowing. In these areas the undifferentiated hydromorphic soils of I set are mapped. In the lower parts of the area, the duplex soils of Z (Lowveld) and K sets are found. These are typical of the Lowveld and their occurrence shows that the climate is sufficiently arid for some of the bases to be merely redistributed within the landscape rather than entirely removed from it into the river system.

Vegetation and Land-use.

As in the Western section, a long history of settlement, fairly high present population densities, localised overstocking, and burning at too short intervals have blurred the ecological boundaries (I'Ons, 1967, Jones, 1968). The 'natural' vegetation grades from a fairly open grassland in the higher areas to an open savannah. Three vegetation types are distinguished in the accompanying vegetation map. The moistest type is the Tall Grassveld, which is an open grassland with occasional patches of Euclea crispa and Dichrostachys cinerea scrub. The commonest grasses are Hyparrhenia spp., Eragrostis racemosa, Heteropogon contortus, and Cymbopogon excavatus. The Dry Tall Grassland is also fairly open, but there are scattered large trees. These are very varied and include Acacia nilotica, Dichrostachys cinerea, Ficus spp. The commonest grasses are normally Hyparrhenias, but overgrazing causes them to be replaced by shorter grasses such as Aristida spp., Heteropogon contortus, Cynodon dactylon etc. The third and most arid vegetation type is the Upper Broad-leaved Tree Savannah and Hillside bush. This varies from an open tree savannah to dense bush on the steeper hill-sides. Common trees present are Sclerocarya birrea, Dichrostachys cinerea, Combretum spp., Pterocarpus angolensis etc. The grass cover is similar in composition to that of the Dry Tall Grassveld, but the Aristida spp. and other short grasses increase in importance at the expense of the Hyparrhenias (after I'Ons, 1967).

The Swazi Nation Land in the Eastern section is heavily cultivated. The commonest crops are maize, pumpkins, beans, groundnuts and some cotton. On the Individual Tenure land, small areas of maize and cotton are the only raingrown crops. In the Calaisvale block slope irrigated rice, citrus, and a small but flourishing area of youngberries are grown under irrigation. In the Peebles area, pump irrigation schemes are growing good crops of cotton and potatoes. However, neither the dryland nor irrigated crops account for large areas and much of the Individual Tenure land is given over to extensive cattle-rearing.

Land Capability.

The shallow, coarse textured soils and the generally steep slopes combine to give most of the area a low capability classification for irrigated farming. Only the small areas of deep red soils, in either M, L or W sets, can be recommended for the development of irrigation in view of the limited water resources of the basin.

Swazi farmers have shown a preference for new areas of the grey sandy soils of G and F sets for dryland maize cultivation in other parts of the Eastern Middleveld. This is thought to be due to chemical deficiencies in the long cultivated, more leached soils of M set, and the advantage of the shallow soils may disappear as they become increasingly exhausted by continual cropping or as the use of artificial fertilisers increases. The unreliability of the rainfall (see Table 6.1) precludes the development of intensive dryland farming over most of the area, but some of the lighter soils in the higher, moister area could be included in any large expansion of the pineapple acreage.

Areas of Soils and Land Capability classes.

In Tables 6.3, 6.4, 6.5 and 6.6 the subdivisions of the survey area are not separated for purposes of areal measurement. However, from the above description of the area and the accompanying maps it is clear that the distribution of the various mapping units is most uneven.

Table 6.3

Areas of soil mapping units in Central Middleveld area
(in hundreds of acres).

Series	Set	Area
Am		t
At		7
	A	7
Bc		3
Bo		t
Bu		33
	B	36
Cm		9
Co		4
	C(Hv)	13
Eb		3
Ek		30
Em		17
	E	50
Fr		1
Fu		22
	F	22
Gb		2
Gc		45
Gn		2
Gz		8
	G	56
Ha		11
	H	11
Jb		7
Jw		46
	J(Hv)	53
Jk		1
Jv		1
	J(Lv)	1
Kn		t
	K	t

Series	Set	Area
Ld		1
Le		8
Lz		6
	L	14
Ma		228
Mb		t
Md		13
Mt		172
Mv		7
Mz		5
	M	426
Nd		2
	N(Hv)	2
Or		51
Os		1
Ot		155
	O	207
Pb		15
Po		43
Pt		9
	P	67
Qb		t
Qo		9
	Q(Hv)	10
Ro		t
	R	t
Sa		29
Sp		t
	S(Hv)	29
So		2
	S(Lv)	2
Tx		1
	T(Hv)	1
	U	202

Series	Set	Area
Vs		1
	V	1
Wn		6
	W	6
Xu		1
	X	1
Za		t
Zo		10
	Z(Hv)	11
Zd		5
Zl		1
	Z(Lv)	6
TOTAL		1,327

Notes:

t = 0-50 acres

Set areas are taken by addition of the series areas before they are rounded to the nearest hundred acres.

In Table 6.4 the commonest soil sets in the survey area are listed and their frequency within the area is compared with that in the whole Middleveld region of the Usutu basin.

Table 6.4

Percentage Distribution of commonest soil sets in Central Middleveld area

Soil Set	Percentage of Survey Area	Percentage of Middleveld in Usutu basin (After Murdoch, 1968)
M	32	11
U	15½	35
O	15	19
I	7	4
P	5	5
G	4½	2½
J (Highveld)	4	2
E	4	2
B	2½	2
S (Highveld)	2	3
F	1½	1
L	1	2
Z (Highveld)	1	1
C (Highveld)	1	1

As intensive dryland farming is a distinct possibility for much of the area, the land capability maps were drawn for the irrigated rotation of annual crops and for the dryland maize - beans rotation. The areas of the land capability classes for each system are listed in Tables 6.5 and 6.6.

Table 6.5

Areas of Irrigated Rotation Land Capability classes in the Central Middleveld area

Class	Area (in hundreds of acres)	Percentage of survey area
A1	181	13
A2	123	9
B1	69	5
B2	75	6
C1	82	6
C2	98	7
D1	104	8
D2	154	12
X	440	33
Total	1,327	99

References

Andriesse J.P., 1959; Soil and land classification in Ezulwini valley with special reference to citrus grown under irrigation, Swaziland Dept. of Land Utilisation, mimeographed.

Andriesse J.P., 1959; The soils of Tung Oils, Swaziland Dept. of Land Utilisation, mimeographed.

Andriesse J.P., 1959; Soil survey of Peebles (South), Swaz. Dept. of Land Utilisation, manuscript.

Andriesse J.P., 1960; Report on a Soil survey of Malkerns valley.

Baillie I.C., 1966; Soil survey of part of Mbiza, Swaziland Dept. of Agriculture, mimeographed.

De Blij H.J., 1959; The geomorphology of Swaziland, unpublished thesis, Northwestern University, Evanston, Ill., U.S.A.

De Villiers J.M., 1962; A study of soil formation in Natal, unpublished thesis, University of Natal.

D'Hoore J.L., 1964; Soil map of Africa, Explanatory monograph, C.C.T.A., Lagos.

Dodson P.G.C., 1960; Report on the possibilities of avocado production in the Ezulwini valley, Tech. Comm. No. 2, Swaziland Dept. of Land Utilisation, mimeographed.

Hallsworth E.G., and Studies in pedogenesis in New South Wales VI., The ironstone soils, Jnl. Soil Science, 4, 24-45.

Hunter D.R., 1957; Geology, petrology and classification of Swaziland granites and gneisses, Trans. Geol. Soc. S. Afr. 60, 85-125.

Hunter D.R., 1961; The geology of Swaziland, Swaziland Geological Survey and Mines Dept.

Hunter D.R., The granitic rocks of the Swaziland Precambrian, in preparation.

I'Ons J.H., 1967; Veld types of Swaziland, Bull. No. 18, Swaziland Ministry of Agriculture.

Jackson P., Venn A.C., and I'Ons J.H., 1965; Responses on Swaziland soils to lime and trace elements, Proc. C.A.U. Symp. on Soil Fertility, 286-302, Khartoum, Sudan.

Jones H.M., 1968; Report on the 1966 Population Census, Swaziland Government, Mbabane.

Jones P.A., and Murdoch G., 1965; Review of soil fertility research in Swaziland, Pro. C.A.U. Symp. on Soil Fertility, 303-324, Khartoum, Sudan.

King L.C., 1951; South African scenery, 3rd edition, Oliver and Boyd, Edinburgh.

Loxton R.F. and associates, 1967; Soils classification project Eastern Transvaal Highveld, A.C.C. Tech. services Johannesburg.

Murdoch G., 1956; Soils of the Mdutshane Research Station, Swaziland Dept. of Land Utilisation, mimeographed.

References (Cont'd)

Murdoch G., 1958; Report on the soils of Bideledi and Dakeni lands, Tung Oils, Malkerns, Swaziland Dept. of Land Utilisation, mimeographed.

Murdoch G., 1960; Soil survey of Sitsheni, Swaziland Dept. of Land Utilisation, manuscript.

Murdoch G., 1960; Soil survey of a protion of Midlands, Swaz. Dept. of Land Utilisation, manuscript.

Murdoch G., 1960; Soils of the Calaisvale block, Swaziland Dept of Land Utilisation, mimeographed.

Murdoch G., 1962; Soil survey of Portion 6, Peebles, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1962; Soil survey of Matsapa, Swaziland Dept. of Agriculture, manuscript.

