AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY ARDA
Batch 84

1. SUBJECT CLASSIFICATION
A. PRIMARY: Food production and nutrition — AF10-0000-G162
B. SECONDARY: Meterology and climatology--Lesotho

2. TITLE AND SUBTITLE
Agroclimatology of Lesotho

3. AUTHOR(S)
Wilken,G.C.

4. DOCUMENT DATE: 1978
5. NUMBER OF PAGES: 35p. 36p.
6. ARC NUMBER: ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Colo.State

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(IN LASA discussion paper no.1)

9. ABSTRACT

This paper presents a general introuctory appraisal of agroclimatology in Lesotho. Gaps in the information base are identified that suggest directions for future research. Some special areas of agroclimatology that are discussed include agroclimatic analogs, microclimates, climatic hazards and risk perception. Lesotho enjoys a pleasant climate with clear skies and moderate temperatures prevailing most of the year. Although average rainfall is adequate for traditional grains such as maize, sorghum, and wheat, damaging or lethal moisture stress may occur during seasonal or mid-season droughts. Crops grown on shallow and eroded soils are especially susceptible. Temperature and radiation levels are relatively high and most lowland areas appear to have average frost free periods adequate for a variety of crops. But late or early frosts can shorten the growing season and ground level measurements suggest that frost risks may be present in most months. Hail storms are also known to cause extensive damage. Factors such as evaporation, wind and solar radiation have not yet been seriously studied. Inadequate climate information is of particular concern in Lesotho. Although agricultural production is limited, the country inevitably is heavily dependent upon the agricultural sector as a source of food, income and employment. Effective agricultural planning must consider the limitations and opportunities offered by the physical environment.

10. CONTROL NUMBER: PN-AAF-576
11. PRICE OF DOCUMENT:

12. DESCRIPTORS
Data
Climatology
Lesotho
Precipitation
Seasonal variations
Temperature

13. PROJECT NUMBER:
14. CONTRACT NUMBER: AID/ta-BMA-6
15. TYPE OF DOCUMENT:

AID 590-5 (4-74)

AID/ta-BMA-6
PN-AAF-576

LASA Discussion Paper Series

AGROCLIMATOLOGY OF LESOTHO

Gene C. Wilken

LASA Discussion Paper No. 1

LESOTHO AGRICULTURAL SECTOR ANALYSIS PROJECT

Ministry of Agriculture
Kingdom of Lesotho

Department of Economics
Colorado State University

35 p.

AID/ta-BMA-6
Colo. State

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6162

AGROCLIMATOLOGY OF LESOTHO

by

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LASA Discussion Paper No. 1
Lesotho Agricultural Sector Analysis Project

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Prepared with partial support of the United States Agency for International Development, Cooperative Agreement AID/ta-CA-1. All expressed opinions, conclusions, or recommendations are those of the author and not of the funding agency, the United States Government or the Government of Lesotho

April 1978

INTRODUCTION

The climate of Lesotho could be described as better for people than for crops (Turner 1975, p. 6). Crisp, clean air and a high percentage of sunny days contribute to the country's rising toursit appeal (e.g., Ambrose 1976, pp. 25-27). But semi-arid conditions and atmospheric hazards have caused more than one analyst to label climate a major constraint to agricultural production and development (e.g., Guma 1977; Smit 1967, p. 33).*

A rigorous appraisal of agroclimatology in Lesotho must await detailed analyses of the several elements, and the accumulation of data from the various regions. This review will serve as a general introduction to the subject and to the particular situation in Lesotho.** In the process, gaps in the information base will be revealed that will suggest directions for future research. Finally, some special areas of agroclimatology that seem particularly important will be discussed. These include agroclimatic analogs, microclimates, and climatic hazards and risk perception.

General Characteristics

Precipitation

The tiny (30,350 km^2) Kingdom of Lesotho lies entirely within latitudes 28° and 31° S. and thus is dominated by the subtropical high pressure belt of the Southern Hemisphere (Map 1). Above a relatively shallow layer of maritime air there is a strong and persistent subsidence inversion that inhibits lifting of air masses and thus precipitation. The most common type of weather is anticyclonic which prevails in the winter but also occurs in the summer in weakened form.

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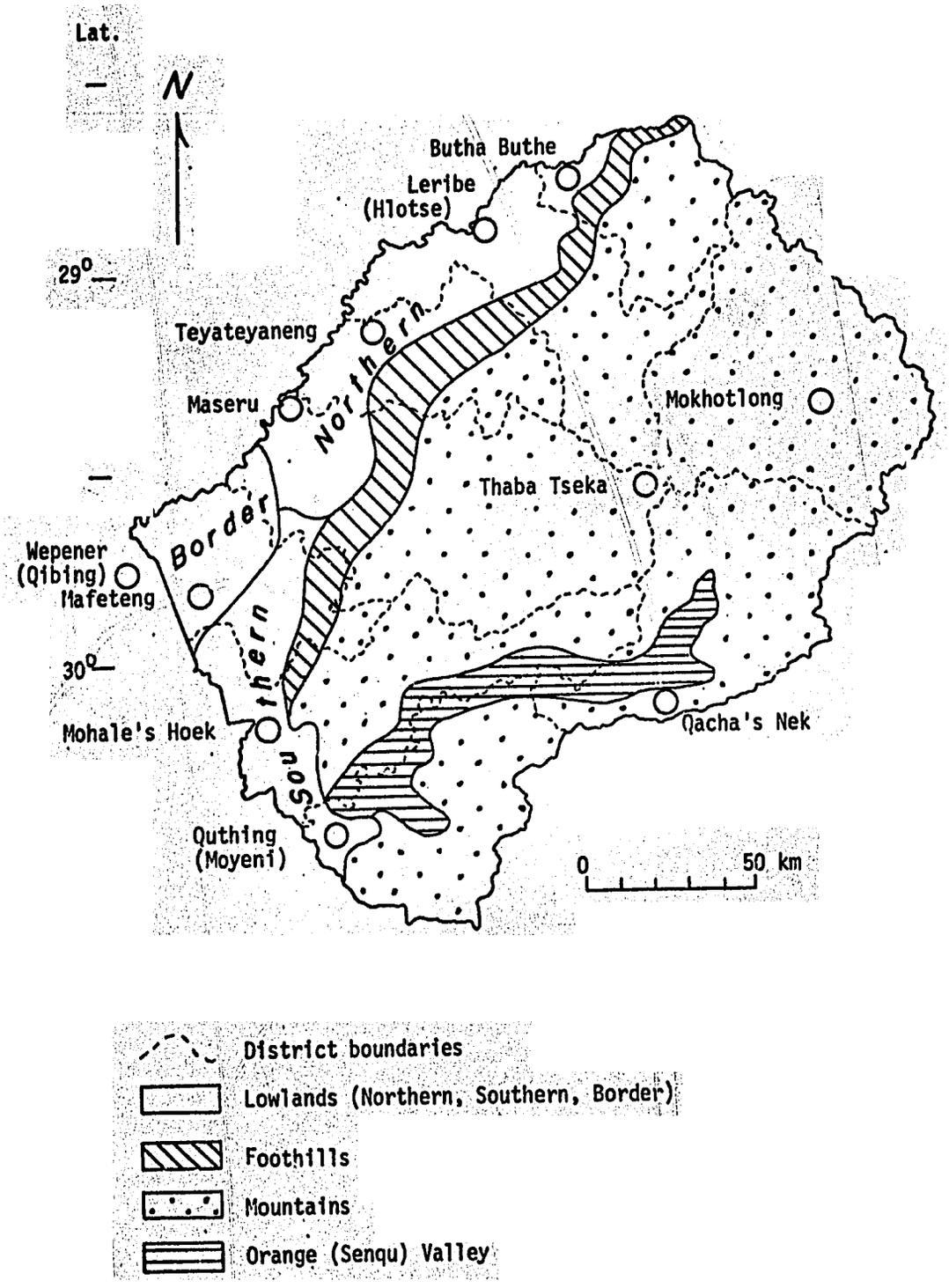
*A measure of the importance of climate to Lesotho is suggested by the national slogan: Khotso Pula Nala; Peace Rain Prosperity.

