PRODUCTION OF AN AGRO-ECOLOGICAL ZONES MAP OF NAMIBIA (first approximation)

PART II: RESULTS

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INTRODUCTION

In Part I, the methodology employed to produce a First Approximation Agro-ecological Zones Map of Namibia, was described. In this article, the findings of the study are presented, as summarized from Technical Report 1, by E de Pauw (1996).

RESULTS

Station Results

Fifty-two rainfall stations, with sufficiently long and complete records, were considered for the climatic analysis. For each of these stations, a growing period matrix was generated with a computer programme. The growing period matrix of Andara (see Table 1) is printed below as an example.

TABLE 1: EXAMPLE OF A GROWING PERIOD MATRIX, FOR DROUGHT-SENSITIVE CROPS AND SMAX = 50 MM.

Station-ID:	NA81NDRO	Station:	ANDARA
Latitude:	-18.04° South	Longitude:	21.28° East
Altitude:	1100 m		

Analysis based on 39 years of data

LGP-ANALYSIS: MODEL FOR DROUGHT-SENSITIVE CROPS

Smax = 50 mm

Planting month	Probability to equal or exceed a GP of duration (days)											
	30	60	90	120	150	180	210	240	270	300	330	360
JUL	92	91	88	73	18	0	0	0	0	0	0	0
AUG	100	100	95	73	18	0	0	0	0	0	0	0
SEP	100	100	95	73	18	0	0	0	0	0	0	0
OCT	100	100	95	73	18	0	0	0	0	0	0	0
NOV	100	100	95	71	18	0	0	0	0	0	0	0
DEC	100	96	88	40	0	0	0	0	0	0	0	0
JAN	96	88	48	0	0	0	0	0	0	0	0	0
FEB	91	50	0	0	0	0	0	0	0	0	0	0
MAR	50	0	0	0	0	0	0	0	0	0	0	0
APR	0	0	0	0	0	0	0	0	0	0	0	0
MAY	4	4	3	3	0	0	0	0	0	0	0	0
JUN	59	58	56	51	0	0	0	0	0	0	0	0

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TABLE 1 (CONTINUED)

Planting month	Ave LGP	S.D. LGP	C.V. LGP	Length of GP to be equalled or exceeded with probability (%) 50	67	75	80	90	Plant fail.
JUL	122	40	33	132	122	118	104	80	0
AUG	130	21	16	132	122	118	108	96	0
SEP	130	21	16	132	122	118	108	96	0
OCT	130	21	16	132	122	118	108	96	0
NOV	129	21	16	132	122	113	108	96	0
DEC	111	20	18	117	101	95	94	88	0
JAN	84	21	25	89	74	65	64	58	0
FEB	56	19	33	60	47	37	34	31	0
MAR	27	17	65	30	17	7	4	1	0
APR	6	8	135	0	0	0	0	0	0
MAY	4	22	616	0	0	0	0	0	0
JUN	81	69	86	121	0	0	0	0	0

Planting month	% of actual planting expected in JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
JUL	0	0	0	3	56	33	7	0	0	0	0	0
AUG	0	0	0	3	56	33	8	0	0	0	0	0
SEP	0	0	0	3	56	33	8	0	0	0	0	0
OCT	0	0	0	3	56	33	8	0	0	0	0	0
NOV	0	0	0	0	59	33	8	0	0	0	0	0
DEC	0	0	0	0	0	92	8	0	0	0	0	0
JAN	0	0	0	0	0	0	100	0	0	0	0	0
FEB	0	0	0	0	0	0	0	100	0	0	0	0
MAR	0	0	0	0	8	5	0	0	87	0	0	0
APR	0	0	0	0	33	18	5	0	0	44	0	0
MAY	0	0	0	3	56	33	8	0	0	0	0	0
JUN	0	0	0	3	56	33	8	0	0	0	0	0

A growing period matrix generates a range of indicators that allow the assessment of the suitability for different crop cultivars and the relative productivity of each climatic station. The matrix allows for the estimation of the length of growing period availability and optimum planting date considering the following variables:

- drought-sensitive or drought-resistant crops;
- soil moisture storage capacity within rooting depth;
- rainfall variability.

The growing period matrix for Andara (above) can be interpreted as follows:

- The optimal planting month is November. There exists a 95% probability to equal or exceed a growing period of 90 days, and a 71% probability to equal or exceed a growing period of 120 days. The average length of growing period is 129 days. In 3 years out of four, one can expect a minimum growing period of 113 days.

