A SYSTEM FOR DROUGHT MONITORING AND SEVERITY ASSESSMENT

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A SYSTEM FOR DROUGHT MONITORING AND SEVERITY ASSESSMENT

by

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"COME, let us sing of Drought,
Drought - the hate of the sun; ...",

...

"Naked is the veld, scorched and naked,
Charred is its coat, once brave and green;
Naked to the sun's lash it quivers –
A victim defenceless.

Silent are the streams, sad and silent;
Drought has sucked their shining souls away;
The stars have slipped from their fingers,
The moon has escaped them."

Extracts from the anthology "Drought: A South African Parable" by Francis Carey Slater, a South African poet, writing under the pseudonym of Jan von Avond.

1. INTRODUCTION

Drought occurs the world over (Riebsame, 1991). The effects of drought have been felt by man since the beginning of humanity (Yevjevich, Hall and Salas, 1977). Written records of drought in China date back to 206 BC while in the United States of America there is evidence of drought long before the arrival of the first pilgrims (Yevjevich *et al.*, 1977). Riebsame (1991) states:

> "*Drought, and the famine it engenders, has probably killed more people than any other natural hazard. More than any other natural hazard, drought threatens the sustainability of the natural resource base upon which society depends.*"

Sastri and Chaudry (1991) point out that the negative effects of drought on the economy are felt longer than those of any other natural disaster.

Droughts are unique in that unlike floods, earthquakes, or hurricanes; during which violent events of relatively short duration occur, droughts are more like a cancer on the land that seems to have no recognized beginning (Mather, 1985). Droughts covering a few hundred square kilometres do exist but these are usually of limited duration and modest severity. It is more common for droughts to cover relatively vast areas, a significant proportion of a continent or sub-continent approaching an area of a million or more square kilometres (Mather, 1985).

The African continent is particularly drought prone (Rasmusson, 1987; Tucker, 1989). Unganai (1993) lists numerous droughts that have plagued the continent from before the turn of the century to more recent times. Glantz (1987) states that drought in the semi-arid regions of Africa is a recurrent but aperiodic phenomenon. The southern tip of Africa and South Africa in particular is not excluded (Bruwer, 1989; Schulze, 1992). Bruwer (1989) notes that considerable agricultural production takes place in South Africa under arid or semi-arid where drought is a recurring hazard.

Drought then must be seen not as one of the vagaries of climate but rather as a normal feature (Wilhite, 1991). The term drought however means different things to different people (Day, 1991). According to Wilhite and Glantz (1987), drought definitions can be characterized as either conceptual or operational. Conceptual definitions are those which identify the boundaries of the concept of drought, eg. dictionary definitions (Wilhite and Glantz, 1987).

The operational definitions are used in identifying the onset, severity and termination of drought episodes. Wilhite and Glantz (1987) group these definitions into four types:

* Meteorological drought - defined solely on the basis of the lack of rainfall and the duration of such dry periods,
* Hydrological drought - definitions concerned with effects of drought on surface or sub-surface hydrology,
* Agricultural drought - links various characteristics of meteorological drought to agricultural impacts, and,
* Socio-economic drought - definitions that express features of the socio-economic effects of drought, but can incorporate features of meteorological, agricultural and hydrological drought.

Two options exist when studying drought:

(i) forecasting the occurrence of drought prior to the beginning of an agricultural production or rainfall season. This includes methods such as making use of general circulation models or using statistical methods such as analysing historical trends to determine the probability of the occurrence of drought, or,

(ii) monitoring the current season as it progresses, providing early warning of impending drought and assessing drought impact.

Research is currently being undertaken to identify the meteorological causes of drought and to forecast the occurrence of drought through the use of general circulation models (Hunt and Gordon, 1988; Hunt and Gordon 1991; Hunt 1991). Although such research has merit, scientists remain dubious about its outcome. Schulze (1987) for example states:
"No one can forecast the onset of drought, and we only know about a drought once we are already in it". Gordon (1983) examined historical rainfall records for both Australia and the United Kingdom and concluded that the cumulative total profiles appeared to obey arcsine laws. This means that almost any observed drought profile could be explained by chance within acceptable limits of significance. Gordon (1993) further concluded that precipitation is largely a series of random events and suggests that thought should be given to the meaning of chance as a mechanism for producing drought as opposed to specific deterministic causes.

Concentrating on drought monitoring research will provide decision makers with useful information that will be of immediate benefit in effective drought management. The need for appropriate pro-active drought planning and management has often been emphasized in the past (eg Da Cunhia, Vlachos, and Yevjevich, 1983; Wilhite, 1989). Wilhite (1989) in establishing priorities for drought planning, gives monitoring/ early warning systems the highest priority. Such systems would provide decision makers at all levels with information about the severity and duration of drought conditions (Wilhite, 1989).

In the outline of his 10 step plan for the facilitation of drought contingency plans by state government, Wilhite (1991) under the heading **"Step (2) - Statement of Drought Policy and Plan Objectives"**, states:

> *"It is imperative that the plan contain both an assessment (monitoring and estimations of impact) and a response component, with well defined linkages."*

Bruwer (1989) speaking at the SARCCUS workshop on Drought, held in Pretoria during 1989, stressed the need to study drought in relation to its duration, intensity, spatial extent and time of occurrence during the agricultural production cycle. He stated:

"*Steps should be taken to expand current efforts to accurately monitor drought and effectively adapt to moisture stress.*"

This study therefore focuses on the development of an agricultural drought monitoring system. Schulze (1987) and Bruwer (1989) define agricultural drought as occurring when soil moisture stress causes crop yield reductions. The overall objective of the work is similar to that of the Drought Monitoring Centres in Nairobi and Harare, namely of supplying appropriate early warning information to decision makers (Ambenje, 1991).

1.1 OBJECTIVES OF THE STUDY

The specific objectives of this study are:

(i) to develop a near real-time crop-specific drought monitoring system that delimits drought stricken areas and assesses the severity of droughts in these areas,

(ii) to produce products from the system which can be used for decision support by decision makers at various levels, and,

(ii) to test the system for maize production using historical production seasons.

The thesis is organized as follows:
Chapter 2 documents the literature survey undertaken for the study. In Chapter 3 the design of the crop-specific agricultural drought monitoring system is discussed. The methodology used in developing, implementing and testing the system designed is presented in Chapter 4. In Chapter 5 the results obtained are documented and discussed. The conclusions drawn and recommendations made are presented in Chapter 6. Chapter 7 is a summary of the previous chapters.

2. LITERATURE REVIEW

2.1 INTRODUCTION

A great number of scientific articles have appeared on various aspects of drought. A review of literature relevant to the stated objectives of the study is presented in this chapter.

2.2 THE USE OF CROP MODELS IN DROUGHT MONITORING

Although indices such as the Palmer Drought Severity Index (PDSI) and Crop Moisture Index (CMI) (Palmer, 1965 & 1968) are popularly used for large-area drought monitoring they are largely based on a series of involved empirical relationships which lack a physical basis (Owe and van de Griend, 1990). Geigel and Sunquist (1981, cited in Easterling *et al.* 1988) point out that physically based crop models hold the greatest promise for identifying and quantifying relationships among weather, agricultural management practices, and crop phenology.

Easterling and Riebsame (1987) add that knowledge on agroclimatic sensitivity comes from weather-crop modelling. These authors define the first two generations of models as statistical black boxes - multivariate regressions with a single output, namely crop yield. According to Easterling and Riebsame (1987) the third generation are deterministic physiological models that simulate effects of weather on individual biophysical processes and management decisions. Model inputs include daily weather data, management, and technology variables, outputs include impacts on growth stages at any point in the growing season.

Mathematical simulation using physically based models enhances knowledge of the understanding of crops because they allow for integration of knowledge on all relevant processes and responses within an appropriate framework (Booysen, 1987). Mechanistic models can respond to any given environmental condition and can be used to make management decisions during the growing season (Booysen, 1987).

Several studies have been undertaken on the application of crop models in drought monitoring, early warning systems, or general food security planning. The models used vary in complexity ranging from simple empirical models (eg Weir 1988) to complex systems analysis (eg Kulshreshtha and Klein, 1989).

Weir (1988) in his simple empirical model defines droughtiness (D) as the difference between the potential moisture deficit (MD) which is the crop's demand for water, less rainfall, and the soil's ability to supply the demand in terms of profile available water (AP), ie D = AP - MD.

Kulshreshtha and Klein (1989) developed an Agricultural Drought Impact Evaluation Model (ADIEM). The ADIEM is an integrated systems model comprised of four components, namely; i) a yield/hydrology simulation model, ii) a farm business simulation model, iii) a regional input-output model and iv) an employment model. Two types of yield prediction model were developed, one for cereal crops and another for forage crops. The sub-models are interlinked with each model using results from one or more of the previous sub-models. The overall aim of the ADIEM is to estimate the cost of a drought both in terms of income levels and employment.

Du Pisani (1987) examined the use of the crop growth model CERES-maize as a tool for drought monitoring. He evaluated a method of completing the growing season with surrogate weather data, using a median rainfall year. It was found that simulated yield estimates made in February best matched the measured yields recorded at the end of the season. Du Pisani (1987) suggested that yield levels be used as an index of drought. There was no spatial component to the system but it was tested at five geographic locations where maize was produced.

Berkhout (1986) recommended that satellite remote sensing be combined with crop growth models to give a spatial dimension to crop condition monitoring. Analysis of satellite images could be used to provide some of the input required in crop models on a spatially distributed basis, such as precipitation and irradiance estimates. This type of approach was adopted by Menenti, Huygen, Azzali, and Berkhout (1990) in establishing a food security system in Zambia. The project was entitled "Monitoring Agroecological Resources using Remote Sensing and Simulation" (MARS). The MARS system combines weather and land resource satellite data with a surface network of weather and crop condition observation. The various sources of data are brought together in a geographical information system and then linked to the crop simulation model SMART.

2.3 OBTAINING SPATIALLY DISTRIBUTED WEATHER DATA

Weather-driven crop growth models require daily rainfall, maximum and minimum temperatures and total radiant flux density as input data (McCaskill, 1990a). Most crop growth models tend to be point-source models using site specific input data (Lal, Hoogenboom, Calixte, Jones, and Beinroth, 1993). A spatially distributed drought monitoring system using crop growth modelling techniques requires spatially distributed weather data input. Three options exist in obtaining such data:

(i) generating data for any unrecorded element using available data,

(ii) interpolating point observations, and,

(iii) making use of weather satellite imagery.