**This review has benefited greatly from the comments of H.L. de Baulny, J. Eckert, R.F. McKee, and P. Rauh.

Map 1

PROVISIONAL REGIONS OF LESOTHO



In winter pressures intensify over land inhibiting the entry of marine air. The blocking pattern is disrupted by southern cyclones that shift north in the winter and bring frontal and orographic percipitation, occasionally in the form of snow, especially in the southern regions.

In summer the high pressure belt shifts south and separates into two cells, the Atlantic and Indian Ocean highs. Pressure distribution over the differentially heated land mass remains anticyclonic but weaker than in winter, permitting the influx of moist tropical air.* Convective, convergent, and orographic lifting of unstable air produce most of the annual rainfall. For most stations more than 75% of the total precipitation falls during the six months October to March (Table 1).

Average total precipitation varies among Lowland stations but with no clear latitudinal trends. The zone may be divided into two sub zones roughly along the Maseru-Mafeteng districts border (Map 1). The Northern sub zone enjoys somewhat better soil conditions and slightly higher rainfall than the Southern sub zone (Lesotho 1963?).

Differences in seasonal totals are slight, but may be significant for certain crops. Thus, Northern Lowland stations receive only 20 percent of annual precipitation during the six winter months, whereas Southern Lowland stations, more affected by frontal storms, may receive 25 percent in winter.

Longitudinal and altitudinal differences are more pronounced. The Lowlands are progressively drier toward the west, culminating in the Border Lowlands that are climatically as well as physiographically distinct. Generally mountain regions receive more precipitation than lowland, with

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*For purposes of this review it is unimportant whether shallow low pressure (Schulze 1972) or weak high pressure (Trewartha) prevails over the southern African plateau in summer. Either condition would permit penetration of unstable marine air masses.

Table 1. Average Monthly Precipitation (mm)

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	Six Months Winter Amt	Six Months Winter %	Six Months Summer Amt	Six Months Summer %
Lowlands																	
Butha Buthe (28° 46'S 28° 15'E 1770m)	12	14	27	78	99	110	127	107	105	58	30	13	780	154	20	626	80
Leribe (28° 53'S 28° 03'E 1740m)	13	13	30	76	104	117	132	115	112	60	34	13	819	163	20	656	80
Teyateyaneng (29° 09'S 27° 44'E 1750m)	11	12	22	68	90	93	111	93	99	57	31	11	698	144	21	554	79
Maseru (29° 17'S 27° 30'E 1530m)	12	13	21	61	88	89	108	91	99	60	29	11	682	146	21	536	79
Wepener, RSA (29° 44'S 27° 01'E 1400m)	12	12	18	49	66	70	85	89	96	56	26	13	592	137	23	455	77
Mafeteng (29° 49'S 27° 15'E 1610m)	12	15	26	59	82	88	104	106	107	66	33	13	711	165	23	546	77
Mohale's Hoek (30° 09'S 27° 28'E 1600m)	14	15	26	62	86	95	113	101	106	61	37	15	731	168	23	563	77
Quthing (30° 25'S 27° 43'E 1740m)	14	17	34	64	83	98	101	93	102	67	37	15	725	184	25	541	75
Mountains																	
Mokhotlong (29° 17'S 29° 05'E 2200m)	9	14	23	57	78	90	105	78	66	36	21	9	586	112	19	474	81
Thaba Tseka (29° 30'S 28° 37'E 2160m)	11	14	22	59	67	86	96	72	74	39	27	8	575	121	21	454	79
Qacha's Nek (30° 07'S 28° 42'E 1970m)	13	19	39	66	103	147	163	140	120	46	26	18	900	161	18	739	82

Source: Hydro Surv. 1971. Period of record 50 years, 1920-1970 except Quthing (47 years to 1970); Mokhotlang (40 years to 1970) and Thaba Tseka (approx. 30 years of broken record to 1970).

means along the Maluti and Drakensberg escarpments in excess of 1300 mm. However, some mountain stations in sheltered valleys, such as at Mokhtlong and along the lower Senqu (Orange) River receive as little as 500 mm on the average, or less than the dry Border Lowlands (Map 2).