- It can be concluded that crop cultivars with a 3-month cycle to maturity are likely to perform well in most years. November is the recommended planting month, with about 60% of all plantings likely to be successful. Earlier plantings may necessitate replanting later in the season Later plantings may result in a loss of available growing period.

- A 4-month crop cultivar will perform well during good rainfall years, but there is about 30 % risk that the growing period will be inadequate, which would result in loss of productivity. The higher yield potential from a 4-month cultivar as compared to a 3-month cultivar may be worth the risk if the rainfall outlook is good and the farmer's risk tolerance high.

Growing Period Zones

At the second level of interpretation, the stations were grouped according to shared growing period[1] characteristics, mainly the duration of the average growing period and the relationship between dependable and average growing period

Eleven growing period zones were mapped by manual interpolation between the positions of these stations, on a 1:2 000 000 scale. The Growing Period Zones map is shown in Map 1, while Table 2 summarizes the main characteristics of the 11 zones and shows which stations were allocated to each zone.

TABLE 2: GROWING PERIOD ZONES AND THEIR CHARACTERISTICS.

Growing period zone	Stations	Zonal characteristics / averages
11	Gobabeb Swakopmund Oranjemund Diaz Punt	No growing period. 2 AGP 0 days; DGP 0 days; PROBEQX90 0%; PLFAIL 99%; EARLST not applicable HIGHST not applicable; SRESP 0 days
10	Aus Sesfontein	Average growing period 10 days or less. AGP 8 days; DGP 0 days; PROBEQX90 0%; PLFAIL 94%; EARLST January; HIGHST January; SRESP 1 day
9	Ariamsvlei Karasburg Koes Usakos Warmbad Berseba Bethanien Tses Keetmanshoop Stampriet	Average growing period 11-20 days. AGP 15 days; DGP 0 days; PROBEQX90 4%; PLFAIL 87%; EARLST January (Nov/Dec); HIGHST January; SRESP 1 day
8	Aroab Gochas Maltahohe Aranos Otjimbingwe Gibeon	Average growing period 21-30 days AGP 25 days; DGP 0 days; PROBEQX90 4%; PLFAIL 75%; EARLST December (November); HIGHST January; SRESP 1 day

[5] Explanatory notes:

AGP:	average growing period
DGP:	dependable growing period (growing period length to be equalled or exceeded in 3 years out of 4)
PROBEQX90:	probability (%) to equal/exceed a growing period of 90 days
PLFAIL:	percentage of years without growing period
EARLST:	earliest month for a growing period to start
HIGHST:	month with the highest probability for a growing period start
SRESP:	increase in growing period length for an increase in soil moisture storage capacity from 50 to 150 mm

1 *Growing Period* is defined (FAO, 1978) as the interval during which precipitation exceeds half the potential evapotranspiration, plus the additional time required to evapotranspire an assumed 100 mm (or less, if not available) of water from excess precipitation, while the average air temperature exceeds 6.5 oC. It is, therefore, the period when both temperature and soil moisture permit crop growth (FAO, 1983)

TABLE 2 (CONTINUED)

7	Rehoboth Karibib Khorixas Leonardville Mariental	Average growing period 31-40 days. AGP 35 days; DGP 0 days; PROBEQX90 6%; PLFAIL 60%; EARLST November -December; HIGHST January; SRESP 3 days
6	Kamanjab Omaruru Dordabis Witvlei	Average growing period 41-60 days, no dependable growing period. AGP 48 days; DGP 0 days; PROBEQX90 8%; PLFAIL 43%; EARLST November; HIGHST January; SRESP 3 days
5	Okahandja Windhoek	Average growing period 41-60 days, dependable growing period 75% of average. AGP 58 days; DGP 33 days; PROBEQX90 18%; PLFAIL 22%; EARLST November; HIGHST January; SRESP 2 days
4	Oniipa Hochfeld Okaukeujo Buitepos Kalkfeld Gobabis	Average growing period 61-90 days, very short dependable growing period. AGP 73 days; DGP 6 days; PROBEQX90 38%; PLFAIL 27%; EARLST November; HIGHST November-January; SRESP 5 days
3	Tsumkwe Omatjenne Otjozondu Ombalantu Outjo	Average growing period 61-90 days, dependable growing period 60% of average. AGP 83 days; DGP 52 days; PROBEQX90 51%; PLFAIL 14%; EARLST November; HIGHST January; SRESP 9 days
2	Rundu Huttenhof Bunja Tsumeb Grootfontein Arbeidsgenot	Average growing period 91-120 days, dependable growing period 80% of average. AGP 105 days; DGP 86 days; PROBEQX90 71%; PLFAIL 4%; EARLST October-; November HIGHST November(-January); SRESP 9 days
1	Katima Mulilo Andara	Average and dependable growing period exceed 120 days. AGP 135 days; DGP 122 days; PROBEQX90 98%; PLFAIL 0%; EARLST October; HIGHST November; SRESP 17 days