Murdoch G., 1962; Subdivision of Ross Citrus estate, Soils report, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Mkwelintaba Soils Reconnaissance, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Usutu Orchard, Soil map, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Lugoba - Soil series, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1963; Soil survey of part of Mkonyeni, Swaz. Dept. of Agriculture, mimeographed.

Murdoch G., 1964; Mkonyeni irrigability survey, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1964; Soils of Umbandzeni's Pride, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1964; Tung Oils Estate - suitability of soils and slopes for pineapples, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1965(a); Practical value of a soils series classification to agricultural research, Proc. S. Afr. Sugar Tech. Association.

Murdoch G., 1965; Lomahula Soil survey, Swaziland Dept. of Agriculture, manuscript.

Murdoch G., 1965; Soil survey of Marularidge, Swaziland Dept. of Agriculture, mimeographed.

Murdoch G., 1967(a); Amended long term mean annual temperatures for Swaziland, Dept. of Agriculture, mimeographed.

Murdoch G., 1967; Pineapple soils of Malkerns and environs, Central Swaziland, Dept. of Agriculture, mimeographed report.

Murdoch G., 1968; Youngberry soils of Tihlahla, Ministry of Agriculture, mimeographed.

Murdoch G., 1968; Soils and Land Capability in Swaziland, in preparation.

Murdoch G., and Andriesse J.P., 1964; A soil and irrigability survey of the Lower Usutu basin (South), in the Swaziland Lowveld, Overseas Research Publication No. 3, Dept. of Technical Cooperation, London.

References (Cont'd)

Murdoch G., and Dlamini R., 1962;	Malkerns Irrigation Scheme Extension to Bethany, soil survey, Dept. of Agriculture, mimeographed.
Murdoch E., and Murdoch G., 1958;	Swaziland meteorological data, Swaziland Dept. of Land Utilisation, mimeographed.
Nye P.H., 1955;	Some soil forming processes in the humid tropics, IV. The action of soil fauna, Jnl. Soil Science, 6, 63 et seq.
Swaziland Geological Survey, 1957;	Geological Survey of Swaziland at 1:50,000. Sheet 2631 AC " 2631 AD " 2631 CA " 2631 CB
Swaziland Geological Survey, 1959;	Geological map of Swaziland at 1:125,000.
Swaziland Geological Survey, 1966;	Geological map of Swaziland at 1:250,000.
Swaziland Ministry of Agriculture, 1967;	Annual Report of the Research division for the season 1965/6.
Turner J.L., 1967;	The mapping and study of certain geomorphological features of Natal and its adjacent regions, unpublished thesis, University of Natal.
Webster R., Murdoch G. and Lawrence C.;	Atlas of Land Systems in Swaziland, in preparation.

CHAPTER VII

Upper Ngwempisi survey area.

The 1:250,000 slope map of the whole Usutu basin shows that there is a large area of fairly gently sloping land set in the midst of the more rugged Highveld along the upper Swaziland reaches of the Ngwempisi, which is one of the major South bank tributaries of the Great Usutu.

The boundaries of the soil survey area are largely determined by the topography. The bases of the Highveld hills to the North and South form distinct breaks of slope, although there is no actual scarp feature, as in much of the Central Middleveld. In the East, the very rugged country of the Ngwempisi gorge marks an obvious boundary. The Western limit of the area is rather more arbitrary. On the North bank, the lower stretch of the Mponono river serves as the boundary, whilst on the South bank, the broken country to the West of Sidakeni is taken.

The area enclosed within these boundaries is about 57,000 acres in extent. Unlike the lower Usutu and the Central Middleveld survey areas, none of it had been surveyed prior to 1965, and it was done as one piece of fieldwork by the writer, mostly in early 1966.

Description of the Area.

Geology.

The area is mostly underlain by the very old rocks of the Ancient Gneiss Complex. In the rest of Swaziland this consists of an intimate intermixture of the biotite and biotite-hornblende gneisses, light and dark granulites, meta-sediments, amphibolites and serpentinites of the Complex itself and the granodioritic gneisses that resulted from its synorogenic granitisation. In addition to this mixture, there are two distinct mapped variants of the Ancient Gneiss Complex and they both outcrop in the Ngwempisi area. They are the hornblende granodioritic gneisses and the A.G.C gneisses with abundant injections of the Ag3 late-orogenic granite (Swaziland Geological Survey, 1966).

The normal A.G.C. mixture of gneissic rocks underlies the eastern part of the area. The commonest rocks in this group are the grey, synorogenic granodioritic gneisses. Within the survey area these gneisses tend to be coarse-grained and of more granitic appearance than those elsewhere in Swaziland. Common minerals are quartz, oligoclase, microcline and mafic minerals, but the relative proportions of these vary widely. Of the less granitised rocks that comprise the Complex proper, the most widespread are the biotite and biotite-hornblende gneisses (D.R. Hunter, private communication, 1968). However, the most conspicuous are the serpentinites which occur as much larger bodies than is common elsewhere in the country. There is a particular concentration of these large bodies in the valley of the lower Mtungulubi and in the hills to the Southeast of the lower Tawela (Swaziland Geological Survey, 1957 and 1959).

The hornblende granodioritic gneisses were originally mapped as the G3 porphyroblastic gneisses and were thought to post-date the infrastructural gneisses and granites (Hunter, 1961). The infrastructural gneisses have since been separated from the granites into the Ancient Gneiss Complex and the less-foliated granodiorites, which are now thought to have been formed in a completely separate and later orogenic cycle. The hornblende granodioritic gneisses are attributed to the earlier cycle and they thus predate the infrastructural granodiorites. They may even predate the synorogenic granitisation phase of the earlier cycle, as it is suggested that they arose as a basic pluton, which, because of its mineralogy and structure, was more resistant to granitisation than the surrounding rocks. Common minerals in the hornblende granodioritic gneisses are quartz, plagioclase, hornblende and biotite with sphene and apatite as prominent accessories. They are relatively hard rocks and outcrop in a wide belt of broken country running north-eastwards across the survey area (D.R. Hunter, 1961 and private communication, 1968).

The western section of the area is underlain by a complex mixture of gneisses and granites. The gneisses are mostly the grey synorogenic granodioritic gneisses from the earlier orogeny. The granites date from the late-orogenic phase of the second cycle and are mapped as Ag3. Those injected in the early stages show strong foliation, parallel to that of the surrounding gneisses. The later injections are manifested as dykes of coarse grained granite cutting across the foliation of the gneisses and earlier granite. The complexity of the geology is due to the almost parallel alignment of the gneiss-granite contact and the present land surface. The area was originally mapped as G4 granite (now named Ag3) with abundant gneissic augen and schlieren (Swaziland Geological Survey, 1959 Hunter 1961). It is now mapped as grey granodioritic gneisses with abundant Ag3 granitic injections. (Swaziland Geological Survey, 1966). Within this gneiss-granite mixture there are bodies of amphibolite especially in the area South of the river (D.R. Hunter, 1961) and these are of local importance in soil formation.

All the gneissic rocks underlying the area contain abundant pegmatites of no known economic importance. There are also stringers and veins of quartz so that weathering releases large quantities of coarse quartz crystals. The hornblende granodiorite gneisses are especially heavily pegmatised, and this rather masks their more basic composition, compared with the other gneisses. The mixed granite-gneiss in the Malangeni area and the grey granodioritic gneiss in the Velizezweni area are intruded by diabase of pre-Karroo age. There are other scattered diabase intrusions but nly in these two areas do they significantly affect soil formation.

The chemical compositions and mineral norms of the commoner rocks of the area are listed in Tables 7.1 and 7.2.

Table 7.1

Chemical composition of the rocks of the Upper Ngwempisi Area

Sample No.	Grey granodiortic gneisses		Hornblende granodioritic gneisses		Ag3 granite
	1	2	3	4	5
SiO_2	71.0	71.9	62.5	68.4	73.8
Al_2O_3	15.5	13.7	14.9	15.5	14.3
Fe_2O_3	0.7	1.0	1.2	0.8	6.5
FeO	1.8	1.6	4.3	2.3	1.1

Table 7.1 (Cont'd)					
Sample No.	Grey granodioritic gneisses		Hornblende granodioritic gneisses		Ag3 granite
	1	2	3	4	5
MgO	0.8	1.2	4.4	2.0	0.4
CaO	3.5	4.2	6.2	3.2	1.0
Na_2O	4.6	4.7	4.0	4.8	4.0
K_2O	1.2	0.9	1.3	1.9	4.6
H_2O+	0.6	0.4	1.1	0.8	0.6
H_2O-	0.1	0.1	0.1	0.1	0.1
TiO_2	0.3	0.5	0.5	0.3	0.1
P_2O_5	0.1	t	0.2	0.1	t
MnO	t	t	0.1	0.1	t

Table 7.2

Mineral Norms of the rocks in the Upper Ngwempisi Area

Sample No.	1	2	3	4	5
Quartz	27.6	27.9	13.8	20.4	28.1
Orthoclase	7.3	5.6	7.5	11.0	27.5
Albite	41.8	42.5	35.7	43.5	35.5
Anorthite	17.2	13.7	19.1	15.2	5.0
Corundum	0.3	-	-		1.1
Diopside	-	5.6	8.6	0.6	-
Hypersthene	4.7	1.9	9.9	8.5	2.1
Magetite	0.7	1.0	1.3	0.1	0.4
Ilmentite	t	0.7	0.8	0.4	0.2
Apatite	0.3	0.1	0.3	0.2	-

Origin of samples:

1. Tawela river (Hunter, 1957).
2. Mbolwane area (Hunter, 1961).
3. South of Sidakeni area (Hunter, 1961).
4. Ngazini area (Hunter, 1957).
5. West of Mankaiana town (Hunter, 1957).