Typically the rainy season begins in September or October. Long term weekly precipitation averages at Maseru show a sharp increase from less than 4 mm to more than 10 mm in the 37th week, or early September. Thereafter 7 day-means increase to more than 30 mm in the peak month of January (Clim. Bul. 1/1977). The five months November, December, January, February and March are relatively uniformly wet on the average, although probably never in any one year. A slight secondary precipitation peak in March that appears in the monthly total of several stations (e.g., Quthing) is largely a product of the short, 28-day February that preceeds it. But less sunshine (Table 9) and stream flood stages also often occur in March, suggesting that an as yet undetermined atmospheric phenomenon may be present. Timing of the rains is the single most important determinant of planting times, and thus cropping seasons (Table 2).

Rainfall varies from long frontal and orographic drizzles to hard convective downpours. With inadequate observational data available, point rainfall intensities have been estimated for Maseru (Table 3).

Table 3. Estimated Maximum Rainfall Amounts for Maseru (elevation 1530 m)

Return Period (years)	15 min.	30 min.	45 min.	60 min.	24 hours
2	17 mm	26 mm	28 mm	33 mm	56 mm
5	24	35	40	45	74
10	27	--	44	52	85
20	31	45	49	58	95
50	36	52	58	68	112
100	39	58	64	74	126

Adapted from Binnie & Partners 1972, Vol. 1, pp 35-36.
Based upon Reich 1963.

Table 2. Lesotho Cropping Seasons

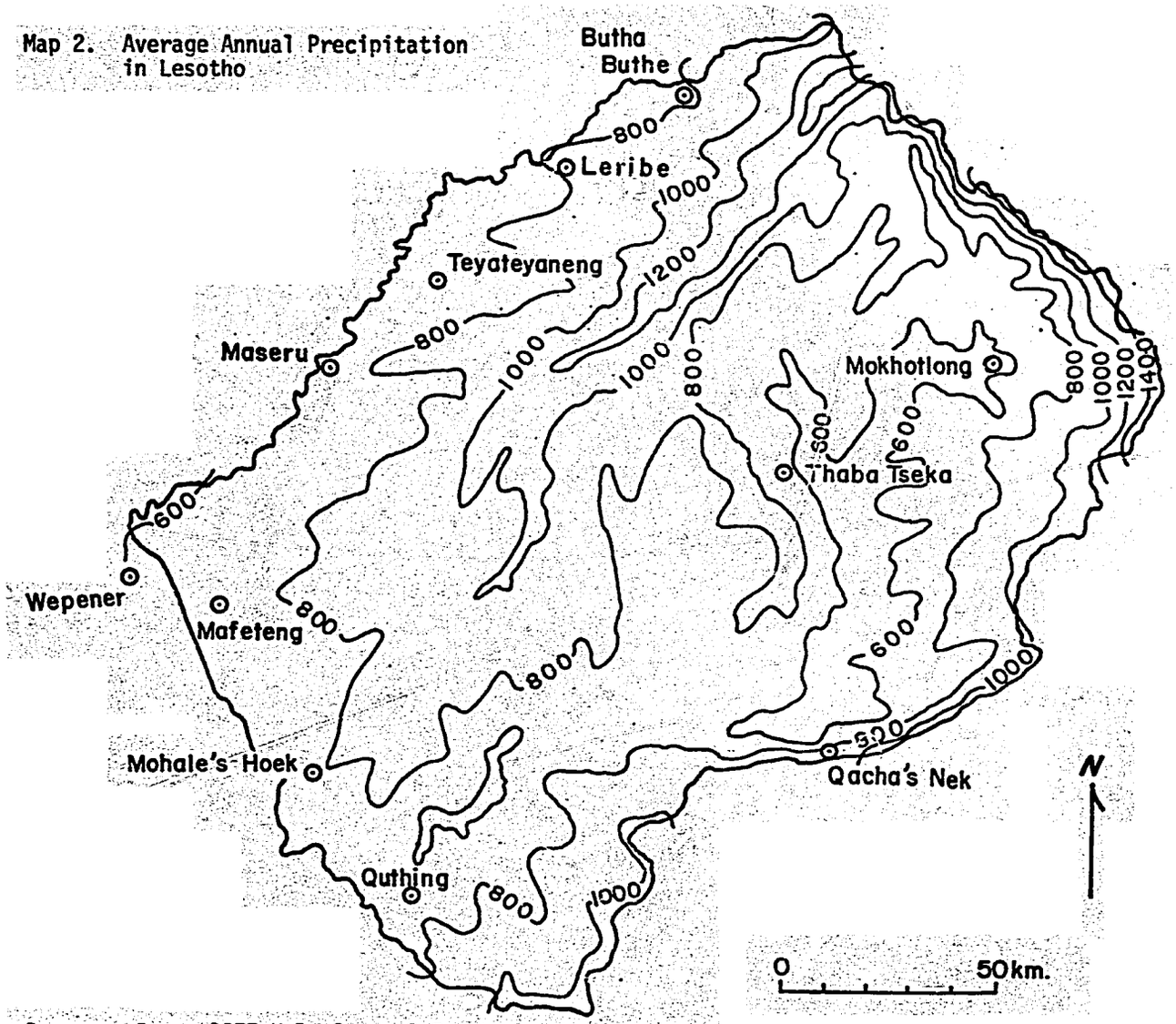
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Lowlands												
Maize	—	—	—	Plant	—	—					—	Harvest→
Sorghum	—	—	—	Plant	—	—					—	Harvest→
Wheat												
Winter	—				—	Harvest	—			—	Plant	—→
Spring	—	—	Plant	—			—	Harvest	—			
Beans			—	Plant	—			—	Harvest	—		
Peas (winter)	—	Plant	—		—	Harvest	—				—	Plant→
Potatoes			—	—	Plant	—	—					
					—	—	Harvest	—	—	—		
Sunflowers			—	—	Plant	—	—	—	Harvest	—	—	
Foothills												
Maize			—	Plant	—					—	Harvest	—
Sorghum			—	Plant	—					—	Harvest	—
Wheat												
Winter												
Spring			—	Plant	—			—	Harvest	—		
Beans			—	—	Plant	—	—	—	Harvest	—		
Peas			—	Plant	—		—	—	Harvest	—		
Potatoes			—	Plant	—			—	Harvest	—		
Sunflowers			—	Plant	—			—	Harvest	—		
Lower Mountains												
Maize				—	Plant	—			-Hvst-			
Sorghum												
Wheat												
Winter												
Spring			—	Plant	—			—	Harvest	—		
Beans				—	Plant	—		—	Harvest	—		
Peas			—	Plant	—			—	Harvest	—		
Potatoes			—	Plant	—			—	Harvest	—		
Sunflowers			—	Plant	—				-Hvst-			

Sources: Bawden and Carroll 1968, p. 22; Brightmore 1963, p. 43; Lesotho 1975; Lesotho 1977-78; Lesotho 1978; Morse *et al*. 1960, pp. 280, 33-334

Notes : 1. Plowing can occur anytime from just after harvesting to just before planting. Some farmers plow early to make the soil receptive to late fall rains. Those without draft power or tools may have to delay plowing and thus planting until they can secure ox- or tractor-drawn plow services.