In general, the station and growing period results can be summarized as follows:

- There exists a wide range of growing conditions in Namibia, from a maximum average growing period of about 4½ months to zero.
- For very short average growing periods (45 days or less), the dependable growing period, here defined as the 75 % minimum growing period, is zero. For longer average growing periods a relationship exists between the dependable and the average growing period. There are some stations that deviate substantially from this relationship. These deviations were used to distinguish separate growing period zones.
- The responsiveness of the growing period to soil moisture storage capacity is generally low, indicating that growing periods are not much longer on soils with higher storage capacity. This responsiveness is also strongly correlated with rainfall.
- the average growing period for a station as calculated by a model for a drought-sensitive crop (DSC) or a model for a drought-resistant crop (DRC), does not deviate substantially, if at all. The maximum deviation occurs at an average 'DSC' growing period of 40 days and is about 15 days higher for the corresponding average 'DRC' growing period. From about 100 days onward the deviation is negligible. This finding indicates that, since viable summer crop cultivars require a growing period of at least 90 days, there is little advantage in breeding for drought tolerance. It would be better to breed for drought evasion combined with high yield.

As mentioned above, some stations deviated considerably from the general relationship between the dependable and the average growing period, either resulting in a very low or an unusually high dependability. The stations in zone 4 belong to the first group. They are characterised by an unusual variability of the growing period, resulting in a similar average growing period as in zone 3, but far lower dependable growing periods.

The stations in zone 5, by contrast, have less variability in their growing periods from year to year than would be expected from the average relationship between dependable and average growing period. Zone 5 can therefore be considered more stable in its productive capacity than zone 6, although they have the same average growing period.

Agro-ecological Zones

Land systems were described in terms of broad landform, SOTER[1] landform classes, regional slope classes, altitude range, relief intensity, drainage pattern, geological substrata and SOTER geology codes. The specific categories identified in Namibia at the scale of the study are summarised in Tables 3, 4, 5 and 6.

TABLE 3: BROAD LANDFORM CATEGORIES IDENTIFIED IN NAMIBIA.

Main Landform	Landform subdivision	Description
Dunefield		Large areas covered by sand dunes. Dunefields in Namibia are associated with vast sand seas ('ergs'). Dunefields differ from sand sheets by the thickness of the sand cover, which allows the wind to model in the sand ridges, and swales with high relief intensity (up to 300 m)
Hills		Land with steep slopes, low to moderate relief intensity (< 600 m) and elevated position with respect to surrounding land.
Hills and footslopes		A footslope (piedmont) is a portion of a plain adjacent to mountain or hill slopes. They have fairly steep slopes, which distinguish them from the rest of the plain. Hills and footslopes are mapped together where they form an association of landforms that cannot be separated at the scale of the study.
Mountain		Land with steep slopes, high relief intensity (> 600 m) and elevated position with respect to surrounding land.
Pan		An enclosed basin varying from a few hundred meter to several tens of kilometres (Etosha pan) without external drainage. Pans are usually dry throughout the year but when they fill up with floodwaters they offer favourable conditions for vegetation growth and watering wildlife and livestock. For agricultural purposes the temporary moisture bonus is usually offset by an irreversible gradual build-up of salinity as a result of the lack of external drainage.
	Salt pan	A saline flat bordering the coast, flooded during storms, where salts precipitate after evaporation of the enclosed seawater.
Pediment		Any relatively flat surface of bedrock (exposed or covered with a veneer of alluvium, colluvium or gravel) that occurs at the base of a mountain or hill, or as a plain having an associated mountain or hill. The angle of a pediment's slope is generally from 0.5° to 7°, which distinguishes it from footslopes (piedmonts) which are usually steeper. The form of a pediment is slightly concave and it is typically found at the base of hills in arid regions where rainfall is spasmodic and intense for brief periods of time. There is frequently a sharp break of slope between the pediment and the steeper hillside above it.
Plain		Any relatively level area of the earth's surface exhibiting gentle slopes and small local relief.
	Alluvial plain	A flat surface near a stream, but higher than the floodplain and, therefore, less likely to be flooded. Often the alluvial plain refers to an old floodplain which has been raised by more recent stream incision and is therefore still characterized by the presence of alluvial deposits.
	Cuesta plain	Plain characterized by a steep cliff or escarpment on one side and a gentle dip or back slope on the other. This landform is typical for areas with tilted geological strata and is caused by the differential weathering and erosion of the hard capping layer and the soft underlying cliffmaker, which erodes more rapidly.