2.3.1 Generation of unrecorded elements from available data

McCaskill (1990b & 1990c) reasons that as rainfall records are the most abundant of any of the weather variables required as input in the models, they should be used to generate the other variables required. He found statistically significant relationships between transformed rainfall (R′, R′=0 for a rainless day, R′=1 if more than 0.1 mm was recorded) for the current (t), preceding (t-1) and subsequent (t+1) days of the rainfall record and the other meteorological parameters. Fourier regression techniques were used to determine coefficients. The desired parameter (P_t) is generated for day t using the equation:

$$P_t = a + b\cos\theta + c\sin\theta + d\cos(2\theta) + e\sin(2\theta) + f R'_{t-1} + g R'_t + h R'_{t+1} \quad (1)$$

where:

θ = day number (N, days since start of the year, January 1, N = 1) converted into a radian form (θ, $\theta = 2\pi N/365$).

a,b,c and d = Fourier regression coefficients

R′ = transformed rainfall

McCaskill (1990a) proposes a similar approach for daily total radiant flux density. An empirical relationship between daily irradiance (Q) and extraterrestrial radiation (Q_{ext}) and rainfall prior to, on the day of estimation (Q_t) and the day after was developed:

$$Q_t = aQ_{ext} + bR'_{t-1} + cR'_t + dR'_{t+1} \quad (2)$$

R′ = transformed rainfall

a,b,c,d = regression coefficients

Standard meteorological observations have been used to estimate solar radiation with models having been developed for this purpose. Some are based on empirical formulae (eg Bristow and Campbell, 1984; Hodges *et al.*, 1985) while other models involve complex numerical relationships (Cengiz *et al.*, 1981; Richardson, 1981). Parameters used as input include air temperature, degree-hours of temperature, relative humidity and rainfall. Historical data (mean annual daily irradiance, amplitude of annual curves of daily solar radiation) and geographical data such as intercorrelations between daily max and min temperatures and solar radiation at a geographical area, are also required.

Bindi and Miglietta (1991) propose a model that uses daily maximum and minimum temperatures and total daily rainfall to estimate irradiance. The model is used to first identify the probability of a particular day being either completely or partly clear, or completely overcast. Atmospheric transmittance is then calculated according to type of day identified. daily irradiance (Rs) is determined as:

$$Rs = QK \qquad (3)$$

where:

K = mean sky transmittance

Q = extraterrestrial irradiance for day.

2.3.2 Interpolation of point observations

Methods to interpolate rain gauge measurements onto a regular grid are well established for monthly and longer accumulations. Methods used include various distance weighting techniques (Ripley, 1980), multi-quadratic surfaces (Adamson, 1978), optimal interpolation (Bras and Rodriguez-Iturbe,1985) and regression techniques (Dent *et al*, 1989). Methods to interpolate daily rain fields are less well established. Shafer (1991) assumed that daily rainfall amounts reflect trends similar to those found in the median monthly rainfields. Seed (1992) concluded that this may be true in areas of significant orographic rainfall, but is unlikely where convective development is the main meteorological process causing summer rainfall. Seed (1992) examined a number of interpolation techniques and suggested that an inverse distance weighting technique be used for interpolating daily rainfall. He outlined a tiling method used in the selection of nearest raingauges. This was adopted in this study and is described in detail in Chapter 4. Seed's study furthermore, showed that the accuracy with which a rain gauge network can reproduce a rain field is largely determined by the characteristics of the network and the rain field sampled rather than the algorithm used for interpolating.

Spatial interpolation techniques may also be used to estimate daily irradiance from nearby weather stations (Bindi and Miglietta, 1991). The accuracy of this method depends on the mean grid size of the radiation measurement network and on the mean variability of weather conditions over the studied region. Weather variability may depend on many factors, especially orography. In a study of the relationship between the extrapolation distance and the error in radiation estimate, it was found that in central Europe, mean absolute errors due to extrapolation are a linear function of the extrapolation distance.

Hutchinson (1989) proposes a surface fitting technique which uses multi-dimensional Laplacian smoothing spline surfaces to estimate a variety of meteorological variables. The degree of smoothing is chosen to minimize predictive error of the final fitted surface.

In a large-scale crop modelling exercise in Canada, De Jong, Dumanski, and Bootsma (1992) made use of the Thiessen polygon weighting technique for interpolating point measurements of temperature, precipitation and potential evapotranspiration.

McCutchan and Chow (1991) made use of multiple regression equations to interpolate 30-day forecasts of temperature and relative humidity for fire hazard warning. They used the technique of maximum r^2 regression (MAXR, SAS 1990) to develop regression models, which enables the selection of subsets of predictors.

The spatial interpolation method of Kriging was developed in early sixties by the French engineer, G. Matheron from an idea originally proposed by the South African geostatistician, D.G. Krige (1951), hence the name Kriging. The concept of a spatially dependent variable is inherent to Kriging. Such a variable may be denoted by the symbol Z(x) where the spatial dependence is denoted by the position vector x. The function $Z(x_i)$ is thus a function defined over an area (G):

$$G : Z(x) = \{ Z(x_i), \} \text{ and } x_i \in G \qquad (4)$$

where G = the area or region in question
$Z(x_i)$ = a point value of the regional variable $Z(x)$
$\in$ denotes an element of a set

Each $x_i \in G$, $Z(x_i)$ is random variable with a given covariance structure between all $Z(x)$ and $Z(y)$ for $x,y \in G$.

In ordinary Kriging two intrinsic hypotheses are satisfied:
1) the expected value of the difference $z(x) - z(x + h)$ is independent of x but dependent on the distance or lag (h):

$$E[Z(x) - Z(x + h)] = m(h) \qquad (5)$$

2) the semi-veriogram is independent of the point x for all distances h

$$\text{gamma}(h) = 0.5\, E[Z(x) - Z(x + h)]^2 \qquad (6)$$

Menenti *et al*. (1990) used ordinary Kriging to interpolate daily rainfall data in Zambia.

Davis (1973) discusses the method of trend analysis which may be described as a mathematical method of separating data into two components - that having a regional nature, and that exhibiting local fluctuations. What is considered as regional and what is considered local, is largely subjective and depends upon the size of the region being examined. A trend may be defined as a linear function of the geographic coordinates of a set of observations so constructed that the squared deviations from the trend are minimized. Using trend surface analysis does not imply the process to be a linear or polynomial function, but these functions are used as approximations. Schulze (1981) made use of trend surface analysis, with altitude, latitude and longitude as variables, to simulate mean monthly temperature fields for Natal. He describes trend surface fitting as an application of least squares theory, where the variable (here temperature) shows a systematic dependence, or trend, with certain functions of physiographic factors.

The software package SPANS (Spatial Analysis System, TYDAC Technologies Inc., Ottawa, Ontario, Canada) incorporates a system of Voronoi polygons for interpolation of data. Johnson and Worobec (1988) used this approach to interpolate precipitation data in an effort to relate grasshopper movement and rainfall.

Two-dimensional Lagrange interpolation polynomials, principal components regression and linear regressions using first-order weather stations are among the interpolation methods suggested by Johnson and Viren (1982). The Lagrange method focuses directly on the use of latitude and longitude co-ordinates of first-order weather stations within a specified geographical area and a distance function. Principal components regression involves computation of linear combinations (principal components) of monthly average temperatures with other weather data.

A more general interpolation method, useful for any type of data is given by Watson (1982). He describes a method of contouring values of a dependent variable against two independent variables in the Cartesian plane. The algorithm is given the acronym ACORD - Automatic Contouring of Raw Data. ACORD is a two-dimensional implementation of the algorithm given by Watson (1981), to compute the Delaunay tessellation of an n-dimensional data set. For two independent variables, this is a triangulation technique with triangles having as near as possible equal angles at their vertices (Sibson, 1978). A property of this triangulation is that no data point lies within the circumcircle of any triangle.

Lee and Lin (1986) describe a triangulation of a set of points as a straight-line maximally connected planar graph, whose vertices are the given set of points and whose edges do not intersect each other except at the endpoints. Each face, except the exterior one, of the graph is a triangle. Triangulations of a set of points in the plane have various mathematical applications including interpolation.

2.4 THE USE OF WEATHER SATELLITE IMAGERY

2.4.1 The METEOSAT satellite

The following description of the METEOSAT weather satellite is drawn from Mason (1987).

The first METEOSAT-1 weather satellite was launched in November, 1977. METEOSAT-4 is currently operational. The satellite is spin-stabilised in a geostationary orbit at 35800 km and located over the Gulf of Guinea, at the crossing between the equator and the Greenwich meridian (0°N,0°E). Reserve satellites are located nearby in a hibernated condition.

The satellite is equipped with a multispectral radiometer. Visible and infra-red radiances of the earth's disc as seen from the satellite are transmitted to ground receiving stations.

The radiometer operates in three spectral bands:

0.4 - 1.1 μm	Visible band
5.7 - 7.1 μm	Infra-red water vapour absorption band
10.5 - 12.5 μm	Thermal infra-red band

The spatial resolution at the sub-satellite point is approximately 5 km for infra-red and water vapour images and 2.5 km for visible images. Images in each of the three bands are scanned at half-hourly intervals. Data gathered by the satellite radiometer have been used for estimating irradiance and spatially distributed rainfall depths.

2.4.2 Methods for estimating irradiance from satellite imagery

The methods applied to satellite data to estimate global irradiance can be divided into two categories: empirical statistical models that relate satellite brightness values to surface insolation (Hart and Nunez, 1979; Tarpley, 1979; Delorme *et al.*, 1983; Raphael and Hay, 1984), and physical models which simulate atmospheric processes relevant to surface irradiance (Gautier *et al.*, 1980; Möser and Raschke, 1984). Models of varying complexity are used in both the statistical and physical approaches.

2.4.2.1 Statistical Models

Hay and Hanson (1978) developed a simple statistical model relating normalized satellite-measured brightness to normalized atmospheric transmittance. The Hay and Hanson model describes irradiance at the surface as:

$$K\downarrow = I_o \cos\theta(a - bSR) \qquad (7)$$

where,

$K\downarrow$ = surface irradiance (W m^{-2})
I_o = solar constant (1353 W m^{-2})
θ = local solar zenith angle
SR = normalized satellite brightness
a,b = empirical constants

Nunez *et al.* (1984) and Nunez (1987) follow a similar approach, relating atmospheric transmittance (τ) and satellite reflectivity α_{BA}. The transmitted fraction of extraterrestrial irradiance (τ), as obtained from a pyranometer can be described in a simple model where absorption occurs before scattering and the non-absorbing cloud layer is at the bottom of this atmosphere. Nunez *et al.* (1984) neglect multiple ground-atmosphere reflections in their model which reads:

$$\tau = K_C\downarrow \;/\; K_O\downarrow = (1 - \phi)(1 - \alpha_A)[C(1 - \alpha_C) + 1 - C] \qquad (8)$$

where,

$K_O\downarrow, K_C\downarrow$ = daily global irradiance at the top of the atmosphere and the surface respectively (MJ m^{-2})

ϕ = daily absorptivity of solar radiation (dimensionless)

α_A = daily reflectivity by the atmosphere (dimensionless)

α_C = cloud reflectivity (fraction)

C = cloud cover (fraction).