2. Possible, rather than optimal ranges for planting are shown. Planting is determined by such factors as farmer assessment of frost or rain probabilities, moisture condition of the soil, and availability of equipment for field preparation and planting.

Map 2. Average Annual Precipitation in Lesotho



Source: Sweco 1977 Vol. 2, p. 2:5

It is useful to compare these estimates with recorded rainfall intensities at Wepener, located less than 65 km south and west of Maseru in the Republic of South Africa (Table 4). At 1440 m elevation and with an average annual precipitation of 625 mm Wepener is slighlty lower and drier than Maseru (elevation 1530 m; average annual precipitation 681 mm). The Wepener record suggests that the estimates presented are a good indication of rainfall intensitites that can be expected in Maseru.

Table 4. Highest Recorded Rainfall at Wepener, RSA 29° 44'S, 27° 02'E 1440m. (Period of record 1955-1972)

15 min.	30 min.	45 min.	50 min.	24 hours
27 mm	45 mm	53 mm	59 mm	121 mm

Source: RSA-WR Pt. 11 (WR 36) 1974, p. 21.

But precipitation intensities by themselves can only suggest the likelihood of exceeding soil infiltration rates and storage capacities. In Lesotho, where soils often are thin and underlain by relatively impermeable layers, the threats of flooding and erosion obviously are great. Standing water in fields and silt-laden runoff are common sights following heavy rains.

Hail is a recurrent threat, especially the hard hails of summer that can stip fruit from trees and flatten grain fields in seconds. Unfortunately, information on distribution and severity of hailstorms and estimates of crop damage are lacking. Schulze (1972) estimates that most points in Lesotho can expect hail 7 to 8 times per year. Basotho farmers perceive the frequency, and thus the risk, to be higher. Since risk of hail damage seems to play an important part in farmer's planning and expectations, it merits considerably more attention. (pp ~~16-19~~ 21-23)

Snow falls frequently in the mountains and is not uncommon in the lowlands. But data on depth of falls and duration of the snow cover is lacking. Opinions differ markedly on the hydrological significance of snow. One recent report is of the opinion that "snow contributes substantially to the water resources of Lesotho" (Sweco 1975, p. 2: 4) whereas another concludes that "snow . . . is normally an insignificant, and certainly unreliable, storage element in the annual water balance" (Binnie & Partners 1972, Vol. 1, p. 38). Local professional opinion supports the latter view.

As is true of most semi-arid regions severe and prolonged droughts are a persistent threat. A fifty-year record 1920-1970 for Maseru indicates that total annual precipitation has varied from 1119 mm to 419 mm, or from 63 percent above to 39 percent below the average of 687 mm. In the ten-year period 1960-1970 the critical month of February varied from 274 percent (1962) to 8 percent (1968) of normal. (Hydro Surv. 1971, p. 40).

The intensity, duration and recurrent nature (Dyer and Tyson, 1977) of droughts in Lesotho have not been analyzed. Of particular interest are short-term droughts that may occur during the growing season. Climatological records adequate for these purposes are available. In addition, there is a presssing need to relate precipitation and soil moisture levels to particular crop needs to develop a better perspective on the drought hazard.

Temperature

All parts of the relatively narrow southern portion of Africa are accessible to cool maritime air, resulting in cooler temperatures than occur at comparable latitudes over larger landmasses in the Northern Hemisphere (Schulze, 1972). More important, Lesotho is one of the highest

countries in the world. From the western border at about 1,500 m elevation the land slopes up across the so-called "Lowlands" (actually high plains) through a narrow band of foothills from 2,000 to 2,500 m and quickly rises into high mountains that along the eastern marches contain substantial areas above 3,000 m (see map). Except for river valleys in the south and east, for which there is little environmental data, most farmland is located in the western lowlands. The cooler hill and lower mountain lands are suited primarily to grazing or, in the case of higher elevations, are nonagricultural.

The annual march of temperature for selected stations are shown in Table 5. Highest average monthly temperatures occur in January or February; lowest in June or July. Diurnal temperature ranges are considerable. Minimum ranges occur in mid- to late summer and are on the order of 12 to 13°C in the lowlands and 14 to 15°C at higher elevations. Maximum diurnal ranges occur in mid- to late winter and are about 14 to 15°C in the lowlands, increasing to 18 to 20° C in the mountains.

Frost is one of the more threatening climatic hazards in Lesotho. Although most lowland stations on the average enjoy a seven- to eight-month frost free period, early or late frosts can reduce the growing season* by a month or more (Table 6).

The frost dates reported in Table 6 originally were published in 1954 (RSA-WB Pt. 1, WB 19, p. 115). In addition to possible errors (e.g., Clim. Bul. 2/1977 and 8/1977) the data are badly out of date. Probabilities of frost should be calculated for each week of the entire

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*A true growing season is that part of a year when environmental conditions permit a specific crop to grow. A more general definition is the time elapsed between the average dates of the last and first killing frosts, which may not coincide with occurance of freezing temperatures (0°C). For a discussion of this see ~~Chang~~ Wang 1972, p. 112ff.