6 SOTER, the World Soils and Terrain Digital Database (FAO, 1993), promotes the use of standardised and simplified terminology for describing soils and landforms world-wide.

	Floodplain	Flat land adjacent to a stream, composed of unconsolidated sedimentary deposits (alluvium) and subject to periodic inundation by the stream. Floodplains are produced by lateral movement of a stream and by overbank deposition.
	Inselberg plain	Plain characterized by the presence of isolated hills or mountains. Inselbergs occur as ridges, ranges or isolated individual hills or mountains. Their formation is the result of the resistance to erosion by structural irregularities.
	Sand plain	Landform developed on sand, differing from dunefields by the thickness of the sand deposits and the gently undulating surface with low relief.
Plateau		Extensive area of flat upland, usually bounded by an escarpment on all sides. The essential criterion that distinguishes plateaux from plains is the relatively elevated position in comparison to the surrounding landforms. A special case of a plateau is the surface of a table mountain.
Upland		An undifferentiated watershedding area, used in areas where the exact characterization of the landform was too speculative.
Valley		An elongated depression of the earth's surface. Valleys are commonly drained by rivers and may be in a relatively flat plain or between ranges of hills or mountains. Valleys in Namibia are usually formed by the incision of streams or by slope denudation, exceptionally by glaciation.
	Canyon	Very narrow and deep valleys cut in resistant rock or having steep, almost vertical sides. They may reach depths of several hundred meters. Smaller valleys of similar appearance are called 'gorges'.

TABLE 4: SOTER LANDFORM CLASSES (FAO, 1993) IDENTIFIED IN NAMIBIA.

SOTER code	Second level landform	Definition
LP	Plains	All level lands not enclosed between higher lying lands, that do not protrude above the surrounding country, or that do not rise gently against land with a considerably steeper slope.
LL	Plateaux	Level lands that are, compared with the surrounding landscapes, situated at relatively elevated positions. Plateaux can be very extensive, but must always on at least one side be bounded by a slope or escarpment (8 % or more), connecting it with lower lying land.
SM	Medium-gradient mountains	Relatively gently sloping (15 - 30 % gradient) mountains with a local relief intensity of more than 600 m.
SH	Medium-gradient hills	All sloping land with an undulating relief (minimum relief intensity 50 m per slope unit), not elongated, or more than 600 m high, or incorporated in mountainous terrain.
SP	Dissected plains	Sloping land with a more or less constant crest level, and relief intensities of less than 50 m per slope unit.
TM	High-gradient mountains	All steep land with a relief intensity of more than 600 m/km^2, and surrounding one or more outstanding peaks.
TH	High-gradient hills	Steep, but low relief land (relief intensity of less than 600 m/km^2).
TV	High-gradient valleys	Very steep valleys, with normally very little valley floor.
CV	Valleys	The valley, made up of sideslopes and a valley bottom, is taken as one landform.
CL	Narrow plateaux	A narrow strip of level land surrounded on all sides by sloping or steep falling land.

TABLE 5: SOTER LITHOLOGICAL GROUPS (FAO, 1993) IDENTIFIED IN NAMIBIA.