Nunez (1987) showed that atmospheric transmissivity τ can be related to satellite reflectivity. Equation 8 can then be rewritten as:

$$\tau = K_C\downarrow \;/\; K_O\downarrow = c_1 + c_2\alpha_s \qquad (9)$$

where,

c_1, c_2 = empirical constants

α_s = satellite reflectivity

The Tarpley (1979) statistical model is more complex than those previously described. The model takes into account the differences in the radiative transfer process under clear, partly cloudy or overcast conditions. The model was developed and tested using data captured by the GOES geostationary satellite over the Great Plains of the United States. Irradiance estimates were based on the average brightness measured from the satellite using a 50 x 50 km array with a resolution of 8km. A minimum brightness parameterization is determined by:

$$B = a + b\cos\theta + c\sin\theta\cos\phi + d\sin\theta\cos 2\phi \qquad (10)$$

where,

B = predicted minimum brightness

θ = local solar zenith angle

ϕ = azimuth angle between sun and satellite

a,b,c and d = regression coefficients

Three regression equations are used to estimate irradiance at the surface under clear, partly cloudy or overcast conditions:

Clear conditions $n < 0.4$

$$K\downarrow = a_1 + b_1 \cos\theta + c_1 \tau + d_1 n + e_1 (I_m / B)^2 \tag{11}$$

Partly cloudy $0.4 \leq n < 1$

$$K\downarrow = a_2 + b_2 \cos\theta + c_2 n (cld / B_0)^2 \tag{12}$$

Overcast $n = 1.0$

$$K\downarrow = a_3 + b_3 \cos\theta + c_3 (cld / B_0)^2 \tag{13}$$

where,

I_m = mean target brightness

B = predicted clear brightness - Equation 10

cld = mean cloud brightness (sensor digital count)

B_0 = normalized clear brightness

τ = atmospheric transmittance

n = cloud amount $(N_2 + 2N_3)/2N$

N_2, N_3 number of pixels in partly cloudy and overcast categories respectively

N = total number of pixels in an array

a,b,c,d and e are regression coefficients.

2.4.2.2 Physical Models

The model of Gautier *et al.* (1980) is based on energy conservation within an earth/atmosphere column. In the case of statistical models, cloud effects are treated as one of a few discrete conditions. Whereas in their physical model Gautier *et al.* (1980) treat cloud effects as continuous. There are two facets to the model; a clear sky model and a cloudy atmosphere model. The clear sky model is represented by three equations describing the flux measured at the satellite, $SW\uparrow$, the albedo of the surface, α, and the irradiance at the surface, $K\downarrow$:

$$SW\uparrow = F_0B + F_0(1 - B)[1 - a(u_1)] * [1 - a(u_2)](1 - B_1)\alpha \quad (14)$$

$$\alpha = (SW\uparrow - F_0B)/\{F_0(1 - B)[1 - a(u_1)] * [1 - a(u_2)](1 - B_1)\} \quad (15)$$

$$K\downarrow = F_0(1 - B)[1 - a(u_1)](1 + \alpha B_1) \quad (16)$$

where,

F_0 = instantaneous shortwave flux at the top of the atmosphere ($I_o \cos\theta$)

B, B_1 = reflection coefficients for direct and diffuse irradiance

$a(u_1), a(u_2)$ = absorption coefficients for optical path lengths (sun and satellite respectively)

α = surface albedo.

The cloudy atmosphere model retains the clear sky formulation with the added effect of clouds which are assumed to occur in a discrete layer. The flux at the satellite under cloudy conditions $SW\uparrow_c$, and the irradiance at the surface under cloudy conditions, $K\downarrow_c$, are given by:

$$SW\uparrow_c = F_0B + F_0(1 - B)[1 - a(u_1)t] * (1 - B_1)A_c[1 - a(u_2)t] + F_0(1 - B) * [1 - a(u_1)t](1 - A_c)^2[1 - a(u_1)b]\alpha(1 - B_1) * [1 - a(u_2)t](1 - abs)^2[1 - a(u_2)b] \quad (17)$$

$$K\downarrow_c = F_0(1 - B)[1 - a(u_1)t](1 - A_c) * (1 - abs)[1 - a(u_1)b] \quad (18)$$

where,

A_c = cloud albedo

abs = cloud absorption

$a(u_1)t, a(u_2)t$ = absorption coefficients above cloud level for the sun and satellite paths, respectively.

$a(u_1)b, a(u_2)b$ = absorption coefficients below cloud level for the sun and satellite paths, respectively.

Another physical model is that of Möser and Raschke (1983). The model is also based on radiative transfer calculations in clear atmospheres as well as non-homogeneous atmospheres with various cloud layers. The calculations are performed using a two-stream approximation (Kerschgens *et al.* 1978). The model considers absorption by atmospheric gasses (oxygen, ozone, water vapour, carbon dioxide), aerosols and Rayleigh scattering (Tuzet *et al.*, 1984). The exponential sum-fitting method of transmission functions developed by Wiscombe and Evans (1977) is employed in the model. The model considers the downward flux of global irradiance at the surface M_G, and the upward flux of reflected irradiance at the top of the atmosphere M_R. Under cloudless conditions these quantities are functions of the local solar zenith angle, θ, and M_G will reach a maximum M_{GO} whereas M_R will reach a minimum M_{RO}. However, above a solid and optically thick cloud layer M_R will reach a maximum M_{RU} and M_G will be approximately zero.

Möser and Raschke (1983) define a normalized global irradiance:

$$M_{GN} = M_G / M_{GO} \tag{19}$$

and a normalized reflected irradiance:

$$M_{RN} = (M_R - M_{RO}) / (M_{RU} - M_{RO}). \tag{20}$$

Both M_{GN} and M_{RN} are mainly dependent on the optical depth of the cloud layer. M_{GN} decreases with increasing optical depth in nearly the same order as which M_{RN} increases. The equations for M_{GN} and M_{RN} can therefore be combined to obtain:

$$M_G = M_{GO}(\theta) * M_{GN}(M_{RN}, \theta) \tag{21}$$

M_G has been split into M_{GO} which is mainly dependent on the zenith angle of the sun and on the condition of the boundary layer and the

weighting function, M_{GN}, which is mainly dependent on the normalized reflected irradiance M_{RN}.
Since the METEOSAT satellite measures radiances L_R in uncalibrated units a normalized reflected L_{RN} radiance is derived:

$$L_{RN} = (L_R - L_{RO}) / (L_{RU} - L_{RO}) \qquad (22)$$

where,

L_{RO} is the minimum value of L_R under cloudless conditions.
L_{RU} is the maximum value of L_R above a solid and optically thick cloud layer.

L_{RN} is therefore used as an indicator of M_{RN}. The instantaneous global irradiance, G_i, is calculated for each pixel in the image as:

$$G_i(\theta) = \{ 1 - f(L_{RN},\theta)\} * G_o(\theta) \qquad (23)$$

where,

G_o = global irradiance under clear skies for solar zenith angle θ.
$f(L_{RN},\theta)$ = a function of effective cloud cover nearly linearly dependent on L_{RN}

The daily sum of global irradiance is arrived at by the integration of G_i values obtained from images available for a particular day.

2.4.3 <u>Precipitation estimates from METEOSAT data</u>

Two approaches can be adopted for estimating rainfall depths from weather satellite imagery. Barret *et al.* (1987) differentiates between wet and dry areas on METEOSAT images using predetermined threshold values for visible and infrared images. Pixels deemed wet are assigned the climatological mean rain per rain day. This map is then adjusted by regressing pixel estimates against synoptic station rainfall data using the best fit line to adjust the derived rainfall amounts.

A second approach is that of Flitcroft, Milford, and Dugdale (1989) and Milford and Dugdale (1990). Here, multiple thermal infra-red images from METEOSAT are used to define areas covered by cloud below a certain temperature threshold. The duration of cold cloud for each pixel is totalled over a ten day or longer period. A calibration factor is applied to convert the cloud duration into a rainfall total

2.5 THE USE OF A GEOGRAPHIC INFORMATION SYSTEM (GIS)

A GIS is a computer system designed to collect, store, retrieve, manipulate, and display spatial data (Franklin, 1992). As such it may be used in analyzing drought which is a spatially related phenomenon (Sakamoto and Steyaert, 1987). Sakamoto (1989) describes a GIS as "*a powerful tool for rapid and meaningful combination of and presentation of information*".
Furthermore, Lal, Hoogenboom, Calixte, Jones, and Beinroth , (1993) point out that the scope and applicability of point-source crop models can be extended to broader spatial scales for regional planning by combining their capabilities with a GIS.

There is a trend to link GIS and models of temporal and spatial processes. According to Burrough (1989) there is a general move away from storing spatial information on paper to electronic storage in GIS. Good spatial results are however dependent on good input into the GIS (Burrough, 1989).

Berkhout (1986) advocates the combination of GIS and simulation models for quantitative land evaluation and as a tool for early warning. Models may be linked to a GIS, both to obtain spatially distributed input parameters and to display the results of the model in their spatial context (Wolfe and Neale, 1988; De Roo, Hazelhoff, and Burrough, 1989; Hayward, 1991; Walklet and Hitchcock, 1991). Zhang, Haan, and Nofziger (1990) outline three major tasks in linking a GIS with hydrological models: (i) spatial data base construction, (ii) integration of spatial layers, (iii) GIS and model interface. The same would apply to crop models.

2.6 ESTABLISHING AN OBJECTIVE BASIS FOR COMPARISON

Wilhite and Glantz (1987) state that drought "..*is a condition relative to some long-term average condition of balance between rainfall and evapotranspiration in a particular area, a condition often perceived as "normal.""* An objective method of defining the normal condition is therefore required. One such method is the determination of the cumulative probability distribution function, denoted CDF, of yield for a given crop cultivated in a specific area (De Jager and Singels, 1990). The CDF's are obtained by using crop growth models to simulate yields over long periods of time, eg 100 years.

In establishing regional norms, regions of similar climate response may be treated as units. This requires the classification and delimitation of climate zones. One such climate classification system currently used in South Africa is the homogeneous climate zone (HCZ) classification of Dent, Schulze and Angus (1988). HCZ's are delineated in terms of physiography and trends in rainfall. A combination of altitude and mean annual precipitation (MAP) is used. A digital elevation grid of 1′ x 1′ of latitude and longitude, was combined with rainfall stations where more than ten years of data are available, in order to choose key long-term rainfall stations to represent a particular zone. The positions of rainfall stations were superimposed on the altitude grid. This combination was in turn overlaid on 1:250 000 topographical maps to delimit the homogeneous climate zones.

2.7 PREVIOUSLY PROPOSED APPROACHES TO DROUGHT MONITORING OR EARLY WARNING

Several examples exist in the literature of drought monitoring approaches that are based primarily on the use of the Normalized Vegetation Index (NDVI) obtained from processing satellite data from the NOAA Advanced Very High Resolution Radiometer (AVHRR) (eg Tucker and Goward, 1987; Carelton *et al.*, 1991; Thiruvengadachari, 1991; Kogan, 1991; Peters, Rundquist and Wilhite, 1991; Mulenga and Sandoval, 1993).

The NDVI is defined as:

$$NDVI = \frac{\text{Infra-red} - \text{Red}}{\text{Infra-red} + \text{Red}}$$

The overall vigour of surface vegetation (natural or cultivated) is the main subject analyzed in the assessment drought. The NDVI may however be used in conjunction with indices such as the Palmer Drought Severity Index or the FAO Crop Water Requirement Satisfaction Index (Frere and Popov, 1986).

Kalensky, Howard, Colella, and Barrett (1985) propose an approach which only uses data from the METEOSAT weather satellite. Thermal Infra-red data are used for precipitation estimates over north-eastern Africa. This information is used in empirical estimates of crop production.

The "Monitoring Agroecological Resources using Remote Sensing and Simulation" (MARS) project in Zambia is an example of the linking of GIS, data base management and crop growth simulation models for routine functioning in an early warning system for food security (Menenti *et al.*, 1990). Satellite data are also used in the MARS project. NOAA data are used for NDVI calculations, while METEOSAT data are used to map rainfall. The FAO Crop Water Requirement Satisfaction Index is computed on a ten day basis. Kriging and co-kriging with satellite data methods are used for interpolating rainfall measurements. The crop model SMART is used for yield estimations.