Table 5. Average Monthly Temperatures for Ten Stations in Lesotho. (units °C)

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Year
Western Lowlands													
Butha Buthe (28° 46'S 28° 15'E 1770m)	7.3	9.6	13.1	16.2	18.0	19.5	19.8	19.1	17.4	14.6	10.1	6.9	14.3
Leribe (28° 53'S 28° 03'E 1740m)	7.1	9.9	13.7	16.9	18.3	19.8	20.3	19.2	17.8	14.4	10.4	7.3	14.6
Teyateyaneng (29° 09'S 27° 44'E 1750m)	8.0	10.7	13.9	16.9	18.0	20.1	20.3	19.6	17.8	14.7	11.5	8.4	15.0
Maseru (29° 17'S 27° 30'E 1530m)	6.7	10.1	13.3	16.0	18.3	20.5	21.0	20.4	18.3	14.7	10.3	6.7	14.7
Wepener, RSA (29° 44'S 27° 01'E 1400m)	7.5	10.5	13.8	17.2	19.1	21.2	22.1	21.3	19.1	14.9	10.9	7.5	15.4
Mafeteng (29° 49'S 27° 15'E 1610m)	7.4	10.3	13.2	16.4	17.6	19.9	20.4	19.5	17.5	14.4	10.9	7.9	14.6
Mohale's Hoek (39° 09'S 27° 28'E 1600m)	8.1	10.7	13.8	16.9	18.8	20.4	21.4	20.2	18.6	14.9	10.9	7.3	15.2
Quthing (30° 25'S 27° 43'E 1740m)	6.9	10.4	13.2	16.1	17.7	19.4	20.5	19.3	17.5	13.9	10.8	7.8	14.5
Eastern Mountains													
Mokhotlang (29° 17'S 29° 05'E 2200m)	4.9	9.8	10.9	13.6	14.4	16.3	16.6	16.3	14.4	11.6	7.4	5.0	11.6
Thaba Tseka (29° 30'S 28° 37'E 2160m)	5.6	7.9	11.1	14.0	15.1	17.1	16.9	15.9	14.7	11.8	8.3	5.6	12.0
Qacha's Nek (30° 07'S 28° 42'E 1970m)	7.4	9.8	12.7	14.9	15.9	17.6	18.5	18.0	16.5	13.9	10.6	7.6	13.6

Source: Clim. Bul. 10/1975. Average monthly temperatures for Thaba Tseka developed from Binnie & Partners 1972, Vol. 1, p. 7, and from data in the files of the Hydrological and Meteorological Services Branch, Ministry of Works, Lesotho; for Wepener from RSA-WB Pt. 1, WB 19, p. 32.

period from earliest to latest recorded frost to serve as a basis for agricultural planning.

Table 6. First and Last Frost Dates for Lesotho

	Years of Record	Elevation	Extreme Last Frost	Average Last Frost	Average First Frost	Extreme First Frost	Frost Free Days Between Average Last & First Frost Dates
Leribe	29	1740	1 Dec	14 Sep	10 May	7 Apr	237
Teyateyaneng	28	1750	2 Oct	24 Aug	2 Jun	5 Apr	281
Maseru	29	1530	4 Oct	6 Sep*	18 May	2 Apr	254
Wepener	27	1400	17 Dec	3 Oct	1 May	8 Apr	209
Mafeteng	25	1610	13 Nov	20 Sep	19 May	23 Apr	240
Mohale's Hoek	28	1600	1 Dec	26 Sep	11 May	6 Apr	226
Mokhotlong	21	2200	30 Nov	13 Oct	9 Mar	19 Apr	187
Thaba Tseka	11	2160	25 Dec	21 Oct	3 May	9 Apr	193

Source: RSA-WB 1954 (Pt. 1, WB 19) p. 115 except average last frost date* for Maseru adjusted to 6 Sep vice 6 Aug in concurrence with suggestion of Clim. Bul. 2/1977.

The data presented in Table 6 are from measurements at standard screen (shelter) height of 120 cm. Of greater interest for agriculture is the likelihood of frost near the surface where most crop plants grow, and where all crop plants pass their early growth stages. Screen (120 cm) and grass minimum (5 cm) frost dates for Maseru based upon nine years of observation are given in Table 7. It is of considerable significance that the average frost-free growing season is more than two months shorter if surface, rather than screen temperatures are used, and that January is the only month completely free of the possibility of frost.

Table 7. Comparison of Frost Dates at Maseru 120 cm and 5 cm Above the Ground. (Period 1968-1976)

	Extreme Last	Average Last	Average First	Extreme First	No. of Frost Free Days Between Average First & Average Last Frost Dates
Screen (120 cm)	8 Oct	14 Sep	14 May	2 May	241
Grass (5 cm)	5 Dec	30 Oct	14 Apr	6 Feb	165

Source: Clim. Bul. 2/1977

Although frost (i.e., $0^{o}C$) has been stressed here, it by no means is the only significant temperature with respect to agricultural risk. Many crops are damaged or killed at temperatures somewhat above freezing, or cease to grow when temperatures drop below certain threshhold levels. At the other extreme, temperatures can be too high for optimum plant development. Table 8 presents lethal and threshold temperatures for seed germination of several crops.

Table 8. Soil Temperatures for Selected Vegetable Seed Germination (^{o}C)

Crop	Lower Lethal	Lower Threshold	Optimal Range	Upper Threshold	Upper Lethal
Asparagus	0	10	25 - 30	35	41
Lima Bean	3	16	18 - 27	29	38
Beet	-1	4	10 - 29	35	--
Cabbage	0	4	7 - 35	38	--
Carrot	-1	4	7 - 29	35	--
Maize	1	10	16 - 35	41	42
Lettuce	0	2	4 - 27	29	38
Onion	0	2	10 - 35	35	38
Pea	1	4	4 - 24	29	35
Raddish	1	4	7 - 32	35	38
Squash	3	16	21 - 35	38	--
Tomato	2	10	16 - 29	35	--

Adapted from Wang 1972, p. 108

A further important measure of plant-temperature relationships is degree-units or degree-days; the accumulation of daily mean temperatures above a specified threshold temperature during the growing season. The requirements for most crop plants (i.e., varietal constants) are well known. But as far as can be determined, degree-day figures have not been developed for the various regions of Lesotho.

Sunshine

Given persistent anticyclonic pressure conditions Lesotho's reputation for clear skies and bright sunny days is not unexpected. Table 9 indicates the consistency with which bright sunshine prevails in Maseru. Over the year the city enjoys more than 70 percent of possible sunshine and even in the rainy summer months more than two-thirds of the theoretical maximum possible is received. Although solar radiation measurements are not available, it seems likely that farmlands, at least in the lowlands, receive heavy cascades of solar radiation during much of the year.