Although they are actually outside the survey area, the belt of hard rocks, through which the Ngwempisi has cut its gorge, are thought to have indirect effects on soil formation within the area. The lower area of the gorge is cut into the post-orogenic Ag5 porphyritic granite. The upper reaches run through the gabbros and pyroxenities of the Usushwane Complex (Swaziland Geological Survey, 1966; R.P. Edwards private communication). Both these widely differing rock types are highly competent and they are thought to indirectly affect the survey area in two ways. Firstly, the hills of the Madashane - Mtungulu block form a rainshadow over the eastern section of the area. The second effect is a postulated standstill in river level in the Early or Middle Quaternary due to a rock bar in the gorge section of the river.

Landform.

The area consists of a basin which ranges in altitude from 3,600 to 2,700 feet. It is set in the midst of rugged Highveld hills, the summits of which range from 4,000 to 4,700 feet. The surface capping the concordant Highveld hills is of Late Tertiary age (De Blij, 1959; Turner, 1967), although some of the very highest hills, such as Zwartkop to the North and Mtungulu to the Southeast, may carry remnants of the Early Tertiary 'African' surface (De Blij, 1959). The rather broken floor of the basin is thought to have been fashioned by either very Late Tertiary or Early Quaternary erosion. These tentative datings for the basin correspond with those for the Western and Eastern sections of the Central Middleveld.

Although lower than the surrounding hills, the basin is not particularly flat and it varies from rolling to quite rugged country, although the relief is generally moderate. To some extent the terrain varies with the underlying rock type. The 'normal' non-granite intruded gneisses in the East give fairly dissected country with straight or slightly convex slopes. This terrain is similar to that found in parts of Eastern section of the Central Middleveld. There is no extensive flattening of the interfluve crests although they exhibit concordance. The large amphibolite bodies in this block of gneisses generally outcrop in areas of upstanding relief, but this is variable and the landform of the lower Mtungulu valley is not thought to exhibit strong lithological control.

The hornblende granodioritic gneisses seem rather harder than the surrounding rocks and give a belt of higher, more rugged country. Rock outcrops are common, often in the form of small tors (Hunter, 1961).

The only extensive flattish area in the basin occurs at Musi-Sidakeni and is underlain by the Ag3 granite intruded grey granodioritic gneisses (Swaziland Geological Survey, 1966). It is thought that the granitic component is dominant in the Musi section. The landform of the Musi section is similar to that of the Western section of the Central Middleveld, with wide relatively flat interfluves and convex slopes down to the streams. The rock in the area appears to be deeply weathered, although there are no deep boreholes to confirm this.

The very widespread occurrence of thick quartz stone lines overlying weathered, but still structured, and therefore in situ, rock indicates that most soil material is transported. The great density of old anthills, revealed by the vertical air photographs in areas where stone-lines are shallow, suggests that faunal segregation as well as colluviation may be an important process in stone-line formation (Nye, 1955). The abundant pegmatites are the major source of the coarse quartz fragments.

Thick ferricrete sheets are found in the Mhalatane valley and on both banks of the Ngwempisi north of Musi. The soils of G set actually form a smaller fraction of this survey area than they do of the Central Middleveld area ($3\frac{3}{4}$% versus $4\frac{1}{2}$%) but it is thought that the more broken terrain rather than the lack of a ground-water level hiatus precluded the formation of more extensive sheets (Hallsworth and Costin 1953). The sheets in the area are very massive, by Swaziland standards, and an exposure in the lower Tawela valley is at least 8 feet thick.

Alluvial deposits.

The lower of the Late Quaternary terraces is poorly expressed and the fraction of the area covered by its characteristic B set soils is small. In contrast, the upper, W set, terrace is relatively extensive for an Upper Middleveld area. The soils tend to be slightly heavier than the W set soils of the Lowveld.

In addition to these two levels of Late Quaternary terraces, there are considerable remnants of earlier deposits. Along the lower stretches of the river within the survey area, especially on the Ncoseni Crown Land (No. 196) on the South bank, there are extensive beds of rounded boulders. These may be as high as 200 feet above the present river level. As there is no trace of terracing in the topography, it is assumed that erosion has been active for some time. Thus the boulders may already have been moved diagonally downwards since the deposition. Similar, but less extensive, boulder beds are found in the very lowest reaches of the Ngwempisi and the Mkondo in the Central Middleveld area. Further afield, Barradas noted beds of rounded stones high above the red fine-sandy alluvial terrace on the Limpopo in Moçambique (Barradas, 1962).

There are fairly large areas of deep, red soils, especially along the Badzeni-Ncoseni stretch of the river, which may be of alluvial origin. They are much higher above the present river level than any W set soils and no trace of terraced topography is apparent, but their alignment along inside river beds and the occurrence of some rolled Middle Stone Age artefacts in an exposed profile at Badzeni suggest alluvial rather than colluvial deposition. However, it is not thought that the deep, red soils at Musi are alluvial as has been suggested (Beggs, 1964). If they are alluvial as the Badzeni-Ncoseni red soils have developed to become indistinguishable from the colluvial soils of H and J (Highveld) sets, and have been mapped as such. This disappearance of recognisably alluvial characteristics, such as high silt or fine sand contents, is also found in the Lowveld (see chapter V, and Murdoch, 1963).

There is a large area of alluvial deposits in the Sidakeni area. These are spread out for a considerable distance away from the present river and the shape of the area suggests that it was once a flood plain or, possibly, a lake. There is a knoll rising out of the deposits which is clear of them and it is mantled by the normal colluvial soils of the vicinity. It is supposed that it was an island. The deposits show strong textural stratification, but the coarser particles are only slightly rounded. There is a very much smaller area of similar deposits just across the river, on the North bank. The deposits are being dissected by the current erosion cycle. The Mtagane and its tributaries have cut steep walled gullies in the main South bank deposits, revealing up to 30 feet of alluvial material, but the deposits vary in thickness, according to the topography prior to inundation and the intensity of erosion since emergence.

These thick alluvial deposits, the high level beds of rounded boulders, and the thickness of the ferricrete sheets all suggest that there was a considerable period of base level stability in the Early or Middle Quaternary. Traces of similar hiatuses are found on other Swaziland rivers, but only in certain localised areas, such as Mtondozi (see Chapter VI), are they strongly expressed. The widespread distribution and thickness of the deposits in this survey area suggest that a (or the) hiatus was very much prolonged in the Ngwempisi area. Because the prolongation was localised to the Ngwempisi, local factors were held responsible. It is thought that the period of base level stability was caused by a downstream band of hard rock, which prevented the inland movement by a nick point (King, 1951). There are only two feasible bands of rock that could have held up a nick point for any length of time. The resistance of the hornblende granodioritic gneisses to sub-aerial erosion is shown by the belt of broken country they form. The river passes through this terrain in a series of minor rapids, indicating a resistance to fluvial abrasion. However, these rapids are upstream of the Mhlatane ferricretes and the beds of boulders, although they are below the Musi ferricretes and Sidakeni deposits. The more likely site of the rock bar is in the Ngwempisi gorge, where the river cuts through the hard basic and ultrabasic rocks of the Usushwana Complex and further downstream, through the younger post orogenic Ag5 porphyritic granite. The river falls at over 70 feet per mile in the gorge section (from the Mtimane to the confluence with the Usutu), compared with approximately 25 feet per mile fall in the survey area (from the Mponono to the Mtimane). The steepest rapids are in the upper end of the gorge, where the rock is mostly fine-grained gabbro. There are outcrops which are conspicuously dificient in feldspars and they are probably pyroxenites (Swaziland Geological Survey, 1966; R.P. Edwards, private communication, 1968). The resistance of these rocks to abrasion by river action is evidenced by the sheen they develop in the rapids.

Climate.

Unfortunately there are no meteorological stations within the survey area, although rainfall is recorded at Mankaiana town, just to the North. The mean annual rainfall at Mankaiana is 36.1 inches, which is fractionally greater than that of Manzini (after Murdoch and Murdoch, 1958). On grounds of altitude and from the ecological evidence, the temperatures at Mankaiana town and in the Western section of the survey area are thought to be lower than those of the Central Middleveld and nearer to those recorded at Goedgegum in the South of Swaziland (I'Ons, 1967). Some pertinent climatic data are listed in Table 7.3.

Table 7.3

Climate of Mankaiana and some comparable stations

Station	Manzini	Mdutshane	Goedgegun	Mankaiana
Altitude - feet	2,000	2,500	3,300	3,300
Mean annual rainfall - inches (after Murdoch and Murdoch, 1958).	35.9	38.7	33.7	36.1
Mean annual temperature °F (after Murdoch and Murdoch, 1958).	67.8	66.9	64.3	N/A
Vegetation zone (after I'Ons, 1967).	Tall Grass veld	Moist Tall Grassveld	Upland Tall Grassveld	Upland Tall Grassveld

The combination of the lower rainfall and the slightly lower temperatures are thought to give a soil leaching regime similar to that of the Western Central Middleveld (see Table 1.5).

Within the survey area, the climate becomes warmer and more arid to the East, and the climate of Mankaiana town is typical only of the Western section. At the Eastern end of the survey area there appears to be a strong rain-shadow effect and the mean annual rainfall may be as little as 30 inches. The red, medium textured soils have moderate, rather than weak, subsoil structures and the vegetation is typical of the drier parts of the Middleveld. The hill masses of Ntungulu and Madashane block the area from all directions except to the West.