Major class		Group		Type	
I	igneous rock	IA	acid igneous	IA1	granite
		IB	basic igneous	IB2	basalt
				IB3	dolerite
M	metamorphic rock	MA	acid metamorphic	MA1	quartzite
				MA2	gneiss, migmatite
		MB	basic metamorphic	MB1	slate, phyllite (pelitic rocks)
				MB2	schist
S	sedimentary rock	SC	clastic sediments	SC1	conglomerate, breccia
				SC2	sandstone, greywacke, arkose
				SC3	siltstone, mudstone, claystone
				SC4	shale
		SO	organic sediments	SO1	limestone, other carbonate rocks
U	unconsolidated	UE	eolian		
		UF	fluvial		
		UC	colluvial		
		UM	marine		

TABLE 6: FAO SOIL UNITS (FAO-UNESCO, 1990) IDENTIFIED IN NAMIBIA.

FAO soil unit code	FAO soil unit name	Description	FCC[1] code
AR	Arenosols	Undifferentiated sandy soils	Se
ARb	Cambic Arenosols	Sandy soils	Se
ARo	Ferralic Arenosols	Sandy soils with poor capacity to retain nutrients	She

1 FCC: Fertility Capability Classification (Sanchez et al., 1982)

Explanatory notes:

- S or L in1st position: sandy (sand or loamy sand), or loamy (<35 % clay, but not loamy sand or sand) topsoil texture
- L or C or R in 2nd position: subsoil is either Loamy (L): < 35 % clay, but not loamy sand or sand, or
  Clayey (C): > 35 % clay, or
  Rock (R) or other hard root-restricting layer
- ' in second position: gravelly soils (> 15 % gravels or stones)
- d: dry soils (associated with very dry moisture regimes)
- e: low capacity to provide nutrients to plants
- h: presence of soil acidity (pH < 6)
- b: basic reaction as evidenced by either free $CaCO_3$ within 50 cm of the soil surface,
  or pH > 7.3
- s: presence of soluble salts
- n: presence of excess sodium
- v: presence of dark, cracking clays
- g: evidence of periodic waterlogging

TABLE 6 (CONTINUED)

ARl	Luvic Arenosols	Sandy soils with clay-enriched subsoil	SLe
ARh	Haplic Arenosols	Modal sandy soils	Se
CL	Calcisols	Undifferentiated soils with high lime concentrations in the subsoil	S'db L'db Ldb
CLh	Haplic Calcisols	Modal calcareous soils	Ldb Sdb
CLl	Luvic Calcisols	Soils with high lime concentrations and clay enrichment in the subsoil	SLdb Ldb
CLp	Petric Calcisols	Soils with high lime concentrations in indurated form in the subsoil	SRdb LRdb
CM	Cambisols	Undifferentiated moderately developed soils.	L
CMc	Calcaric Cambisols	Moderately developed soils with lime enrichment at shallow depth	Lb
CMe	Eutric Cambisols	Moderately developed soils with fair to good nutrient status	L
CMx	Chromic Cambisols	Moderately developed soils with strong brown or red colours	L
FL	Fluvisols	Undifferentiated soils formed on recent alluvium	S L
FLc	Calcaric Fluvisols	Calcareous alluvial soils	Sb Lb
FLe	Eutric Fluvisols	Alluvial soils with fair to good nutrient status	S L
GY	Gypsisols	Undifferentiated soils with high gypsum concentrations in the subsoil	Ldb
GYk	Calcic Gypsisols	Soils with both high gypsum and lime concentrations in the subsoil	Ldb
GYl	Luvic Gypsisols	Soils with gypsum concentrations and clay enrichment in the subsoil	SLdb Ldb
LP	Leptosols	Undifferentiated shallow soils	LR
LPe	Eutric Leptosols	Shallow soils with fair to good nutrient status	LR
LPk	Rendzic Leptosols	Shallow soils limited by very calcareous material	LR
LPq	Lithic Leptosols	Very shallow soils limited in depth by hard rock or cemented material	LR
LVk	Calcic Luvisols	Non-acid soils with clay enrichment and lime concentrations in the subsoil	LCb
SC	Solonchaks	Undifferentiated saline soils	Ss Ls

TABLE 6 (CONTINUED)

SN	Solonetz	Undifferentiated sodic soils	Sn
SNg	Gleyic Solonetz	Sodic soils with poor drainage	Sgn
SNh	Haplic Solonetz	Modal sodic soils	Sn
VRe	Eutric Vertisols	Dark cracking clays with deficient drainage and good nutrient status	Cv
VRk	Calcic Vertisols	Dark cracking clays with deficient drainage and calcium enrichment in the subsoil	Cv

Overlaying of the Land Systems map and Growing Period zones map, with some adjustments as described in Part I, resulted in the differentiation of 10 'major land systems' (Namib, Escarpment, Central Plateau, Damaraland, Kaokoland, Kalkveld, Kalahari, Etosha, Mountains/Rock, Gorges) and 69 agro-ecological zones. They are represented in AEZ Map 2, and summarized in the Addendum.