Gulaid (1986) describes a FAO environmental monitoring programme in which precipitation is estimated from METEOSAT data and vegetation greenness is estimated using the NDVI.

Crop growth simulation approaches to monitoring drought are also advocated by Ainsworth and Arkin (1983), Du Pisani (1987), Kulshreshtha and Klein (1989) and Walker (1989). Du Pisani (1987) and Walker (1989) propose a method of forecasting crop yield at the end of a growing season using current season data up to the present date and completing the season with surrogate weather data. Walker (1989) uses long-term average weather data to complete the season while Du Pisani (1987) suggests a method of constructing a median year from historical data.

Fouché (1992) uses a similar approach of running the PUTU rangeland model with observed weather data up to the present date and completing the season with surrogate data. Fouché's method to obtain the surrogate data is to determine the cumulative probability distribution function of total monthly rainfall and then to construct three hypothetical rainfall series: (i) a below average rainfall year, (ii) an average rainfall year and (iii) an above average rainfall year. These three scenarios are constructed by selecting months from historical data which correspond to the 10%, 50% and 90% probability intervals.

At one rainfall station, for instance, the 10% scenario was constructed by using daily rainfall data from 1951 for January, data from 1957 for February, data from 1947 for March, etc. This system is currently used operationally for short term rangeland production and drought monitoring in the Orange Free State province of South Africa. A similar approach was adopted in this study and is explained in detail in Section 4.6.2

3. DROUGHT MONITORING SYSTEM DESIGN

3.1 INTRODUCTION

This chapter describes the designing of a crop-specific drought monitoring system (DMS), bearing the literature reviewed in mind as well as systems previously proposed. The requirements of a drought monitoring system, and concepts on which the system are based are discussed.

3.2 FUNDAMENTAL SYSTEM REQUIREMENTS

Drought is a spatially related phenomenon (Karl and Koscielny, 1982; Karl, 1983; Zucchini and Adamson, 1984; Mather 1985). The first requirement of a drought monitoring system then is an ability to describe drought intensity quantitatively on a spatial basis (Bruwer , 1989; Shelly 1991).

The second requirement for an agricultural drought monitoring system is that the sensitivities of specific crop growth stages to drought, must be taken into account (Easterling and Riebsame, 1987). A plant's demand for water is dependent on the prevailing meteorological conditions, biological characteristics of the plant, its stage of growth, and the physical and biological properties of the soil (WMO, 1975). The monitoring system must be a synthesis of these factors.

The third requirement is that the output from such a system will be readily usable by decision makers involved in drought planning or drought relief management. The typical decision maker weighs a wide variety of inputs in reaching a decision (Redmond, 1991). Presenting information succinctly will assist in sound decision making. A useful way of presenting drought information to decision makers is through the use of an index. A major reason for using indices is that they are simple, usually consisting of a single number, which is easy to remember (Redmond, 1991).

The desirable properties of an index are listed by Redmond (1991) as:

1. a wide audience should be able properly to interpret the index without detailed understanding of underlying procedures,
2. the index should not be an oversimplification,
3. the index must offer improved information over the raw data,
4. data must be readily available for operational indices,
5. social and economic impacts should be proportional to the index, and,
6. index should be open-ended to account for unprecedented values.

Two well known drought indices are the Palmer Drought Severity Index (PDSI) and the Crop Moisture Index (CMI) (Palmer, 1965 & 1968). Although these indices have been criticized (Alley, 1984; Meyer, Hubbard and Wilhite ,1991a) they remain popular and in wide use throughout the USA (Strommen and Motha, 1987). The reason for their popularity is that they meet the fourth requirement of a drought monitoring system, namely that the index used should be easily updated from observed weather data obtained from the national observation network.

The fifth requirement is that an agricultural drought monitoring system should be crop-specific. Meyer, Hubbard, and Wilhite (1993b) point out that the advantages of a crop-specific drought index are threefold: (i) weather's probable impact on crop production can be assessed any time during the growing season using standard meteorological variables, (ii) probabilities of projected outcomes can be assigned based on historical climate data, (iii) specific outcomes can be inferred using climatological analogs. Hubbard (1987) also suggests that specific crop indices be used for the characterization of drought and other anomalous events.

3.3 SYSTEM DESIGN

3.3.1 Establishing a spatial base

The first step in the design process was to decide on the base unit to use when describing drought severity quantitatively on a spatial basis. The base unit chosen covers an area of 2° of longitude and 1° of latitude. This base unit was selected as it is a common division used by the Surveyor General for topographical and cadastral mapping and many thematic maps produced by other organizations (eg soil maps) also use these boundaries. These maps are known as the South African 1:250 000 map sheet series. There are a total of 70 such map sheets on which South Africa is mapped.

3.3.2 Spatially distributed crop modelling

The second step in the design process was that of satisfying the requirements that the system should be sensitive to crop development stage and that it should be crop-specific. Applying crop growth models in the drought monitoring system was decided on as the solution. Selection of the particular crop model to run for a given map sheet or part thereof, would depend on the geographic area mapped and the time of year.

The models and their input data would however have to be spatially distributed. It was decided to divide the base unit into a number of smaller cells for which simulations could be performed. Each base unit was divided into cells covering an area of two minutes by two minutes of latitude and longitude (± 14 km^2). There are thus 1800 grid cells (60 columns and 30 rows) in one such unit.

The techniques used in obtaining spatially distributed weather data input and the adaption of the crop model for grid-based simulations are discussed in Chapter 4.

3.3.3 Establishing drought norms

The third step in the design process was to decide on a mechanism to use in determining drought severity, for a particular crop in a particular area. It was decided to use the probability distribution of crop yield as the norm for defining drought severity.

Yield norms would be obtained by using crop modelling to establish the cumulative probability distribution function (CDF) of a particular crop for given soil, climate and management (planting date, density and row widths) combinations. The CDF would be subdivided into classes to obtain threshold levels for the drought index classes (Table 3.1). The same approach as used in the PDSI, where numerical values are linked to brief definitions of drought intensity, was followed.

TABLE 3.1 Drought index class definition

Index	Description	Range in probability of non-exceedence on CDF of seasonal yield (%)
1	Extreme Drought	0 - 10
2	Severe Drought	>10 - 20
3	Moderate Drought	>20 - 30
4	Mild Drought	>30 - 40
5	No Drought	>40 - 100

3.3.4 Undertaking regular monitoring

The final step in the design process was to plan the functioning of the DMS, for regular drought monitoring during a production season, such that the requirements for easily comprehensible output and readily updateable indices could be met.

It was decided that a fourteen day interval would be used for reporting on the drought situation. However the system would be designed so that the interval could be shortened if so desired. Simulations would be performed using the observed weather data series up to the current calendar date and completing the season with surrogate data. Final expected grain yield for each of the 1800 cells within the bounds of map sheet would be forecast. Three scenarios would be used to complete the weather data series for the simulations: i) the season continues below normal (rainfall of the 1st decile), ii) the season continues normally (median rainfall), and iii) the season continues above normal (rainfall of the 10th decile). Surrogate weather scenarios would have been previously established for each homogeneous climate zone. The homogeneous climate zone within which a cell lies would be identified in choosing the appropriate surrogate data set.

The grid of forecasted yields for below, above and normal seasons would then be fed into the GIS. Here the yield forecast for each cell would be compared to the CDF of the particular crop, for its particular soil, climate and management situation. On the basis of this comparison a drought index value would be assigned to each grid cell. Maps and tabulated information produced from the GIS would then be distributed to decision makers.

The system designed would be iterative, continuing to the end of the season, with the observed weather data base increasing while less use would be made of the surrogate data base. The drought monitoring system designed is shown in Figure 3.1. The methodology used in the development, implementation and testing of the system is described in Chapter 4.

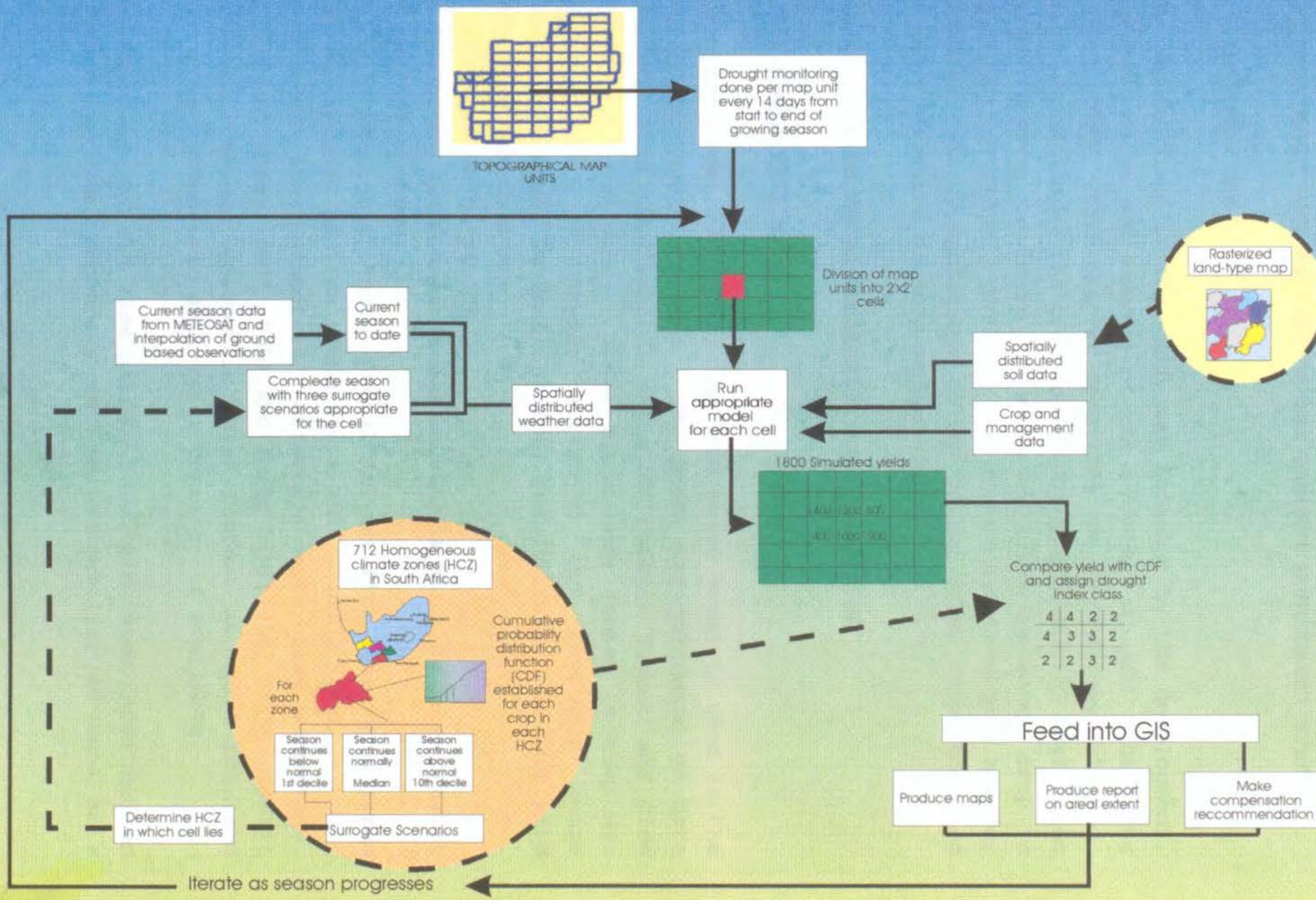

Figure 3.1 The Drought Monitoring System

4. DEVELOPMENT AND TESTING OF THE DROUGHT MONITORING SYSTEM

4.1 INTRODUCTION

The design phase of the study was followed by the development, implementation and testing of the proposed drought monitoring system (DMS). This chapter describes the methodology followed. Maize was chosen as the crop to monitor in the initial evaluation of the system, as it is the most important agronomic crop in South Africa (Anon., 1992). The techniques developed however would be equally applicable to any of the other crops modelled by the PUTU suite of crop models (De Jager, 1992).