Vegetation and Land-use.

Three veld types have been distinguished within the survey area. The Upper Broad-leaved Tree Savannah and Hillside Bush stretches right up the gorge from the Lowveld around Nkonyeni and just encroaches into the rain-shadow belt in the East. Common trees and shrubs are Dichrostachys cinerea, Combretum spp, Pterocarpus angolensis, and Ficus capensis. The grass cover is rather poor and includes Hyparrhenia spp., Pogonarthia squarrosa, Heteropogon contortus and Aristida congesta.

The rest of the survey area is covered by fairly open grassland. The Tall Grassveld occurs in the Eastern part. Common grasses are Hyparrhenia spp., Eragrostis racemosa, Sporobolus capensis, Heteropogon contortus and Cymbopogon excavatus. There are small patches of scattered bush, in which the commonest trees are Euclea crispa and Dichrostachys cinerea. The higher and cooler Western section of the area is covered by the Upland Tall Grassveld. In Swaziland this has only been mapped in this area and around Goedgegun and is transitional to the Highveld Sourveld. Common grasses are Tristachya hispida, Hyparrhenia filipendula, Trachypogon spicatus, Eragrostis racemosa and Setaria nigrirostis. Very few trees are found and these are mostly Acacia spp. (after I'Ons, 1967).

The survey area is almost entirely Swazi Nation land and is farmed under the traditional tenure system. The commonest crops are maize, beans and pumpkins. There are small vegetable and fruit gardens, often irrigated by small furrows drawn off minor streams. As yet, there is little cotton grown, but the acreage is increasing. The Mooseni Crown Land (No. 196) to the South of the river is leased to a Transvaal farmer. Transhumance is practised and the land is only occupied and grazed in winter.

The Soils.

The climatic and ecological patterns are similar to those in the Central Middleveld although the range is not as great. There is also a vestigial similarity in the topographic pattern but the terrain is really too broken to exhibit as clear differences as those between the Western and Eastern sections of the Central Middleveld area. As might therefore be expected, the distribution of soils in the two survey areas also shows some similarities.

In the Western part of the area, the flatter terrain around Musi is mantled with deep, red, leached loams - clay loams. The commonest soil sets are H, J (Highveld) and F, Ezulwini valleys. The soils have weak structures or are apedal and have a friable consistence, even when dry. Further East the deep red soils occur in smaller pockets except for the belts of possibly alluvial origin close to the river. These soils are also mapped as H and J (Highveld) sets but they are slightly more fersiallitic than those around Musi. They have moderate subsoil structures and a slightly hard consistence when dry. Unfortunately, no samples from this area have been chemically analysed, so their pH and base status are not known. Indicator testing in the field showed them to be quite acid, with pHs of less than 6.

There are some small areas of P set, especially Peebles series, in the Eastern part of the area, but these soils are not nearly as extensive as they are in the Eastern section of the Central Middleveld.

These similarities to the Central Middleveld area are somewhat masked by the very widespread distribution of shallow or stony soils. The most extensive soils in the areas are those of U set (bare rock), O set (shallow, sandy soils) and J (Highveld) set (thick stone-line soils). These soils predominate because of the rather broken topography and steep slopes and because of the large quantities of coarse quartz released by the weathering of the heavily pegmatised rocks. Within O set, the proportion of Otandweni series (grey shallow loamy coarse sand over hard rock) is surprisingly high for such a high rainfall area. Erosion gullies reveal that many of the soils mapped as Otandweni series have certain morphological affinities to Orrin series or J (Highveld) set. The profile consists of a grey, loamy coarse sand of less than 12 - 18 inches depth, overlying a very thick and impenetrable stone-line, usually of angular quartz. The rock under the stone-line is weathered and often reddish in colour. However, the stone-line is completely impenetrable to the auger and the degree of weathering of the underlying rock is impossible to determine away from gullies. As the stone-lines are also an effective mechanical barrier to root penetration, reclassification of these soils will not affect their land capability rating. The Otandweni series soils in the Eastern end of the region are more like those of the Lowveld, with hard bedrock occurring within the top two feet.

The preponderance of stone-line soils in this survey area is shown in Table 7.4, in which the ratios of the areas of various soil mapping units to those of their stone-line analogues are compared for the Mgwempisi and Central Middleveld survey areas. For the purposes of this comparison, Otandweni series is regarded as the stone-line equivalent of Orrin series.

Table 7.4

Stone-line soils in the Upper Mgwempisi and Central Middleveld areas

	Mgwempisi	Central Middleveld
J (Highveld) set area / M set area	1.08	0.12
Peebles series area / Pofane series area	2.55	0.35
Otandweni series area / Orrin series area	3.42	3.04

The amphibolites in the Mtungulubi valley give rise to areas of dark coloured, heavy textured soils. As well as B (Highveld) and C (Highveld) sets, there are quite extensive areas of King series. This is a blocky, black cracking clay, which differs from the Lowveld members of K set in that it is non-calcareous to some depth from the surface.

The alluvial deposits at Sidakeni are highly stratified and very heterogeneous, as is shown by the simplified profile description in Table 7.5.

Table 7.5

Stratigraphy of a profile in the Sidakeni deposits

Depth (in feet)	Material
0 - 1	Dark grey brown clay
1 - 3	Light brownish grey gritty clay
3 - 6	Alternating bands of gravel and loamy coarse sand
6 - 6½	Pale yellow silty loam
6½ - 7	Dark grey silty clay loam
7 - 8	Light grey silty clay loam
8 - 8½	Gritty coarse sand
8½ - 9	Pinkish grey coarse sand
9 - 11	Alternating bands of gritty sand and stones
11 - 14	Brownish yellow loamy coarse sand
14 - 16	Pale grey clay
16 - 17½	Light brownish grey clayey coarse sand
17½ - 19	Yellow silty clay
19½ - 22+	Light grey clay

The deposits have been somewhat eroded since emergence and the present land surface undulates more than the strata. This means that the nature of the material exposed at the surface can vary greatly within short distances. However, the soils have all been mapped as T set (hydromorphic soils). Abundant rust mottling, which is omitted in the colour descriptions in Table 7.5, indicates that the soils have poor profile drainage and most of the area away from the deep gullies has poor external drainage.

X-ray diffractograms made on the deferruginised clay fraction of a black heavy textured soil at Sidakeni revealed a high proportion of montmorillonite, as well as a lesser quantity of kaolinite and a trace of gibbsite. Originally the profile had been put into Ingoje series (heavy textured mineral hydromorphic soil) as standing water was found at 3 feet. The soil is actually in Vuso series, which is a deep non-calcareous swelling black clay. It is thought that the montmorillonitic clay minerals are derived from the gabbros or amphibolite to the West, or from the amphibolites in the hills to the South, in which the Mtagano and its tributaries rise (Beggs, 1964).

The areas of the soil mapping units found in the area are listed in Table 7.6.

Table 7.6

Areas of Soil Mapping Units in the Upper Ngwempisi Area
(in hundreds of acres)

Series	Set	Area	Series	Set	Area	Series	Set	Area
Al		1				Po		2
At		2		I	30	Pb		5
	A	3				Pt		1
							P	8
Bc		t	Jb		2	Qo		5
Bu		6	Jw		59	Qb		t
	B	6		J (Hv)	61		Q (Hv)	5
Co		2	Kn		2	Sa		13
Cm		4		K	2	Sv		6
	C (Hv)	6					S (Hv)	13
Eb		t	Ma		33		U	224
	E	t	Mt		20			
			Md		3	Wn		6
Fu		3	Mo		t		W	6
Fr		2	My		t			
	F	5	Mz		t	Za		t
				M	57	Zb		6
							Z (Hv)	7
Gc		7	Ol		5			
Gz		4	Ot		90			
Gn		8	Or		26	T O T A L		567
Ge		1	Ck		1	Note:		
Gb		1		O	121	t = 0 - 50 acres		
	G	21						

In Table 7.7, the fractions of the survey area covered by the most extensive soils sets are compared with similar fractions for the Central Middleveld survey area and for the Middleveld physiographic region of the whole Usutu Basin (after Murdoch, 1968).

Table 7.7

Percentage distribution of the commonest soils in the Upper Ngwempisi area

Soil Set	Percentage of survey area	Percentage of Central Middleveld survey area	Percentage of Middleveld in whole Usutu basin
U	39½	15½	35
C	21½	15	19
J(Highveld)	11	4	2
M	10	32	11
I	5	7	4
G	3½	4½	2½
S(Highveld)	2½	2	3
P	1½	5	5
Z(Highveld)	1	1	1
B	1	2½	2
C(Highveld)	1	1	1
W	1	½	

Land Capability

The rainfall is sufficient to practise intensive dryland farming, except, possibly, in the very Eastern end of the area. Therefore land capability maps were compiled for the rotation of irrigated annuals and for the dryland maize-beans rotation.

The areas of highly irrigable land are discontinuous, but fortunately they are mostly riparian and could be served by small pump schemes. The steepness of the topography is shown by the relatively high proportion of land in classes A2, B2 and C2.

The acreages and percentages of the land capability classes for each cropping system are listed in Tables 7.8 and 7.9.