The data available for this first zoning exercise, were insufficient for zone-specific interpretations of agricultural potential and constraints. A grouping of zones with more or less similar biomass productivity potential from the viewpoint of the regional water balance, as determined by rainfall and the evaporative demand of the atmosphere, was made. This allows for an initial ranking of zone-groups in terms of their suitability for cropping and grazing of either large or small stock (Table 7).

It should be noticed here that the numbers of the present growing period zones, described in this article and used in the computerised AEZ Database, differ from those in the original Technical Report 1 of De Pauw. This was done to bring the zone numbers and productivity ranking in line. Some of the agro-ecological zone names mentioned in the Technical Report, had consequently also been changed (e.g. CPL16-7B changed to CPL16-4, etc.). The 'old' and 'new' growing period zones are mentioned in Table 7.

TABLE 7: SUMMARY EVALUATION OF POTENTIAL PER AGRO-ECOLOGICAL ZONE.

'New GPZ ' & ranking	'Old GPZ'	Suitability	AEZ's
1	9	Short-maturing crops;	KAL3-1, KAL6, KAL7
2	8	Large stock grazing	CPL16-2, KAL3-2, KAL8, KALK-2
3	7A	Large stock grazing	CPL16-3, KAL3-3, KAL4, KAL9-3, KAL10, KAL11, KALK-3, KAL5
4	7B		CPL2, CPL1, CPL3-4, ETO, KAL1, KAL3-4, KAL9-4, KALK-4
5	6A		CPL3-6, CPL5, CPL16-6, ESC4, KAO4, KAL3-6
6	6B	Mixed large stock &	ESC2
7	5	sheep grazing	CPL3-7, ESC5, KAL2-7, KAO2
8	4	Sheep grazing only	CPL4-8, CPL6, CPL10, KAL2-8, KAO1
9	3		CPL3-9, CPL4-9, CPL7, CPL8, CPL9, CPL13, CPL14, CPL15, ESC3, KAL2-9
10	2		CPL11, CPL12, DAM1, DAM2, ESC1, ESC6, KAO3, KAO6
11	1	Unsuitable for grazing	DAM3, KAO5, NAM1, NAM2, NAM3, NAM4, NAM5, NAM6, NAM7
	N.A.	N.A.	R, GOR

Table 8 points out some important differences between agro-ecological zones of the same broad suitability group, that affect their cropping potential.

TABLE 8: EVALUATION OF CROPPING POTENTIAL FOR INDIVIDUAL AGRO-ECOLOGICAL ZONES.

Rank	AEZ	Evaluation of cropping potential
1	KAL6	Terrace system of the Kavango river, probably the most suitable for irrigation. Soils, land slope, surface smoothness, nearness of a permanent water source, commandibility[2] of the irrigable area, an already intensive degree of cultivation in the area and potential to increase farmer incomes are factors that earmark this area as a prime target for irrigation development. The main limitation of this AEZ is that it is small. Techniques for supplementary irrigation, rather than full irrigation should be developed and promoted.
	KAL7	Floodplain of the Zambezi river with heavy, fertile soils. Very important AEZ for cropping, partially inundated during the rainy season to various depths. Various combinations of mixed cropping systems, based on flood recession cultivation, combined with fisheries possible. The possibility of 'polder' rice cultivation requires further investigation.
1	KAL3-1	Growing period adequate to allow short-maturing crops, but soils are very sandy with poor fertility status and low water holding capacity. Water retention and fertilizer use efficiency should be improved by application of organic matter.
2	KAL8	Soils vary from red sands on dune crests to fairly heavy soils in drainage lines between dunes. Potential for cropping higher than indicated by the growing period zone, owing to the presence of residual soil moisture in drainage lines.
	CPL16-2	Mainly sandy and loamy soils, often shallow; usually underlain by calcrete. Dependable growing period can be adequate for crop growing, provided soils are deep and have a good moisture retention capacity.
	KAL3-2	Mainly deep sandy soils; dependable growing period marginal even for drought-resistant crops, owing to the low moisture retention and fertility status of the soils.
	KALK-2	Not suitable for cropping due to predominance of shallow soils on calcrete. Good grazing areas.
3	KAL9-3	Alluvial fan of the Kunene river with alluvia composed of either sandy soils on levees and sands and clays with high sodium or soluble salts in drainage lines. Soils have generally low fertility status, but allow cropping mainly at the interface between the sandy ridges and clayey bottomlands because of the nearness of perched groundwater. There is a tendency of saline groundwater to rise in dry years. Prospects for intensification of farming systems must be based on strengthening the integration of the crops and livestock components.
	KAL10	Dependable growing periods too short for rainfed cropping. However, groundwater sources are more readily accessible than in the Kalahari sands, which may allow supplementary irrigation for garden-scale production of food crops for local consumption.
	KAL3-3, KAL4	Unsuitable for crop production due to low dependable growing period, combined with sandy soils.
	CPL16-3, KAL10, KALK-3KALK-3	Unsuitable for crop production due to low dependable growing period, combined with shallow soils.
4	KAL9-4	Comparable to KAL9-3, except for a higher risk of drought and salinization and more reliance on additional water supplies from perched groundwater.