Table 9. Percent Possible Bright Sunshine at Maseru (12 years of record)

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Avg
79	82	78	68	67	71	67	71	68	69	76	75	73

Source: Binnie & Partners 1972, Vol. 1, p 11. Theoretical maximum not adjusted for effective horizon.

Evaporation

Records of evaporation from Class A pans in Lesotho are presented in Table 10. The short periods of record and in some cases questionable quality of data preclude detailed analysis in relation to precipitation and soil moisture storage. Furthermore, evaporation calculated by any of the standard formulae has not yet been adequately reconciled with measured evaporation. (Binne & Partners 1972, pp 54ff). However, it

appears that pan evaporation at most stations exceeds precipitation in all months and that annual deficits (P - E) are substantial. In the warm lowlands available moisture normally is not sufficient to satsify the atmosphere's capacity to absorb water. Therefore, in rainy years losses to evaporation and plant transpiration actually increase (de Baulny n.d., p. 13). Developing reasonably reliable potential evapotranspiration estimates for the agricultural regions of Lesotho deserves highest priority since it is essential information for crop planning.

Table 10. Class A Pan Evaporation for Three Stations in Lesotho (units:millimeters)

Yrs. of Record	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Butha Buthe													
7	97	139	181	212	215	245	230	197	178	125	110	84	2013
Maseru													
3	84	122	186	215	230	260	288	227	174	117	83	62	2048
Mokhotlong													
6	102	158	193	225	211	211	225	184	176	121	114	100	2020

(Binnie & Partners 1972, Vol. 1, p. 54)

Relative Humidity

Information on relative humidity is of limited value since it only partially indicates the conditions of evapotranspiration. In addition, the figures presented in Table 11 do not include recent data. However, relative humidity is one of the more commonly reported moisture parameters and the data may be useful for general comparisons.

Table 11. Monthly Mean Relative Humidity for Nine Stations in Lesotho (Years of Record in Parenthesis)

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Year
Butha Buthe (12)												
58	51	48	52	61	60	62	66	65	72	66	60	60
Leribe (16)												
56	49	49	56	58	59	63	68	69	71	67	62	61
Teyateyaneng (13)												
56	47	47	54	58	62	64	63	67	68	64	62	59
Maseru (20)												
68	46	42	46	53	53	55	63	64	67	64	59	57
Mafeteng (5)												
50	41	43	50	52	53	51	64	62	61	59	55	53
Mohale's Hoek (13)												
48	41	41	45	46	46	49	54	55	59	54	53	49
Quthing (17)												
50	43	40	47	48	49	49	55	59	62	58	56	51
Mokhotlong (14)												
55	50	45	50	57	54	57	58	61	58	55	58	55
Qacha's Nek (13)												
54	46	54	57	65	62	64	69	72	65	60	57	60

Source: Binnie & Partners 1972, vol. 1, p. 10. Based upon data published in the Annual Report of the South African Weather Bureau. Calculated from 0800 and 1400 hour readings.

Wind

Wind usually is considered of secondary importance in agricultural climatology, of significance mainly as it relates to evapotranspiration. But strong winds, especially those associated with summer storms, can cause considerable damage to standing crops such as maize and wheat, and significant soil erosion in some areas (Binnie & Partners 1972, vol. 4, p. 411). Table 12 presents only average monthly windspeeds at Maseru based upon three years of observation, and two years at the proposed site for the new international airport near Mazenod, about 15 km southeast of Maseru. At Mazenod the highest hourly windspeed recorded

(in October) was 54 km/hr; the strongest gust (recorded in November) was 116 km/hr. (Clim Bul. 9/1977; Sweco 1975, p. 2:11). Comparison with stations in South Africa suggests that over longer periods even higher windspeeds could be expected (RSA-WB 1974, Pt. 11, (WB 26), p. 29).

Table 12. Average Wind Speed in Km/Hr

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Year
Maseru	4.9	5.8	6.9	6.3	6.0	6.1	6.1	5.9	4.5	4.0	4.1	4.5	5.4
Mazenod	2.8	4.6	6.6	7.2	7.9	7.8	4.9	3.0	3.1	2.6	3.1	2.3	4.7

Source: Binnie & Partners 1972, Vol. 1, p. 14; Clim. Bul 9/1977

Agroclimate Analogs

The combination of relatively low latitude, high altitude, and position with respect to prevailing pressure and wind patterns produces distinctive climates in Lesotho. Classification by three different systems are given in Table 13. In the Köppen and Thornthwaite systems Lesotho stations are transitional between the two types indicated, often falling into one or the other by slim margins. World maps showing the distribution of climate types reveal that in all cases these climates are among the least common or least extensive types.

Table 13. Climate Types of Lesotho

Classification System	Type Symbol	Description
Köppen	Cwb; Cfb	Humid mesothermal with warm summer; rain in summer (w) or all seasons (f)
Thornthwaite	CB'd; CC'd	Sub-humid warm (CB') or cool (CC') with moisture deficient in all seasons
Troll-Paffen	IV_4	Dry winter climates with long summer humidity.

But rare is not the same as unique and at similar latitudes and altitudes similar climates may be found. Thus, a preliminary survey has revealed possible climatic analogs for Lesotho in Argentina, Australia, Laos, southern China (People's Republic), Zimbabwe (Rhodesia), and, of course, neighboring South Africa. Lack of available data has prevented detailed comparison. Nevertheless, conditions appear to be sufficiently similar to warrant careful investigation of climate and other environmental conditions, and of farming systems practices in those areas.

One objective of climatic analogs is to uncover cropping and livestock systems that have proven successful in one area and that might be transferred to another, environmentally similar area. Another goal is to identify techniques for modifying agriculturally similar environments (e.g. Wilken 1972). For example, there has been much discussion of the possibilities for irrigation in Lesotho. It would be helpful to examine the successes and failures of irrigation in environmentally similar areas where common problems might be encountered (e.g. Morris 1969).