Table 7.8

Areas of Irrigated Rotation Land Capability classes in the Upper Ngwempisi area

Class	Area (in hundreds of acres)	Percentage of the Survey area
A1	22	4
A2	26	4
B1	14	2
B2	16	3
C1	34	6
C2	84	15
D1	20	3
D2	73	13
X	279	49
Total	567	99

Table 7.9

Areas of the dryland maize-beans rotation Land Capability classes in the Upper Ngwempisi area

Class	Area (in hundreds of acres)	Percentage of the Survey area
A1	24	4
A2	32	6
B1	15	3
B2	28	5
C1	32	6
C2	72	13
D1	19	3
D2	89	16
X	256	45
Total	567	102

References

Barradas L., 1962;	Esboco Agrologico do Sul de Moçambique, Serviços de Agricultura e Florestas, Lourenço Marques.
Beggs C J., 1964;	Geology of the Sicunusa-Mankaiana area, South-western Swaziland at 1:25,000, Swaz. Geological Survey and Mines Dept., unpublished.
De Blij H.J., 1959;	Geomorphology of Swaziland, unpublished thesis, Northwestern University, Evanston, Ill., U.S.A.
Hallsworth E.G., and Costin A.B., 1953;	Studies in pedogenesis in New South Wales: IV The ironstone soils, Jnl. Soil Science, 4, 24-45.
Hunter D.R., 1957;	Geology, petrology and classification of Swaziland granites and gneisses, Trans. Geol. Soc. S. Afr. 60, 85-125.
Hunter D.R., 1961;	The geology of Swaziland; Swaz. Geological Survey and Mines Department.
Hunter D.R.;	Granitic rocks of the Swaziland Precambrian in preparation.
I'Ons J.H., 1967;	Veld types of Swaziland, Bull. No. 18, Swaz. Ministry of Agriculture.
King L.C., 1951;	South African scenery, 3rd edition, Oliver and Boyd, Edinburgh.
Murdoch G., 1963;	Soils of Balegane Ranch, Swaziland Dept. of Agriculture, mimeographed.
Murdoch G., 1968;	Soils and Land capability in Swaziland, in preparation.
Murdoch E., and Murdoch G., 1958;	Swaziland Meteorological data, Swaziland, Dept. of Land Utilisation, mimeographed.
Nye P.H., 1955;	Some soil forming processes in the humid tropics: IV The action of soil fauna, Jnl. Soil Science 6, 63 et seq.
Swaziland Geological Survey, 1957,	Geological survey of Swaziland at 1:50,000 Sheet 2630 DB " 2630 DD " 2631 CA " 2631 CC
Swaziland Geological Survey, 1959;	Geological map of Swaziland at 1:125,000.
Swaziland Geological Survey, 1966;	Geological map of Swaziland at 1:250,000.
Turner J.L., 1967;	The mapping and study of certain geomorphological features of Natal and its adjacent regions, unpublished thesis, University of Natal.

CHAPTER VIII

Siphocosini semi-detailed survey area

This is the smallest of the semi-detailed survey areas and was the first to be surveyed by the writer. It lies in an ill-defined basin, set in the Highveld, on the Usushwane river. The slope gradient map of the whole Usutu basin shows that the area is flatter than the surrounding Highveld, but it is still generally fairly steep. Because of the higher rainfall, large irrigation developments are unlikely in this area, and the suitability of the land for intensive dryland farming is possibly of greater interest than its irrigability. Consequently more steep land, especially that with slope gradients in the range 7 - 22%, is included in this survey area than in the others.

The boundaries of the area are both topographic and cadastral and are chosen to include all the gently sloping land.

Description of the Area.

Geology.

Most of the area is underlain by the Ag3 late-orogenic granite, which is thought to have been emplaced late in the second of the two Swaziland orogenic cycles. Late Tertiary and Quaternary erosion in the Mkondo and Ezulwini valleys have cut right through this widespread granite and revealed that it was intruded as a relatively shallow but very extensive sheet but the granite has not been breached in Siphocosini and underlies the valley bottom (Hunter, 1961).

The granite is grey in colour and is usually of medium-coarse grained texture, with prophyritic phases. No traces of foliation were noted in the course of the soil survey. There are a large number of pegmatites in the rock, the great majority of which contain no economic minerals. These pegmatites are of pedological importance as they release large quantities of coarse quartz upon weathering (see Table 8.2). Quartz is also derived from the numerous quartz veins, most of which are too small to be mapped (Swaziland Geological Survey, 1957; Hunter, 1961). Pre-Karroo diabase was intruded into the granite and forms a broken rectangular stockwork, which is aligned approximately S.E. - N.W., S.W. - N.E. (Hunter, 1961).

The granite is intruded by the rocks of the Usushwane Complex, which outcrop in a thin strip along the southwestern boundary of the survey area. In the Maloyo area, on the higher western slopes of the Umcwabi valley, and in the Mcubani valley the hypersthene gabbros of the Complex contribute to the soil parent material, but it is thought there is also some colluvial admixture of material derived from more quartzose rocks (Winter, 1965).

The chemical compositions and the mineral norms of samples of the rocks underlying the area are shown in Tables .1 and .2.

Table 8.1

Chemical Composition of the rocks of the Siphocosini area

Sample No.	Ag3 granite		Pegmatite	Usushwane Complex gabbro			Diabase dyke
	1	2	3	4	5	6	7
SiO_2	64.1	70.1	74.2	51.1	52.2	54.3	56.2
Al_2O_3	15.6	14.5	12.0	17.0	6.8	20.4	14.8
Fe_2O_3	0.9	0.9	4.0	0.6	1.8	0.6	2.6
FeO	4.3	1.6	2.0	6.2	10.5	5.1	7.0
MgO	1.1	1.0	0.5	8.6	12.3	4.1	3.1
CaO	2.4	2.2	0.7	12.2	14.1	9.5	5.7
Na_2O	4.5	4.3	5.0	2.4	1.1	3.4	3.1
K_2O	4.7	3.9	0.3	0.3	0.1	0.6	3.6
H_2O+	1.1	0.5	0.5	1.6	0.5	1.6	1.0
H_2O-	0.2	0.1	0.1	0.1	t	0.1	0.1
TiO_2	0.8	0.4	-	0.1	0.3	0.2	1.4
P_2O_5	0.3	0.4	-	n.d.	t	t	1.1
MnO	0.1	0.1	0.1	0.2	0.3	0.1	0.2
S	-	-	-	0.1	0.1	n.d.	-
Cr_2O_3	-	-	-	n.d.	0.2	n.d.	-
SnO_2	-	-	6.3	-	-	-	-

Table 8.2

Mineral norms of the rocks of the Siphocosini survey area

Sample No.	1	2	3	4	5	6	7
Quartz	11.8	23.0	40.1	-	0.9	4.1	n.d.
Orthoclase	28.5	23.0	1.5	1.1	0.6	2.8	n.d.
Albite	41.0	39.0	46.0	20.4	9.4	28.8	n.d.
Anorthite	8.6	8.0	3.5	34.7	13.3	38.9	n.d.
Diopside	1.1	-	-	20.7	46.0	6.7	n.d.
Hypersthene	6.2	4.0	1.9	16.1	26.1	15.5	n.d.
Olivine	-	-	-	9.1	-	-	n.d.
Magnetite	0.9	1.1	4.4	0.9	2.6	0.9	n.d.
Ilmenite	1.2	0.6	-	0.3	0.6	0.5	n.d.
Apatite	0.8	0.9	-	-	-	-	n.d.
Corundum	-	0.4	2.6	-	-	-	n.d.

Origin of samples:-

1. On the Transvaal border, west of Siphocosini (Hunter, 1957).
2. Tonkwane area, north of Siphocosini (Hunter, 1957)
3. Tonkwane area, 1 mile S.W. of sample 2 (Hunter, 1957).
4. Embo area (Hunter, 1961).
5. Mtombi river area (Hunter, 1961).
6. Kirkhill farm (Hunter, 1961).
7. Embo area (Winter, 1965).

Landform

The area lies in a basin which is set in the hills of the Highveld. The basin is cut off from the Central Middleveld by the Lupohlo - Nyonyane range of hills. The valley of the Usushwane through this range is narrow, and steep-sided, but it is not as rugged as the gorge on the Ngwempisi (see Chapter VII). The basin ranges in altitude from 3,800 to 3,100 feet and the river leaves the area at 3,000 feet.

The surrounding Highveld hills have roughly concordant summits at about 4,000 - 4,500 feet. Some of them carry sizeable remnants of the Highveld Late Tertiary surface (De Vlij, 1959; Turner, 1967). Coalescing very Late Tertiary and Quaternary dissection has removed the surface entirely from other interfluves and these show no conspicuous summit flattening.

Although lower and flatter than the surrounding Highveld, the topography of the basin is still very broken and varies from rolling to rugged. The landscape of most of the area has been fashioned by dissection of the Highveld plateau surface. The slopes are generally steep and dissection and base-level depression appear to have been fairly continuous. Scarp retreat and pediplanation require a period of base-level stability and any small area of planation resulting from only a brief hiatus is liable to be removed by renewed downcutting (King, 1951).

This appears to be the case over most of the area and only at Mbethe is there a planed area of any size. There the terrain is similar to that of the Western section of the Central Middleveld, with wide and gently convex sloping interfluves. The lower slopes are steepened by dissection subsequent to the planation. The Mbethe surface fragment is isolated from the main body of the Late Tertiary Western Middleveld surface by the rugged country of the Lupholo - Nyonyane range. The river section through these hills includes several rapids and the waterfall at Mantenga. This is thought to be a genuine unimpeded geomorphological nickpoint and not a lithological barrier. If this is the case, the Mbethe surface predates that of the Western Middleveld, but not by very much, and is also Late Tertiary.