4.2 PUTU MAIZE MODEL VALIDATION AND ADAPTATION

4.2.1 Model validation

The most recent version of the PUTU maize model is used in the drought monitoring system. The model was validated on data obtained from experimental sites at Cedara, Ermelo and Glen (Table 4.1, Fig 4.1). These sites were chosen as they are representative of humid, sub-humid and semi-arid maize productions areas in South Africa, respectively. At each site data were obtained on:

a) measured maize yields,
b) management practice information such as planting date, density and row spacing,
c) daily weather elements - total radiant flux density, maximum temperature, minimum temperature and rainfall, and,
d) physical soil parameters - effective depth, clay percentage, drained upper limit (DUL) and lower limit (LL) of volumetric water content, volumetric water content at -1500 KPa, and initial volumetric soil water content, if available.

The model was run for time periods ranging between three and ten growing seasons, dependent on the availability of data at a particular location. The agreement between simulated and measured yield pairs were statistically evaluated in terms of:

a) the root mean square error (RMSE), (Willmott 1981 & 1982)

$$RMSE = \frac{\Sigma(P_i - O_i)}{N}$$ (put square root around)

b) mean absolute error (MAE), (Willmott 1981 & 1982)

$$MAE = \frac{\Sigma(\ |P_i - O_i|)}{N}$$

where:

P_i = model predicted yield
O_i = observed yield
N = No. of cases

c) index of agreement (IA), (Willmott 1981 & 1982)

$$IA = \frac{1 - \Sigma(P_i - O_i)^2}{\Sigma(|P_i - O| + |O_i - O|)^2}$$ (need bar over O's)

d) and systematic and unsystematic RMSE,

The systematic and unsystematic RMSE - give an indication of fit of the model; the smaller the $RMSE_{sys}$ and the closer the $RMSE_{unsys}$ approaches the total RMSE, the better the fit.

$$RMSE_{sys} = \frac{\Sigma(P_i - O_i)}{N}$$ P needs a kappie

$$RMSE_{unsys} = RMSE - RMSE_{sys}.$$

where P_i = regression equation predicted yield

The results of the model validation are shown in Section 5.1 of Chapter 5.

4.2.2 Adaptation of models to function with spatially distributed input

The PUTU suite of crop models (De Jager, 1992) were designed to perform simulations using point-source weather, soil and management input data. All input files are sequential access files. The personal computer (PC) version of the model makes use of a series of data files at each location where simulation is done. Software for the PC version was written using Quick Basic, a compilable format of the BASIC language.

As the drought monitoring system requires a main-frame computer to rapidly perform the vast number of calculations necessary it was decided to translate the BASIC source-code to FORTRAN-77 which could be implemented on the main-frame at the Computing Centre for Water Research (CCWR). Output from the BASIC and FORTRAN-77 versions were compared and found to be identical.

The FORTRAN-77 version was then converted to make use of gridded data input. The manner in which the maize model accessed input data was altered. Rather than reading sequentially from files, as is done in the PC version, a system was developed whereby the gridded input (cells covering 2′ x 2′) data were allocated to dynamic memory to enable direct access to any cell. Software was written to create input data suitable for use in the system. The soil, management and initial soil water content data were accessed in this manner.

The weather data base was treated differently. Random access files of each weather element were created for each base unit (1:250 000 map sheet) in the drought monitoring system. Each record corresponds to a given cell position within the grid. Weather data is accessed directly at each cell using the record number to locate the appropriate value.

The maize model is then treated as a subroutine within the drought monitoring system software. The relevant soil, management and volumetric water content data is passed to the subroutine as each cell is analyzed. Weather data are obtained from within the subroutine using the random access method outlined above. The cell number is used in computing the appropriate record number.

Table 4.1 Description of PUTU validation sites and crop inputs

Location	Season	Planting Density (Plants ha^{-1})	Row Width (m)	Planting Date Day	Month	Cultivar
Cedara	86/87	44000	1.00	01	10	PNR473
29° 32' S 30° 17' E Altitude 1076 m	86/87	44000	0.75	22	10	TX24
	87/88	44000	0.75	07	10	TX24
	87/88	44000	0.75	19	10	TX24
	87/88	44000	0.75	16	11	TX24
	87/88	44000	0.75	30	11	TX24
Ermelo	84/85	42000	0.80	16	10	PNR473
26° 31' S 29° 57' E 1698 m	85/86	44000	0.75	16	10	PNR473
	86/87	35000	0.90	08	10	PNR473
Glen	83/84	17500	1.50	02	12	TX24
28° 57' S 26° 20' E 1304 m	83/84	17500	1.50	02	12	TX24
	84/85	17500	1.50	03	12	TX24
	84/85	17500	1.50	03	12	TX24
	84/85	15000	2.00	04	12	TX24
	85/86	17500	1.50	02	12	TX24
	85/86	17500	1.50	02	12	TX24
	85/86	17500	1.50	02	12	TX24
	86/87	18000	1.20	10	12	PNR6528
	86/87	17500	1.50	01	12	PNR6528
	86/87	15000	2.00	09	12	PNR6528
	90	20000	1.00	01	12	PNR473
	90	13300	1.50	01	12	PNR473
	90	10000	2.00	01	12	PNR473

4.3 SELECTION OF AREAS FOR TESTING THE DROUGHT MONITORING SYSTEM

The drought monitoring system was tested on the area bounded by the 2626, 2726 and 2826, 1:250 000 topographical map sheets (Fig 4.2). These three map sheets were chosen as topographical units for testing the drought monitoring system (Fig 3.1) as the area

mapped encompasses much of the south-western Transvaal and the north-western Orange Free State, where the majority of South Africa's maize is produced (Anon., 1992). The magisterial districts contained within the area covered by each sheet are given in Table 4.2.

Table 4.2 Magisterial Districts occurring partially or completely within the areas bounded by the 2626, 2726 and 2826, 1:250 000 map sheets

2626 MAGISTERIAL DISTRICT	2726 MAGISTERIAL DISTRICT	2826 MAGISTERIAL DISTRICT
COLIGNY	BOTHAVILLE	BETHLEHEM
HEILBRON	HEILBRON	BLOEMFONTEIN
JOHANNESBURG	HENNENMAN	BOSHOF
KLERKSDORP	HOOPSTAD	BOPHUTHATSWANA
KOSTER	KLERKSDORP	BRANDFORT
KRUGERSDORP	KOPPIES	BULTFONTEIN
LICHTENBURG	KROONSTAD	CLOCOLAN
OBERHOLZER	LINDLEY	EXCELSIOR
PARYS	ODENDAALSRUS	FICKSBURG
POTCHEFSTROOM	PARYS	HENNENMAN
RANDBURG	SASOLBURG	HOOPSTAD
RANDFONTEIN	SENEKAL	KROONSTAD
ROODEPOORT	VENTERSBURG	LADYBRAND
SASOLBURG	VILJOENSKROON	LINDLEY
VANDERBIJLPARK	VREDEFORT	MARQUARD
VENTERSDORP	WELKOM	SENEKAL
VEREENIGING	WESSELSBRON	THEUNISSEN
VILJOENSKROON	WOLMARANSSTAD	VENTERSBURG
VREDEFORT		VIRGINIA
WESTONARIA		WELKOM
WOLMARANSSTAD		WESSELSBRON
		WINBURG

A further advantage of using these areas was that spatially distributed soil data could be created from land type survey maps of the Institute for Soil Climate and Water (ISCW) available for these areas. Land type maps were available for all three 1:250 000 map sheets and published inventories were available for the 2626 and 2726 map sheets (ISCW, 1984).

4.4 ESTABLISHMENT OF THE SPATIALLY DISTRIBUTED SOIL DATA BASE

The following procedure was used for establishing the spatially distributed soil data base:

1. Creation of an 1800 cell grid on stable plastic material. Each cell covered 2′ x 2′ of latitude and longitude.

2. Overlaying the grid on each 1:250 000 map sheet and determining the dominant land type within each cell through visual assessment.

3. <u>Selection of the dominant soil form for the land type assigned to each cell.</u>
   For the 2626 and 2726 map sheets the land type inventories were used to guide the selection process. Soil forms occupying the greatest percentage of the land type were chosen. If the soil chosen was not suitable for rainfed maize production (Le Roux pers. comm.[1]) the soil form most suitable for cultivation, covering the largest area in the land type, was used. Land types described in the inventories as consisting of 80% or more rock were marked as uncultivated. This classification was corroborated for magisterial districts surveyed by Ludick and Wooding (1991). Local expertise was used for selection of soil forms on the 2826 map sheet, which had no published inventory (Le Roux pers. comm.[1]).

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[1]P.A.L. Le Roux, Senior Lecturer, Department of Soil Science University of the Orange Free State.

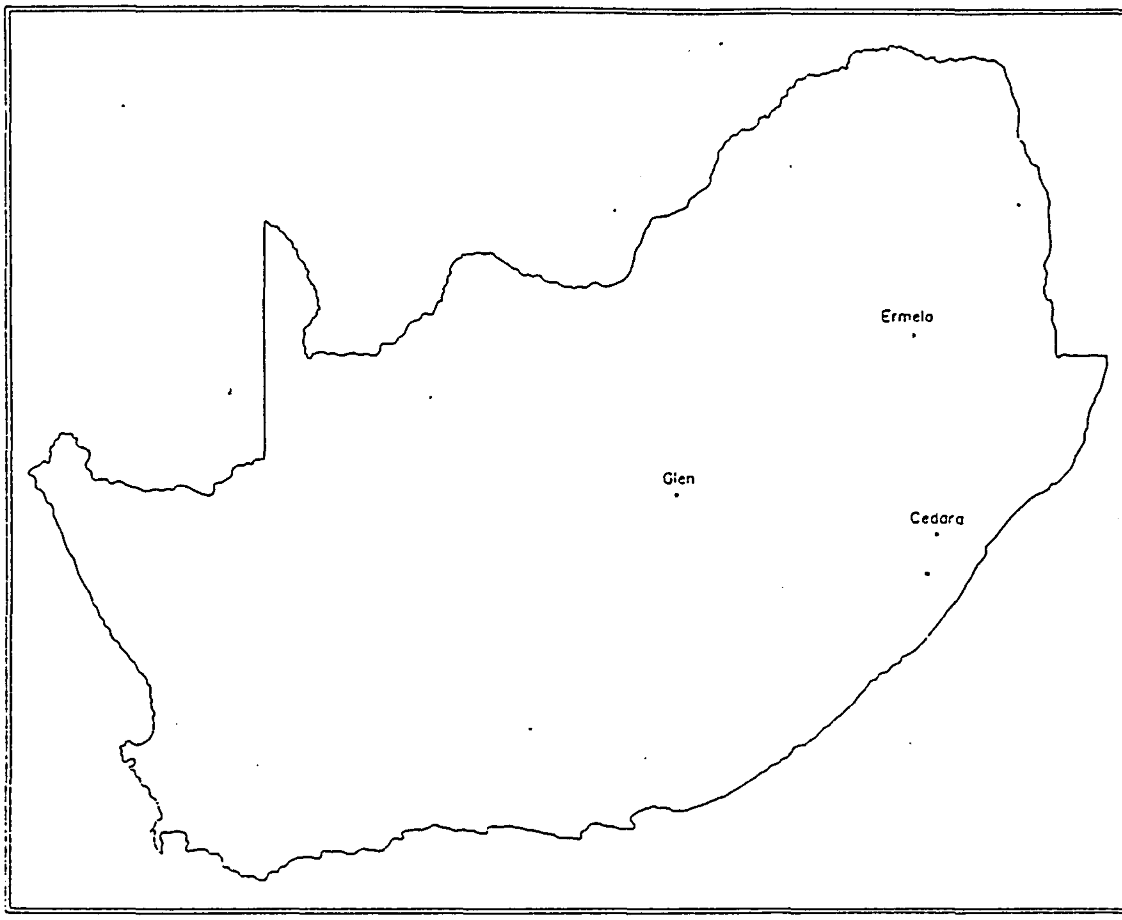

Figure 4.1 Location of the PUTU Maize model validation sites; Cedara, Ermelo and Glen.