Although climatic analogs usually stress physical conditions and crops, it is important to extend comparisons to social and economic conditions. Thus, an ideal analog for Lesotho would be a region with similar climate, soils and topography, population densities, farm sizes, and levels of technological and social development. To a certain extent the constraint of environmental comparability can be relaxed in favor of greater socio-economic similarities. The argument here is that a particular farming system developed, for example, in nearby, economically advanced South Africa under environmental conditions almost identical those in Lesotho might not offer as good opportunities for transfer as

one developed in the small-farm sector of a distant country, even if environmental conditions were less closely comparable.

The use of agroclimatic analogs is a familiar method for identifying environmentally similar regions and for comparing crop combinations and farming systems. It has already been used in Lesotho although never systematically: recommendatons by UNDP-FAO to plant asparagus and cherries in Lesotho were based upon the fact that these two crops grew successfully in nearby South African areas with similar soils and climates (Philippe 1971). What is proposed here is an extension of the method to include all the world's areas with similar environmental conditions in an effort to determine the spectrum of crops, animals, and farming systems that might be considered for introduction into Lesotho.

Meso- and Micro-climates

All climate elements are distributed aerally along continuiums. Identifying climate types involves imposing threshold values or limits. But the near-infinite variation remains and within major climate types it is possible to identify smaller and smaller subdivisions which, depending upon scale and area, are designated meso- or micro-climates. Terms and definitions are somewhat arbitrary but the range runs from small regions to point climates. For example, special climates such as are found in protected or exposed districts, hillsides or valleys or even within fields are of immediate interest to farmers. (Geiger 1969)

Small-scale climates largely are results of local modification of general climate elements. Thus radiation and temperature regimes differ markedly on north- and south-facing slopes. Cold air may pond in valley bottoms. Strong winds may be broken by a row of hills or trees. Microclimates are especially important in hilly or mountainous regions where

vertical zonation and topographic controls create a mosaic of local en-environments with differences significant to agriculture. Point sampling at widespread stations fails completely to reveal these small climates that may be more or less favorable to agriculture in general or to specific crops. (Geiger 1965).

There are perhaps 30 weather stations (temperature and precipitation) in Lesotho with an additional 31 stations that report only rainfall. Some of these stations have only sporodic or short records. Except for a few special purpose installations, this probably represents most of the stations generating meteorological data in the Kingdom. Thus, there is one weather station for each approximately 1,000 km^2 of the national territory. Of course, stations are not uniformly distributed so that in many cases the climate of much larger areas goes unrecorded.

It is obvious that such a sparse network will not reveal even sizable regional climate variations, much less pick up small areas that differ in agriculturally significant ways. Particularly lacking are detailed studies of valley and hillside climates in the eastern and southern (e.g. Senqu or Orange) river valleys that might prove suitable for specialized crops.

No nation can afford to install and maintain a sufficient number of stations to record the climatological differences of its many small regions. Certainly, Lesotho would find it difficult to significantly expand the existing network. It might be possible, however, to develop several portable networks that could be installed in specific places long enough to establish correlative relationships with permanent stations. These could be used to enrich the climatological data of agricultural project

areas and to reveal special micro-climates that might offer possibilities for new crops. (MacHattie and Schnelle 1975, pp. 18ff.)

Environmental Hazards and Risk Perception

Environmental hazards are universally recognized in Lesotho. Almost every account of the country mentions the marginal, variable, and agriculturally risky nature of the climate and the severe and extensive erosion that itself is largely a product of the climate. Certainly environmental hazards are real to Basotho farmers. In a recent survey 48 foothill and mountain farmers in southern Lesotho were questioned concerning their needs and problems (Gay 1977, pp 145-166). After worm damage, which also is a climatically linked hazard, drought, hail, and too much rain were identified by the majority of farmers as leading problems (Table 14). Thereafter, there was little agreement on problems, including frost and snow which were mentioned frequently only by mountain farmers, or storms* which were of concern only to hill farmers.**

Farmers' fears generally are well-placed. In 1970 some 50,000 ha, or more than 13 percent of the total 368,000 ha of farmed land suffered complete crop failure, according to the census of agriculture (Lesotho 1972). Drought was by far the leading cause of complete crop loss, with frost and hail trailing far behind (Table 16).

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*The term "storms" is ill-defined. Probably it means thunderstorms with driving winds and hard rains that can damage crops. "Too much rain" produces standing water on poorly drained soils, and mucky fields that are difficult to work. As far as can be determined it does not refer to runoff and erosion.

**It is striking that soil erosion, rated the main problem in Lesotho by most outside observers, apparently is of little concern to either foothill or mountain farmers.

Table 14. Problems in Farming

Problems	Percent of Farmers Mentioning Problem Foothill	Mountain
Worms	100.0%	100.0%
DROUGHT	96.9	100.0
HAIL	65.6	93.8
TOO MUCH RAIN	59.4	50.0
Weeds	56.3	12.5
No ploughing tools	50.0	25.0
No ploughing power	43.8	12.5
No good seeds	18.8	0.0
FROST	12.5	62.5
Theft	9.4	12.5
Poor soil	9.4	0.0
Rats	9.4	0.0
STORMS	9.4	0.0
No fertilizer	6.3	0.0
Soil erosion	3.1	0.0
Birds	3.1	0.0
Late ploughing	3.1	0.0
SNOW	0.0	37.5
Animals raiding crops	0.0	6.3
No laborers	0.0	6.3

Source: Gay 1977, p. 158

Table 15. Area Suffering Complete Crop Failure (1970)

Causes	Area	Percent
Drought	39,184 ha.	77.8%
Cutworm	1,034	2.0
Hail	2,397	4.8
Frost	1,957	3.9
Others	5,817	11.5
Total Area Failed (= 13.7% of total area planted)	50,389 ha.	100.0

Source: Lesotho 1972, p. 77

From comparison of data it is difficult to correlate farmers' expressed concerns with actual hazards. It may be that drought is more likely to cause complete failure whereas damage by frost, and hail, and worms, although usually only partial, is widespread and significant and looms large in farmers' minds (Leribe 1973).