The fairly continuous dissection and frop in base level precludes the formation of extensive and massive ferricrete sheets, and the soils of G set are found only in very small pockets in two localities.

There are no traces of alluvial deposits predating the higher of the two Late Quaternary river terraces found elsewhere in Swaziland. Even the higher (M set) terrace is practically non-existent and the lower (S set) terrace is present only in widely separated pockets along the river. This scarcity of alluvium is another effect of the brevity of the standstills in river downcutting.

Climate

There are no official meteorological stations within the basin, but there is a private rain gauge at the farm Kirkhill. From this and from the close network of gauges in the Usutu Forest to the south and west, it is clear that the basin lies in a marked rain-shadow. The a nnual rainfall in the basin is probably less than 45 inches, whilst the surrounding hills, especially those to the east and south east, receive between 50 and 60 inches per annum (H.A.F. Long, 1968, private communication; T.R. Brook, 1968, private communication.)

Temperatures are not recorded at Kirkhill but figures are available for Orrin farm for over 20 years. The mean annual temperature ther is 61.4°F, but this is probably lower than that of most of the survey area as the screen is at an altitude of 3,900 feet (after Murdoch and Murdoch, 1950). However, the temperatures in the basin are considerably lower than those of the Central Middleveld, and combined with the slightly higher rainfall, they give a more intensive soil-leaching regime than that of Mdutshane (see Table 1.5).

Vegetation and Land use

Two veld types are distinguished in the survey area, The higher parts of the Lupohlo hills carry Mountain Sourveld, whilst the rest of the area is covered with the Highveld Sourveld, (I'Ons, 1967 and private communication, 1968).

The Mountain Sourveld is a dense, short grassland. There are patches of relict mountain forest in ravines elsewhere in Swaziland, but none are found within the survey area. The commonest grasses are Themeda triandra, Rendlia altera, Loudetia simplex, Papsalum commersonii, and Monocymbium ceresiiforme. The veld is not overgrazed, so Eragrostis and Sporobolus spp. have not come in (I'Ons, 1967).

The Highland Sourveld is also a short grassland but is not as dense as the Mountain Sourveld. In addition to the grasses of the Mountain Sourveld, Hyparrhenia hirta and Tristachys hispida are found. In the southern part of the survey area the veld is overgrazed and contains a relatively high proportion of Eragrostis and Sporobolus spp. There are some patches of bush on steep, bouldery slopes and amongst the commoner trees and shrubs are Burchellia bubalina and Faurea speciosa.

Except for small patches of grazing on Kirkhill and Tonkwane the survey area is entirely Swazi Nation Land. The land is held under the traditional system of tenure and a recent sample survey has shown that holdings in the area are very small (R. I'Ons, private communication). The chief crops are maize, beans, pumpkins and ground nuts. Smaller areas of vegetables are also grown. Cattle are the main livestock but there are also goats. Since the Government designated Siphocosini a Rural Development Area, a pilot scheme to demonstrate and introduce poultry raising and egg production in small battery units has been in operation.

The Soils

The most widespread mapping unit in the survey area is U set (rocky ground), as is to be expected in view of the rugged terrain. Over the rest of the area it seems that the youth and steepness of the present land surface is offset by the high leaching intensity of the present climate. The commonest non-rocky soils are the deep acid loams of M set. Within M set, the most widespread series is Mbeli, which is morphologically very similar to Malkerns series, but is consistently one Munsell hue more yellow in colour (5YR, yellowish red, rather than 2,5YR, Red.) The yellower colour compared with the dominant soils of the Western Central Middleveld may be due to the cooler and moister climate and consequent greater hydration of the free iron oxides. However, it is possible that the quantity rather than the degree of hydration of the iron oxides may be more important. The Malkerns series soils of the Middleveld are developed on parent material derived from rocks of granodioritic composition, whereas the Siphocosini soils are formed on granite which has a lower total iron content. The occurrence of Malkerns series in association with the diabase intrusions in Siphocosini suggests that the rock composition difference is more important than that in the climate.

In the steeply sloping areas where erosion is very rapid, the shallow medium-textured soils of Z (Highveld) set are found. As with the deeper soils, the yellower-hued series - Zayifu - predominates in the Siphocosini survey area, whereas the redder Zombode series is the more extensive in the Central Middleveld.

Where coarse quartz derived from the quartz veins and pegmatites is especially abundant, the stone line soils of J (Highveld) set are found. The commonest series is Jolobela which has a grey, gravelly loam top soil. The stone line sometimes overlies a kaolinitic M set subsoil, but more commonly the subsoil is deeply and highly weathered rock.

N (Highveld) set soils are typically found on the Highveld remnants of the Late Tertiary plateau. Thus, in the survey area, there are extensive stretches of these soils in the valley of the upper Impapa. This is a gently sloping area at over 4,000 feet and is an undoubted plateau remnant. However, there is also a considerable area of this soil on the younger land surface within the basin, especially around Maloyo.

The profile of Nduma series, the deeper and more extensive member of the set, is typically a yellow loam topsoil overlying a red clay loam subsoil with the boundary between the horizons clear rather than abrupt. This profile form could have arisen b y the eluviation of clay and free iron oxides from the upper horizon. Soils with similar profile morphology are widespread in the wattle growing areas of Natal, although they are developed from sedimentary rather than cystalline rocks. Laboratory studies showed that wattle leaf extract was capable of chelating soil iron oxides, and eluviation from the topsoil was deemed to be a major process in the formation of these soils (Darby, 1954). Another possibility is that the lighter coloured and lighter textured topsoil is colluvially deposited on top of the red clay. The widespread occurrence of a thin, discontinuous line of quartz gravel or iron concretions at, or near, the colour and texture boundary, indicates that the two horizons may be of different provenance. However, if colluviation was the only process operating, the reverse profile form, i.e. red clay loam over yellow loam, would be more common than it is. Such a profile has been found in the Mahlangatsha area but the form is extremely rare. X-ray diffractograms did not reveal any marked differences in the clay mineralogy of the two horizons, with kaolinite and gibbsite the only minerals in deferruginised samples from both of them. It is unfortunate that no mineral sampling was carried out on sand fractions, as this would have revealed differences in lithological origin. Such studies were carried out on samples from Kranskop series in Natal, which is of similar profile form to N (Highveld) set. They showed a definite lithological discontinuity in the profile, although t is was not always found to coincide with the colour change. The conclusion drawn was that colluviation is the dominant formative process, but eluviation of free iron oxides, especially by chelating agents derived from wattle littler, also takes place (De Villiers, 1962 and 1964).

The areas covered by the soil mapping units are listed in Table 8.3.

Table 8.3

The areas of soil mapping units in the Siphocosini area

Series	Set	Area	Series	Set	Area
Al		t	Po		2
	A	t		P	2
Bu		2	Qb		5
	B	2		Q (Highveld)	5
Fu		1	Or		2
	F	1		O	2
Ge		t	Sa		1
Gc		t		S (Highveld)	1
	G	t	Tt		1
	I	6		T (Highveld)	1
Jb		10		U	46
Jh		1			
	J (Highveld)	11	Wh		t
				W	t
Ma		6			
Mb		28	Za		6
Mt		1		Z (Highveld)	6
	M	35			
			TOTAL		134
Nd		14			
Ng		3	Note: t = 0 - 50 acres		
	N (Highveld)	17			

The commonest soil sets in the area are listed in order in Table 8.4.

Soil Set	Percentage of the Survey area
U	34
H	26
M (Highveld)	12
J (Highveld)	8
I	7
Z (Highveld)	4
Q (Highveld)	4
O	1
B	1
P	1

Table 8.4

The percentage distribution of the commonest soil sets in the Siphocosini area

Land Capability

Land capability maps were drawn up for the irrigated rotation of annual crops and for the dryland maize-beans rotation. Irrigation in the area will always be merely supplementary to the rainfall. The height of lift necessary to reach most of the area precludes large-scale irrigation development anyway. However, the irrigated rotation land capability map has been compiled for comparative interest.

Intensive dryland farming is possible in the area and is the more likely form of development. It should be noted that chemical criteria were virtually discounted in the soil ratings (see Chapter III) and most of the soils in land classes A1, A2, B1 and B2 are very leached and will require dolomitic liming as well as heavy fertiliser applications. It is expected that there will also be trace element deficiencies (Jackson, Venn and I'Ons, 1965).

The areas of the land capability classes for the two cropping systems are listed in Tables 8.5 and 8.6. Of interest is the large area of A2 class land for dryland rotation, indicating that a high proportion of the soils of H set occur on slopes between 7 and 22%. By comparison with the area of class A2 land for the irrigated rotation, it is seen that much of the steeply sloping H set soil is on slopes of 14 - 22%.

Table 8.5

Areas of the Irrigated rotation land capability classes in the Siphocosini area

Class	Area in (hundreds of acres)	Percentage of the survey area
A1	2	2
A2	12	9
B1	2	2
B2	6	5
C1	3	2
C2	6	4
D1	1	t
D2	4	3
X	97	73
Total	134	100

Table 8.6

Areas of Dryland Maize-beans rotation land capability classes in the Siphocosini area

Class	Area in (hundreds of acres)	Percentage of the survey area
A1	4	3
A2	32	24
B1	1	1
B2	6	4
C1	1	1
C2	4	3
D1	2	2
D2	13	10
X	70	52
Total	134	100

Darby G.D., 1954; The characteristics of South African wattle soils, unpublished thesis, University of Natal.