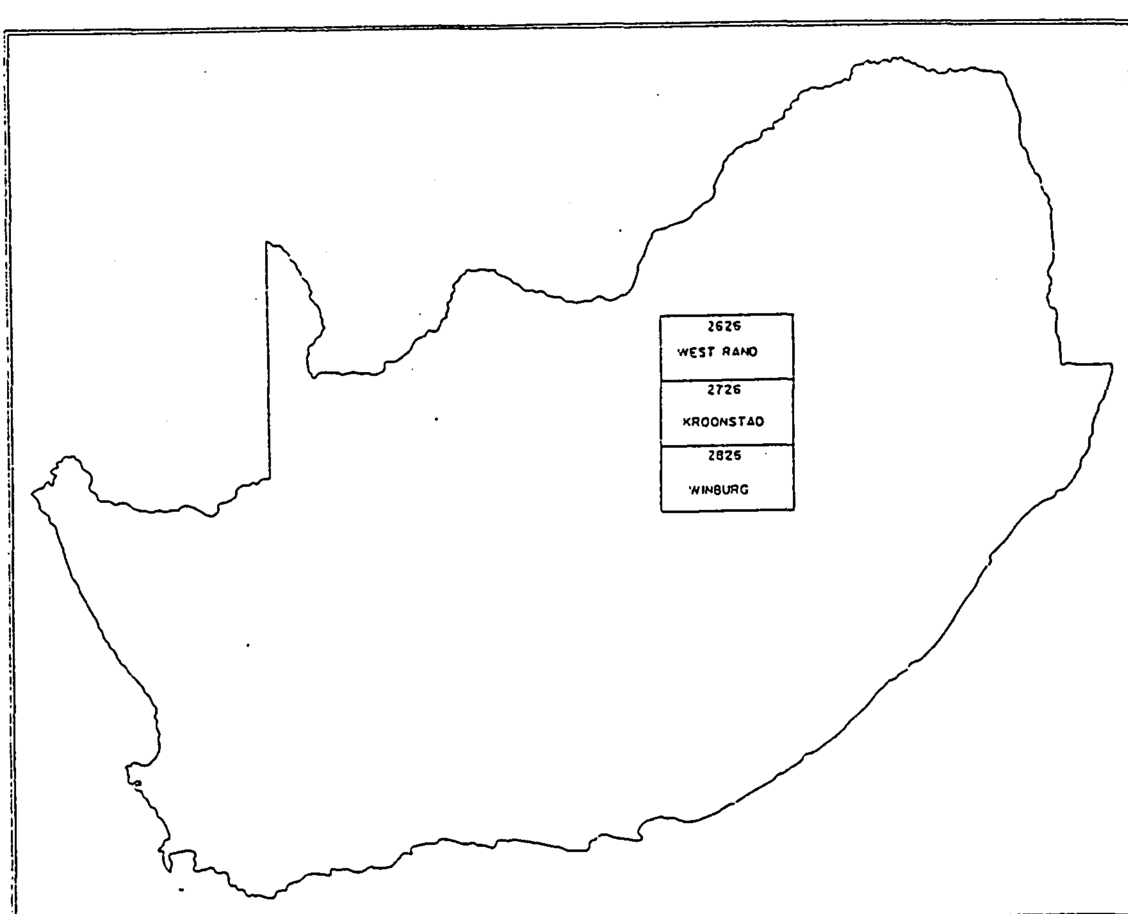

Figure 4.2 Boundaries of the three 1:2500 000 map sheets used in the study

4. Establishing soil parameters required in the model.

The soil parameters required in the model were obtained by combining the specific modal profile description of the soil form chosen for a land type, with the general description contained in the inventory of the land type (Le Roux pers. comm.[1], ISCW (1984)). Effective soil depth, layer thicknesses and clay percentages were obtained in this manner. The volumetric water content at -1500 Kpa was computed by multiplying the gravimetric measurements recorded for the modal profile by an estimated bulk density. Drained upper limit (DUL) and lower limit (LL) of volumetric water content were obtained using the equations of Ritchie (1986):

```
LL(I) = W1 * (1 - XZ) * (1 + BDM - BD) + .23 * XZ
DUL(I) = LL + W2 * (1 - XZ) - (BDM - BD) * .2 + .55 * XZ
```

The terms of the equations are calculated using:

```
PO(I) = 1 - (BD / 2.65)
XZ = OC(I) * .0172
BDM(I) = (1 - XZ) / (1 / BD - XZ / .224)

(If BDM(I) > 2.5 then BDM(I) = 2.5)
```

If the sand fraction of the soil is greater than 75% :

```
W1 = .19 - .0017 * sand(I)
W2 = .429 - .00388 * sand(I)
```

If the sand fraction of the soil is less than 75% :

If the silt fraction is greater than 70% :

```
W1 = .16
W2 = .1079 + .000504 * silt(I)
```

If the silt fraction is less than 70% :

```
W1 = .0542 + .00409 * clay(I)
W2 = .1079 + .000504 * silt(I)
```

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[1]P.A.L. Le Roux, Senior Lecturer, Department of Soil Science University of the Orange Free State.

where:

I = Soil layer number
PO = Porosity of layer
XZ = Correction factor for lower density of Organic Matter
OC = Organic Carbon concentration
BDM = Maximum bulk density to which layer could be compacted.
W1 = Variable to take into account effect of soil texture
W2 = Variable to take into account effect of soil texture
LL = Lower limit of plant-extractable water
DUL = Drained upper limit of plant-extractable water

The soil forms used for each land type are given in Section 5.2 of Chapter 5. Diagrams of the spatial distribution of soil types used, soil depth and plant available water are shown in Section 5.2 of Chapter 5.

4.5 ESTABLISHMENT OF THE SPATIALLY DISTRIBUTED WEATHER DATA BASE

Weekly updates of weather stations measuring daily rainfall and temperatures were obtained from the South African Weather Bureau (SAWB) via the CCWR. Interpolation techniques applied to these data were used for obtaining spatially distributed temperature and rainfall data in the weather data base.

4.5.1 Daily rainfall

The algorithm given by Seed (1992) was implemented to obtain spatially distributed rainfall data. This algorithm was chosen as Seed (1992) demonstrated that the accuracy with which a rain gauge network can reproduce a rain field is largely determined by the characteristics of the network and the rain field sampled, rather than the algorithm used for interpolating between points. In the case of a relatively sparse network such as that of the daily rainfall stations in South Africa (Fig 4.3) mathematically complex methods will not produce more accurate results than simple interpolation methods.

Seed (1992) makes use of distance weighting for interpolation. Rainfall depths at unknown points are interpolated using the inverse square of the distance ($1/d^2$) from the point to a given rain gauge. His approach is to divide the interpolation area into tiles. Each tile consists of nine cells. The central cell of the tile is used to rank rain gauges according to increasing distance from the cell up to a given threshold. The same set of gauges is then used for all nine cells within the tile. The weight that each gauge exerts on a cell within the tile is individually computed for each cell.

The 2626, 2726 and 2826 map sheets were each divided into 50 square tiles of 12′ x 12′ latitude and longitude. Each tile was divided into nine 4′ x 4′cells, the division recommended by Seed (1992). A list of rain gauges within 100 km of the central cell of each tile was compiled. Daily rainfall depths (mm) were determined for each cell using the inverse square distance weighting approach. The same rainfall depth interpolated for each 4′ x 4′ cell was then assigned to each of the four 2′ x 2′ cells lying within the larger cell. This was necessary in order to use the data in the 2′ x 2′ format of the DMS.

4.5.2 Daily maximum and minimum temperatures

De Launay tessellation (Watson, 1982; Lee and Lin (1986)), trend surface analysis (Davis, 1973; Schulze, 1981) and ordinary kriging (van Tonder, 1982) interpolation techniques were compared to determine the most accurate method to be used in establishing the daily maximum and minimum temperature data base. Data from SAWB weather stations recording daily maximum and minimum temperatures (Fig 4.4) were used to interpolate daily values at 89 locations within maize producing regions, where ISCW weather stations are situated (Fig 4.5). The time period used, ranged from September 1992 to June 1993. The interpolated temperature values obtained were compared with values measured at the ISCW stations. The results of the statistical analysis performed are given in Section 5.3 of Chapter 5.

On the basis of the statistical analysis ordinary kriging was chosen for use in establishing the data base. The algorithm of van Tonder (1982) was implemented at the CCWR. Daily maximum and minimum temperatures were interpolated for areas covered by the three 1:250 000 map sheets.

4.5.3 Daily total radiant flux density

The study of Lourens, De Jager and van Sandwyk (1994) showed that a modification of the empirical approach developed by Nunez *et al.* (1987) and Nunez (1987 & 1990), for estimating daily irradiance from visible band imagery obtained from the Japanese Meteorological Satellite, could accurately be applied to METEOSAT visible band data.

Nunez's technique is based on the estimation of daily transmissivity (τ) from visible band weather satellite imagery. Lourens *et al.* (1994) showed that transmissivity over South Africa, could be estimated from METEOSAT data using the linear regression:

$$\tau = 0.892 - 0.00397 \cdot CPB_d$$

where,

CPB_d = Daily mean corrected METEOSAT pixel brightness calculated from hourly mean values.

Global irradiance at the surface was then calculated as:

$$R_s = R_A * \tau$$

where,

R_s = Global irradiance at the surface ($MJ\ m^{-2}\ d^{-1}$)

R_A = Extraterrestrial irradiance ($MJ\ m^{-2}\ d^{-1}$)

The regression coefficients required in the transmissivity model were obtained by using concurrent satellite and transmissivity data for December 1991, at weather stations in Cape Town, Pretoria and Upington (Fig. 4.6). The validity of the regression coefficients for different seasons and geographic locations was determined by using them to compute daily irradiance from METEOSAT data at 16 weather stations in South Africa (Fig 4.6) from November 1992 to June 1993. The results of the statistical analysis are given in Section 5.3 of Chapter 5.