Table 16 indicates to what extent farmers believe that they can cope with or solve their problems and with how much or what kind of help. Not surprisingly, relief from environmental hazards usually requires other than human intervention in the opinion of farmers. The major exception is hail which farmers, especially in the mountains, believe can be averted by human efforts. Physical measures, such as surface mulching as defense against hail or frost (Wilken 1972), are not common in Lesotho except in houseyard garden plots. For the most part the human efforts considered by Basotho farmers consist of not violating certain taboos, such as carrying a corpse through the fields during the day or bringing firewood home at midday, or by soliciting the aid of Sesotho doctors whose functions include hail prevention and rain making (Ashton 1967, pp. 132-133). In addition, foothills farmers believe that to some extent drought and storms can be overcome by human efforts. Farmers' weather prediction methods, perception of event probabilities, or risk-avoidance strategies (e.g., adjusted planting dates; hail insurance) were not indicated by the survey.

Table 16. Aid Required as Perceived by Farmers

Problems	Foothills Farmers				Mountain Farmers			
	By Oneself	With Some Help	With Much Help	With no Human Help	By Oneself	With Some Help	With Much Help	With no Human Help
Drought	0.0	0.0	3.1	96.9	0.0	0.0	0.0	100.0
Worms	28.1	12.5	50.0	0.0	0.0	0.0	100.0	0.0
Hail	0.0	6.3	9.4	53.1	0.0	0.0	68.8	25.0
Too Much Rain	0.0	0.0	0.0	59.4	0.0	0.0	0.0	50.0
Storm	0.0	0.0	3.1	6.3	0.0	0.0	0.0	0.0
Frost	0.0	0.0	0.0	15.6	0.0	0.0	0.0	12.5
Snow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.5
Soil Erosion	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0

Source: Gay 1977, p. 160

Since data from the sample survey and the census are limited, more detailed analyses would be inappropriate. It is clear, however, that further work on this topic would be helpful in understanding the actual and perceived risk environments in Lesotho. (White 1974, pp. 3-5; Whyte 1977, pp. 9-13; Wilken 1978).

SUMMARY AND RECOMMENDATIONS

Lesotho enjoys a pleasant climate with clear skies and moderate temperatures prevailing most of the year. However, climate imposes severe limits and risks on agriculture. Thus although average rainfall is adequate for traditional grains such as maize, sorghum, and wheat, damaging or lethal moisture stress may occur during seasonal or mid-season droughts. Crops grown on shallow and eroded soils with little moisture storage capacity are especially susceptible. Temperature and radiation levels are relatively high and based upon screen (1.2m) measurements most lowland areas appear to have average frost free

periods adequate for a variety of crops. But late or early frosts can significantly shorten the growing season and ground level measurements suggest that frost risks may in fact be present in most months. Hail storms are known to cause extensive damage. Other factors such as evaporation, wind, and solar radiation have been so little measured that it is difficult to discuss their effects on agriculture with any confidence.

Lesotho is plagued with the data problems common to less-developed countries. Early measurements are of questionable quality making it difficult to develop reliable long-term means and deviations. The present sparse station network does not permit detailed regional analyses, much less identification of small-scale local climates.

Until 1967 climatological data gathered in Lesotho were reported directly to the South African Weather Bureau in Pretoria and were included in reports and summaries of that agency. Since 1967 weather data have been collected and processed also by the Department of Hydrological and Meteorological Services, Ministry of Works, Lesotho. Because of the short period of record since 1967, however, and general lack of confidence in earlier data, few new summaries or analyses have been issued. Thus discussions of climatic elements that have appeared in various project reports have been based largely upon earlier summaries in South African sources (as has this review). In some cases this has led to republication of old and possibly erroneous information. An example is the listing of first and last frost dates for Maseru first developed in 1954 (RSA-WB Pt. 1, WB 19, p. 115) and subsequently republished in 1972 (Binnie & Partners 1972, Vol. 1, p. 8) and again in 1975 (Sweco p. 2:11). An exceptionally

early and probably erroneous last frost date for Maseru finally has been challenged (Clim. Bul. 2/1977).

Inadequate climate information is of particular concern in Lesotho. Although agricultural production is less than impressive, in part because of environmental limitations, the country inevitably is heavily dependent upon the agricultural sector as a source of food, income, and employment. Thus, agriculture must be a primary target for development, and effective agricultural planning must include the limitations and opportunities offered by the physical environment. It is unfortunate that there are so many gaps in the climatological information base. The following proposals and recommendations seem appropriate.

1. Graphic presentations of seasonal and annual distribution of such elements as rainfall, frost, and hail are helpful to agricultural planners. Maps should be developed as soon as the data are adequate. Annual and seasonal average precipitation maps such as those developed by de Baulny (n.d.) and Bonney (1975) are useful and should be widely distributed.
2. Sufficient information already exists to tabulate heating-units or degree-days. This should be done right away, and the results promulgated to all concerned agencies and projects on a frequent, regular basis.
3. Measurement of evaporation should be improved and expanded, and efforts made to identify those mathematical models that most closely approximate conditions in Lesotho.
4. Develop agroclimatic analogs for agricultural regions in Lesotho. Investigation should include climate and other environmental conditions, and cropping and farming systems. This information

should be made available to all existing and proposed agricultural projects.

5. Investigate the possibilities for establishing temporary climate stations in relatively dense networks over small areas. These would be used to sample climate characteristics of proposed agricultural project areas and to identify local climates suitable for special crops. Correlation with permanent stations would perpetuate the value of such temporary installations after they were removed.

6. Ascertain the extent, frequency, and distribution of environmental hazards common to Lesotho. These would include drought, frost, hail, and possibly field flooding and wind. Evaluate probabilities and risk environment of farmers, and calculate costs of physical protective measures and insurance. Investigate farmers perception of risk and risk-avoidance strategies.

Existing and needed climatic data are of more than passing interest. Average climatic conditions establish the general range of agricultural options. Extra normal or extreme climatic events form primary risk elements. Thus, in large measure the climate defines the operational and risk environments within which farmers and pastoralists must work. There can be no more practical or needed body of knowledge for agricultural planning.

Fortunately, none of the research or data needs identified in this review are particularly expensive or difficult to develop. With the exception of additional climate stations, most of the proposals could be accomplished with small supplemental support to proposed projects

(e.g., B.A.S.P.; Farming Systems), to the Hydrological and Meteorological Services Branch of the Ministry of Works, or to small independent research efforts. The returns certainly would justify such modest investments.

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