De Blij J.H., 1959; The geomorphology of Swaziland, unpublished thesis, Northwestern Univ. Evanston, Ill., U.S.A.

De Villiers J.M., 1962, A study of Soil formation in Natal, unpublished thesis, Univ. of Natal.

De Villiers J.M., 1964; The genesis of some Natal soils: I, Clovelly, Kranskop and Balmoral series, S. Afr. Jnl. Agric. Sci 7, 417 et seq.

Hunter D.R., 1957; Geology, petrology and classification of Swaziland granites and gneisses, Trans. S. Afr. Geol. Soc., 60, 85-125.

Hunter D. R., 1961; The geology of Swaziland, Swaziland Geological Survey and Mines Department.

Hunter D.R., The granitic rocks of the Swaziland Precambrian, inpreparation.

I'Ons J.H., 1967, Veld types of Swaziland, Bull 18, Swaziland Ministry of Agriculture.

Jackson [illegible], Venn A.C., and I'Ons J.H., 1965; Responses on Swaziland soils to lime and trace elements, Proc. C.A.U. Symp. on Soil Fertility, 2[illegible]6-302, Khartoum, Sudan.

King L.C., 1951; South African Scenery, 3rd edition, Oliver and Boyd, Edinburgh.

Murdoch [illegible], and Murdoch G., 1958; Swaziland meteorological data, Swaziland Department of Land Utilisation, mimeographed.

Swaziland Geological Survey, 1957, Geological survey of Swaziland, at 1:50,000, sheet 2631 AC.

Turner J.L., 1967; The mapping and study of certain geomorphological features of Natal and its adjacent regions, unpublished thesis, Univ. of Natal.

Winter P.E., 1965; The Usushwane Igneous Complex, Bull. 5, Swaziland Geological Survey and Mines Department.

CHAPTER IX

Reconnaissance survey of the whole basin

The remainder of the basin not covered by the semi-detailed surveys has been mapped in the course of the National Soils Reconnaissance. This Reconnaissance has been given high priority in the programme of the Soil Survey section because it was impossible to proceed with national agricultural and industrial planning until a complete inventory of the available resources had been compiled.

The final map of the Reconnaissance is at a scale of 1:125,000 and the mapping units are the soil sets, as listed in Chapter II. Although there is no delineation of series' boundaries, the relative proportions of the component series within each set have been estimated (Murdoch, 1968). The final map incorporates all of the detailed and semi-detailed surveys in the country, which now cover over 900,000 acres, or 21% of Swaziland.

Table 9.1 gives the area of each soil set within the Usutu basin. The boundaries of the basin are not exactly the same as those outlined in Chapter I, as the catchments of Lebombo streams draining into the Maputo have been included.

Table 9.1

Areas of soil sets in the Usutu Basin
(in thousands of acres)

Soil Set	Highveld	Upper Middleveld	Lower Middleveld	Western Lowveld	Eastern Lowveld	Lebombo	Whole Basin
A	29	1	t				30
B	3	5	3	7	6	2	26
C (HV)	10	3	1	-	-	-	14
C (LV)	-	-	1	11	29	1	41
D (HV)	4	-	-	-	-	-	4
D (LV)	-	-	-	1	t	t	1
E	2	2	5	8	-	-	17
F	4	4	2	1	1	2	14
G	21	8	4	8	t	1	42
H	-	-	7	78	2	-	87
I	28	15	4	-	-	t	48
J (HV)	57	7	2	-	-	-	67
J (LV)	-	-	2	17	-	-	19
K	t	t	t	7	26	t	35
L	-	-	10	18	1	7	36
M	45	49	3	-	-	-	98
N (HV)	48	5	-	-	-	-	53
O	81	18	72	78	4	15	268
P	9	5	18	8	t	t	41

Table 9.1 (Continued)

Soil Set	Highveld	Upper Middleveld	Lower Middleveld	Western Lowveld	Eastern Lowveld	Lebombo	Whole Basin
Q (HV)	54	6	7	-	-	-	67
R	-		2	22	38	2	64
S (HV)	30	5	10	t	-	-	46
S (LV)	-	-	14	37	91	10	153
T (HV)	49	1	1	-	-	-	52
T (LV)	-	-	-	-	2	-	2
U	378	42	127	51	46	48	692
V	t	-	t	t	11	-	11
W	2	1	1	3	5	t	11
X	t	1	1	2	1	t	5
Y	-	-	-	-	t	-	t
Z (HV)	11	6	1	-	-	-	17
Z (LV)	-		1	73	6	-	80
TOTAL	867	183	300	432	269	90	2,140
Note: t=0 - 500 acres							

(After Murdoch, 1968).

The commonest soil sets in each region of the basin are listed in Table 9.2. The area covered by these soils is expressed as a percentage of the total area of the physiographic region in the basin.

Table 9.2

The percentage areas of the commonest soil sets in the Usutu Basin

Highveld	U 43	O 9	J (HV) 7	Q (HV) 6	T (HV), N (HV) 6
Upper Middleveld	M 27	U23	O 10	I 8	G 4
Lower Middleveld	U 42	O24	P 6	S (LV) 5	S (HV), L 3
Western Lowveld	H 19	O19	Z (LV) 17	U 12	S (LV) 9
Eastern Lowveld	S (LV) 34	U17	R 14	C (LV) 11	K 10
Lebombo	U 54	O16	S (LV) 11	L 8	B 3
Whole basin	U 32	O13	S (LV) 7	H 4	Z (LV) 4

(After Murdoch, 1968).

Land Capability

The basis of land capability assessment in the M.S.R. is outlined in Chapter III. The areas of the ten land classes in the basin are listed in Table 9.3.

Table 9.3

Areas of the Land Capability classes in the Usutu Basin

(in thousands of acres)

Land Class	Highveld	Upper Middleveld	Lower Middleveld	Western Lowveld	Eastern Lowveld	Lebombo	Whole Basin
AS	31	41	14	43	43	9	169
BS	69	10	7	13	31	2	133
CS	85	27	81	69	96	16	374
DS	58	13	20	251	49	1	392
ES	45	19	13	28	29	3	137
AT	15	8	3	t	t	1	27
BT	53	7	6	t	t	t	67
CT	78	14	30	1	1	11	135
DT	69	4	6	3	--	t	82
ET	366	39	120	26	17	46	660

(Ater Murdoch, 1968).

For discussion on the distribution of soils and land capability classes, Murdoch (1968).

References

Murdoch G., 1968; Soils and land capability in Swaziland, in preparation.

SUBJECT INDEX

FIGURE 6 (a)

DIAGRAMATIC LANDSCAPE SECTION IN THE WESTERN MIDDLEVELD

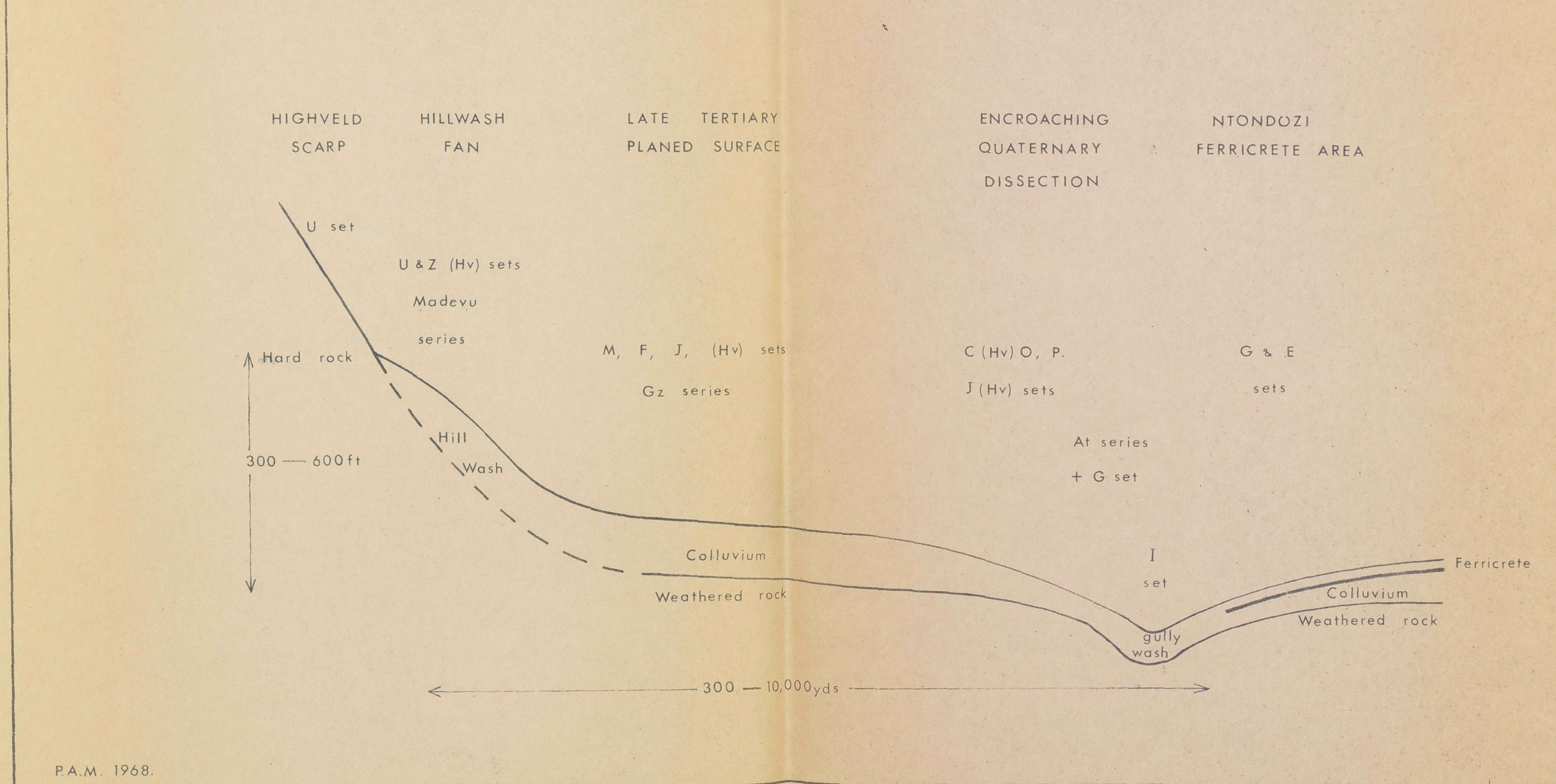


FIGURE 6 (1)