The regression coefficients were found to be valid for different seasons and geographic locations. The daily irradiance data base for the 1992/93 season was obtained by computing irradiance for each 2′ x 2′ pixel within the areas bounded by the 2626, 2726 and 2826, 1:250 000 map sheets. Averaged values were used on days where insufficient satellite images were available for computation or on days where no images had been archived. The average values were obtained by using values from the days immediately preceding and following the missing day.

Interpolation of the daily sunshine duration data obtained for ISCW stations (Fig 4.7) within the bounds of the three 1:250 000 map sheets was performed for the 1988/89 and 1991/92 seasons, as no suitable METEOSAT satellite data were available. Ordinary kriging was used as the interpolation method.

Total radiant flux density was estimated using the modified Angstrom (1924) equation given in Reid and De Jager (1989). The modified relationship can be expressed as follows:

$$Q = Q_o [a + b(n/N)]$$

where,

Q = incoming solar radiation (MJ m^{-2} d^{-1})

Q_o = solar radiation reaching a horizontal surface in the absence of the atmosphere (MJ m^{-2} d^{-1})

n = hours of bright sunshine (h)

N = maximum possible sunshine duration (h)

a, b = empirical constants derived by regression analysis.

The empirical constants of 0.25 and 0.5 were used following the recommendation of Reid and De Jager (1989). These values equal values suggested by Jensen *et al.* (1990).

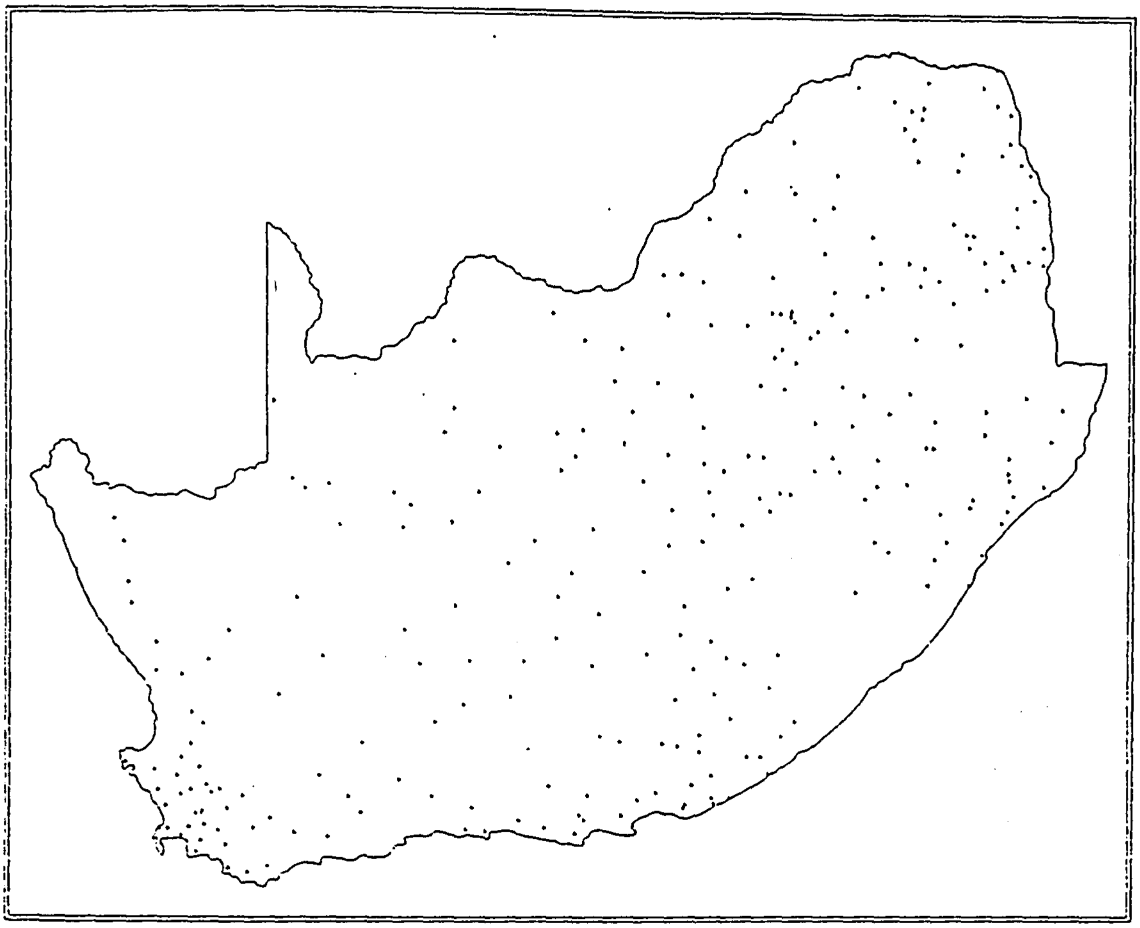

Figure 4.3 Location of SAWB weather stations reporting daily rainfall

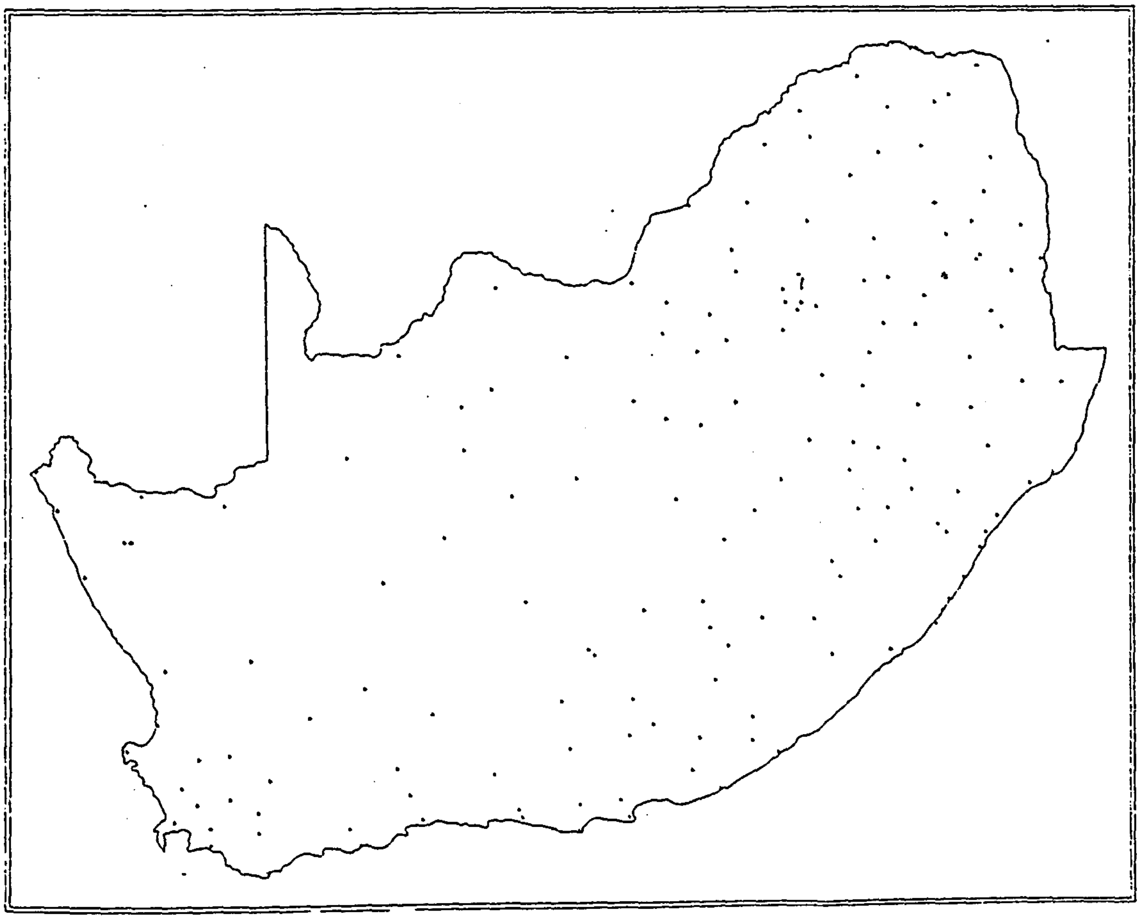

Figure 4.4 Location of SAWB weather stations reporting daily maximum and minimum temperatures

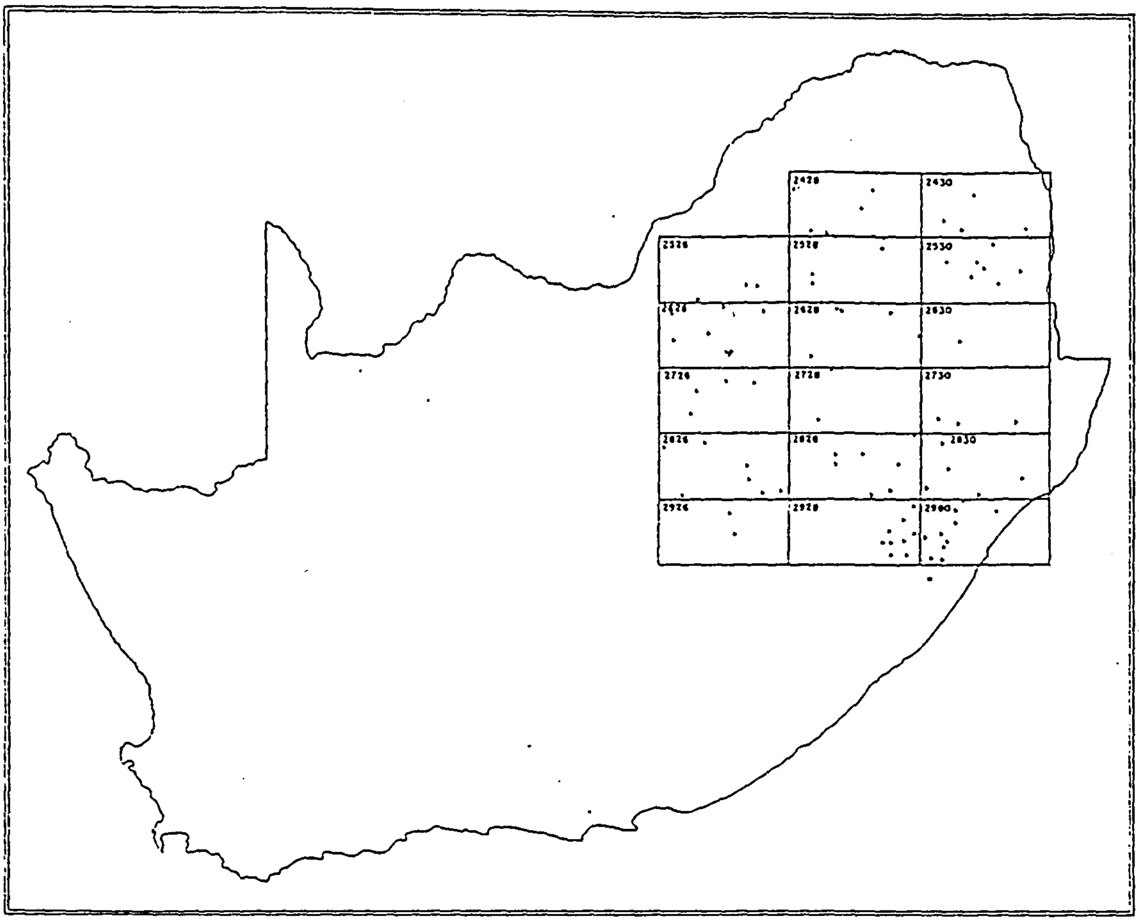

Figure 4.5 Location of ISCW weather stations used to test the accuracy of temperature interpolation techniques