CONCLUSIONS

The main conclusion from this study is the very limited nature of the agricultural resources of Namibia. The overriding factor that determines land use in Namibia is the availability of water. The growing period analysis confirms that only a small part of Namibia receives sufficient rainfall to make crop production feasible. Even where feasible, cropping remains risky and often unproductive, owing to variable rainfall and low moisture retention capacity of the predominantly sandy soils. The risk involved in cropping is expressed by the fact that, with the exception of the commercial maize farming in the Maize Triangle and a few small-scale irrigation schemes, all farming systems in the higher-rainfall areas are mixed systems, of which the livestock component is often the most important.

Various studies have pointed out that environmental degradation (deforestation, overgrazing, salinization) is on the increase in the most endowed areas, owing to the high population concentration. Though the resource base is poor and fragile, there is both scope and need, given the high population pressures in that part of the country, to increase both productivity and sustainability of land use. The main strategy will be to increase the complementary integration of the cropping and livestock components. This can be promoted by:

- short-maturing, drought-evading varieties of the main crops, which increase both yield and biomass that can be fed to livestock;
- increasing use of organic amendments (manure, compost), both to upgrade the low fertility status and moisture retention of the sandy soils, and to increase fertilizer use efficiency;
- optimal use of the available soil resources.

Soil surveys of development areas will play a major role by indicating the most suitable land use options for different soil types.

In the lower-rainfall areas, land use can be optimized by looking broader than just agriculture, to alternatives that can complement income from livestock production. Game-farming is becoming increasingly popular. Eco-tourism possibilities could be better explored. The next, updated version of the AEZ map could, for instance, indicate areas of high scenic value.

This study was limited both in time and scope. The currently defined agro-ecological zones are provisional units, pending further resource surveys and research. One of the findings of the study was the inadequacy of basic and integrated resource data to assess with great confidence agricultural potential and constraints in a given area. Consequently, the AEZ team of the Ministry will continue with collection of natural resource data, *inter alia* through soil, landform and vegetation surveys, to improve the level of detail. The objective is to eventually have information on our agricultural resources and the agricultural potential available on at least 1:250 000 scale for the whole country, and 1:50 000 scale for selected areas of high potential or specific interest.

ENQUIRIES

Different formats of AEZ data are available, as the data are stored in a computer database. A user-friendly interface, written in Visual FoxPro, had been developed. It will be distributed to interested parties. The AEZ Database is a 'stand-alone' application, so that users do not need to have Visual FoxPro on their computers. The computer must, however, operate in Windows 95 or later versions of Windows. MS-Word for Windows 95 (Version 7) or a later version, are needed to access the on-line Help function.

The AEZ Map and Database are available at:

AEZ Programme
MAWRD
Private Bag 13184
Windhoek
Tel (061) 2087039
Fax (061) 2087068

People interested in obtaining the database and interface have to supply eight 3.5" 1.44 MB High Density diskettes ('stiffies'). They must undertake not to use this information for commercial purposes. If the information is to be used for academic purposes, the users must undertake to supply both the Agriculture Laboratory and the National Agricultural Information Centre with copies of theses and publications.

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2 'Commandibility' describes the ease with which water can be imported into an area for irrigation purposes, through either pumping from nearby rivers or a canal system. (Groundwater resources are not considered under this term)