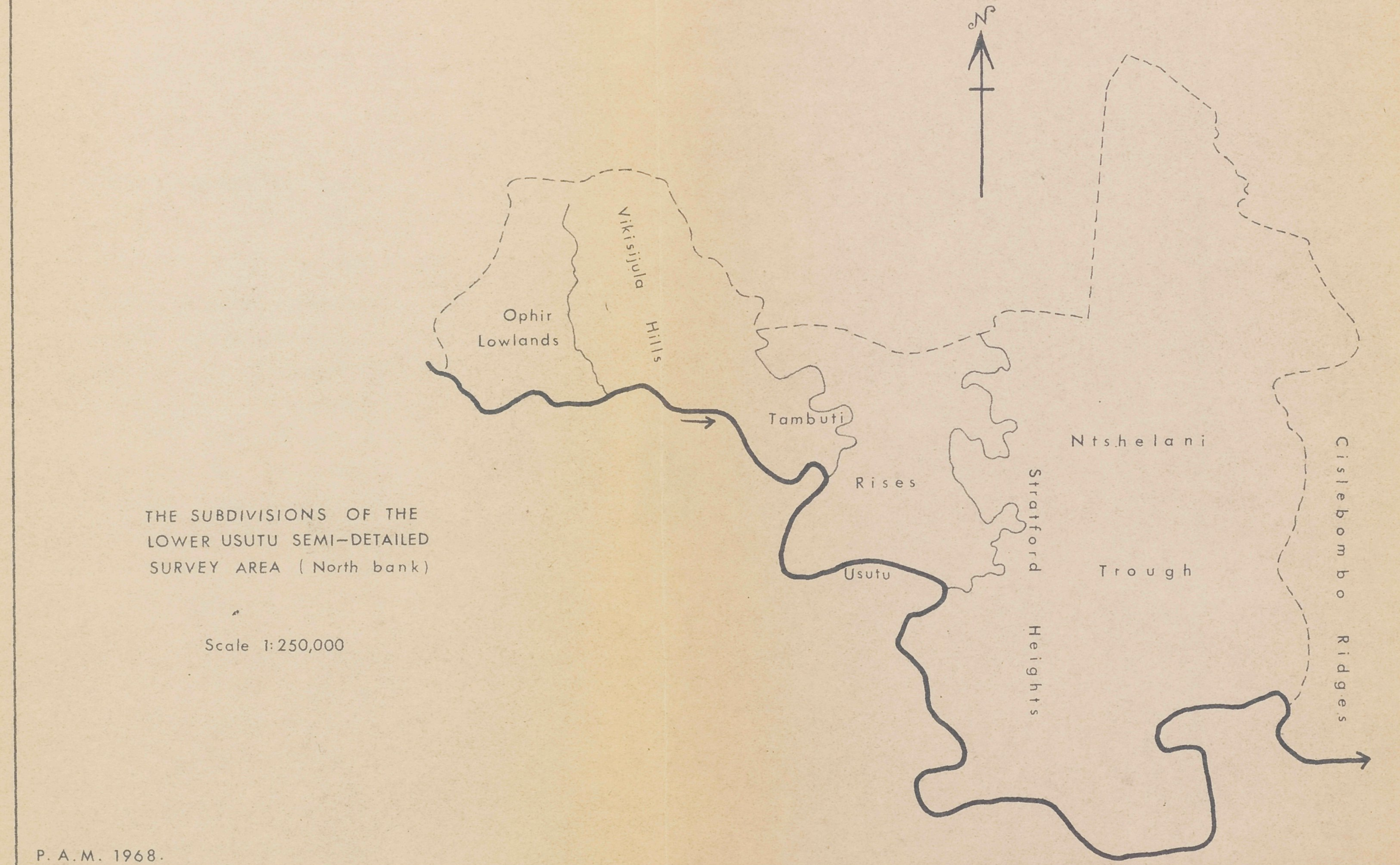
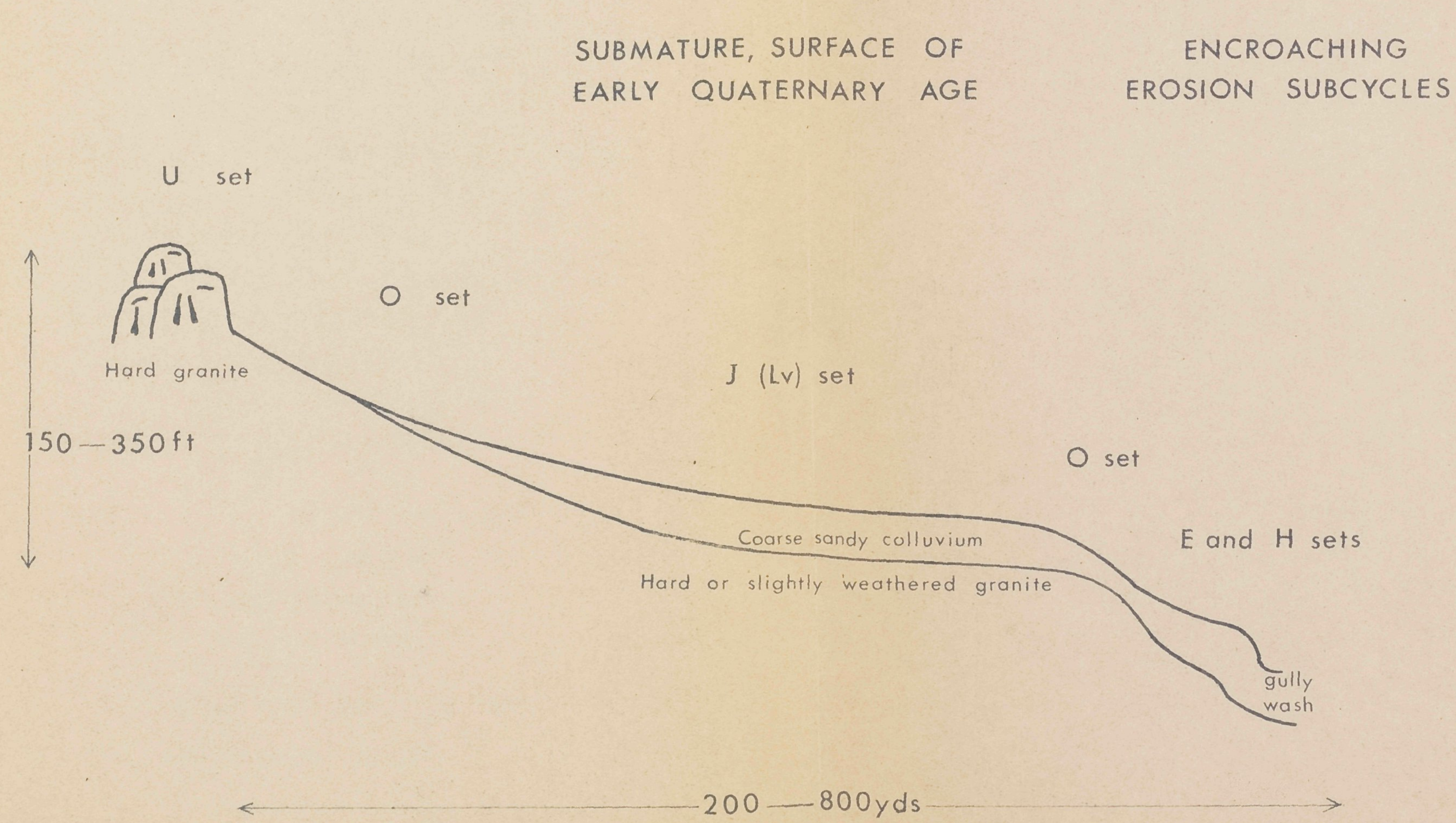

N
Ophir
Lowlands
Vikisijula Hills
Tambuti
Rises
Usutu
Stratford Heights
Ntshelani
Trough
Cislebombo Ridges
THE SUBDIVISIONS OF THE
LOWER USUTU SEMI-DETAILED
SURVEY AREA (North bank)
Scale 1:250,000
P. A.M. 1968.

FIGURE 5 (a)

LANDSCAPE SECTION ON Ag5 GRANITE (OPHIR LOWLANDS)



P.A.M. 1968.

FIGURE 5 (b)

LANDSCAPE SECTION ON ECCA SEDIMENTS (TAMBUTI RISES)