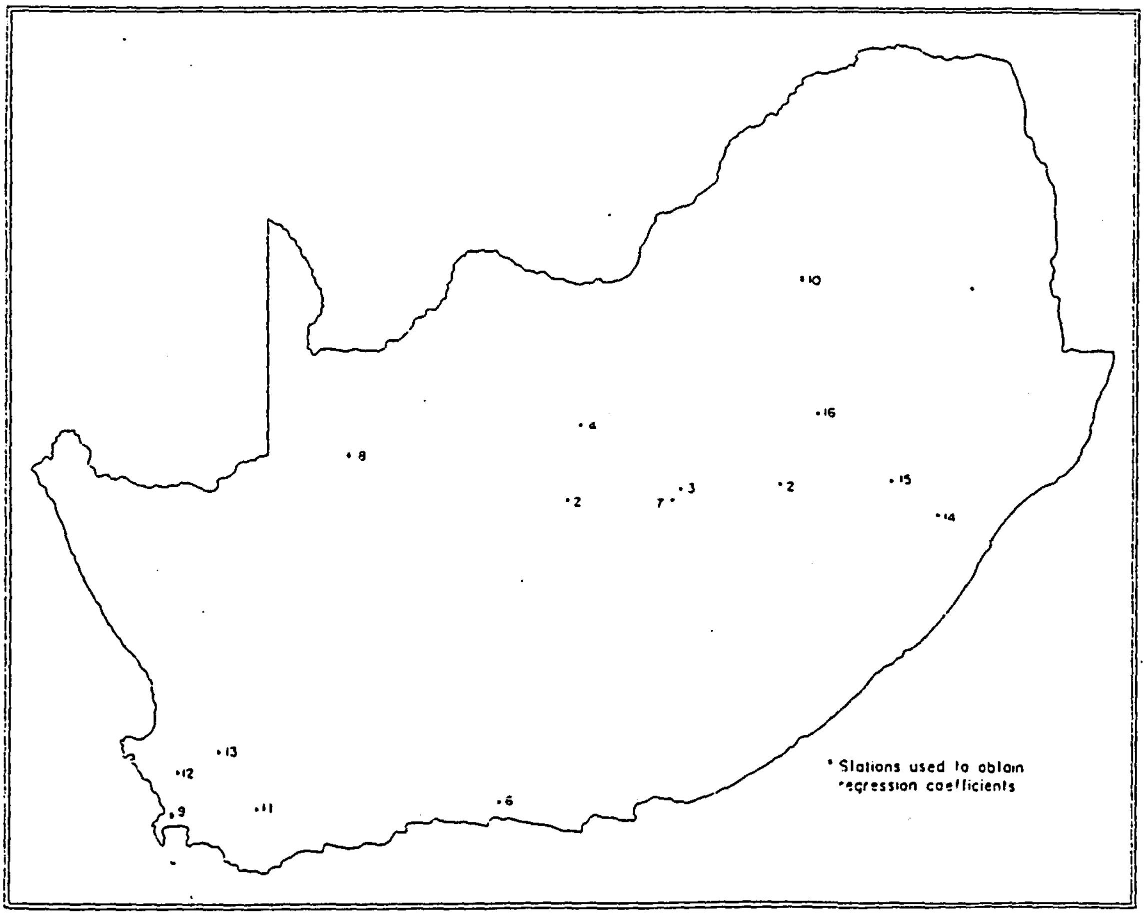

Figure 4.6 Location of weather stations measuring total daily radiant flux density

4.6 DETERMINING CUMULATIVE PROBABILITY DISTRIBUTION FUNCTIONS AND CREATING THE SURROGATE WEATHER DATA BASE

4.6.1 Determining cumulative distribution functions

A cumulative probability distribution function (CDF) of maize yield was determined for each homogeneous climate zone (HCZ) within the 2626, 2726 and 2826 map sheets (Fig 4.8, Table 4.3). This was done by executing the point-source maize model for each homogeneous climate zone for 100 production seasons. Such a procedure requires that a 100 year record of the necessary weather data be available.

In examining the measured rainfall record at stations used to represent each homogeneous climate zone (HCZ), it was found that the length of the record varied and that missing data values ranged from a number of days in the month to entire months. In order to achieve uniformity as far as length of record for a homogeneous climate zone was concerned the daily rainfall data generator of Zucchini and Adamson (1984) was used. All but one (SAWB station 295001, HCZ 342) of the rainfall stations used to represent the homogeneous climate zones had a set of Zucchini parameters (Appendix 6; Zucchini and Adamson, 1984) which could be used to generate daily rainfall values. The closest rainfall station to SAWB station 295001, having a set of Zucchini parameters, was used for HCZ 342.

One hundred years of daily rainfall data were generated for stations representing each homogeneous climate zone. A number of statistics were determined for both the generated rainfall data and measured data of each HCZ. A comparison of the statistics obtained from the measured and generated data was undertaken. Statistics examined included: mean annual precipitation (MAP), monthly mean rainfall, monthly median rainfall, standard deviation, coefficient of variation and number of raindays per month. These comparisons are shown in Section

5.4 of Chapter 5. The high coefficient of determination values obtained between statistics of the generated data and statistics of the measured rainfall showed that the data generation technique could be used to simulate realistic scenarios of daily rainfall.

Application of the model further required daily total radiant flux density, maximum and minimum temperature for the same time period that there was rainfall data. These data were not available. Two options exist to obtain these data; namely that of using average monthly values for each day of the month or creating appropriate daily scenarios. Nonhebel (1994) has however shown that simulation results from crop growth models differ considerably when using average temperature data instead of daily data. This is due to the fact that crop growth models often make use of non-linear relations. For this reason the average approach was not followed.

Yearly rainfall sequences generated for each of the homogeneous climate zones were matched with the three other elements by using the ISCW station closest to the rainfall station representing the HCZ (Fig 4.7). A correlation analysis between daily rainfall measured at the ISCW station and daily temperature and sunshine duration measured at these stations was first undertaken. These comparisons are shown in Section 5.4 of Chapter 5. Extremely poor correlation was found between daily rainfall and the other elements at all of the ISCW stations within the bounds of the three map sheets. This can be attributed to the fact that convective thunderstorms of short duration are the main source of rainfall in these areas (Terblanche pers. comm.[2]). It was therefore not necessary to match temperatures and radiant flux densities estimated from sunshine duration using rain / no rain as the matching criterion.

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[2]D. Terblanche, Deputy Director, Precipitation Research, South African Weather Bureau

Table 4.3 Homogenous climate zones within the map sheets

1:250 000 Map sheet		
2626	2726	2826
458	331	327
459	343	331
467	345	332
468	347	333
469	355	334
470	448	340
471	460	341
472	461	342
473	462	343
474	463	344
475	464	345
476	465	346
477	466	347
478	467	348
479	468	349
480	479	351
489	480	353
490	481	354
491	482	355
492	483	
493	484	
494	485	
495	486	
496	487	
497	488	
498	489	
499	490	
554		
571		
574		

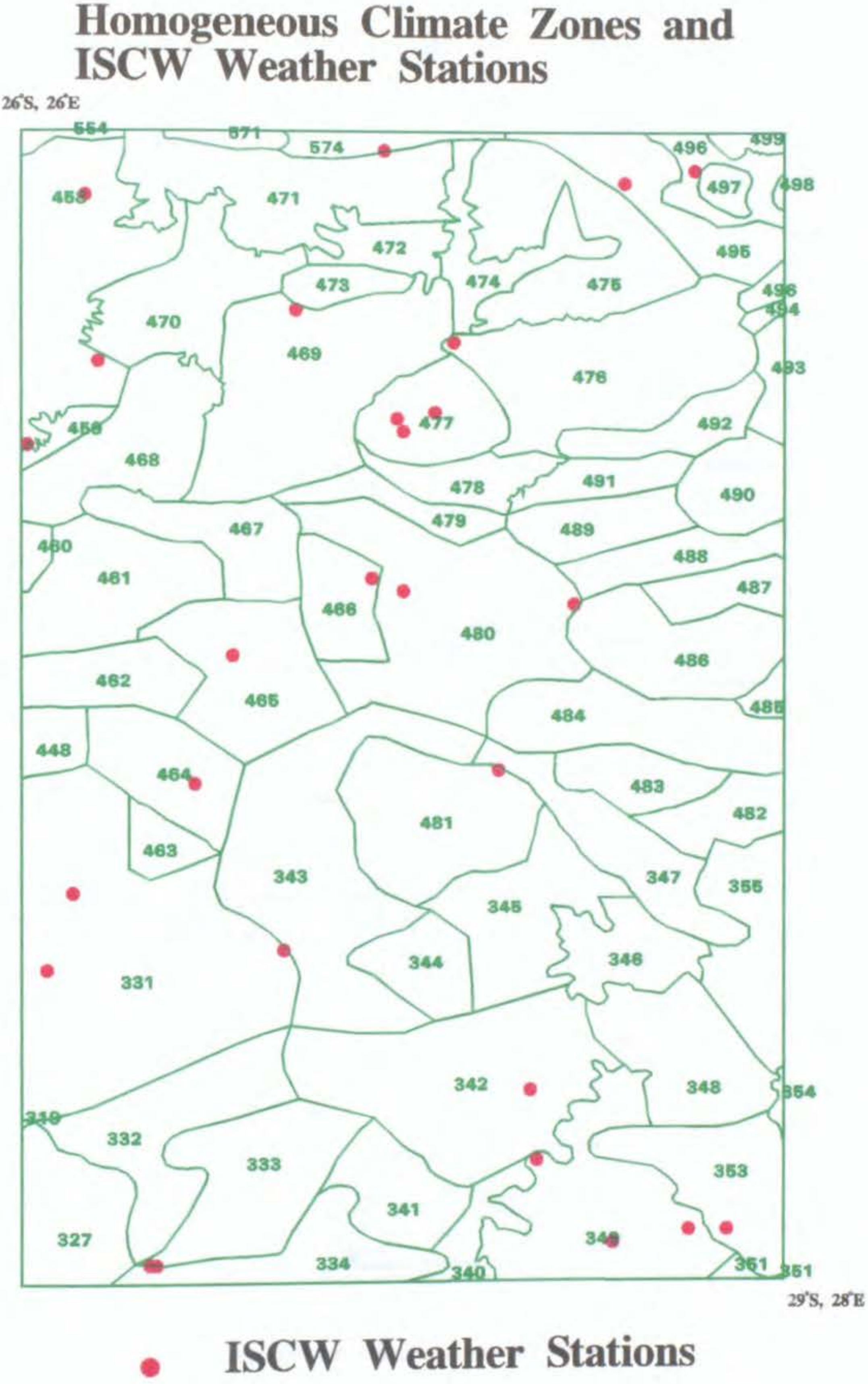

Figure 4.7 ISCW stations within the bounds of the map sheets used in creating data sets of weather elements other than rainfall for determining the required Cumulative Distribution Functions.

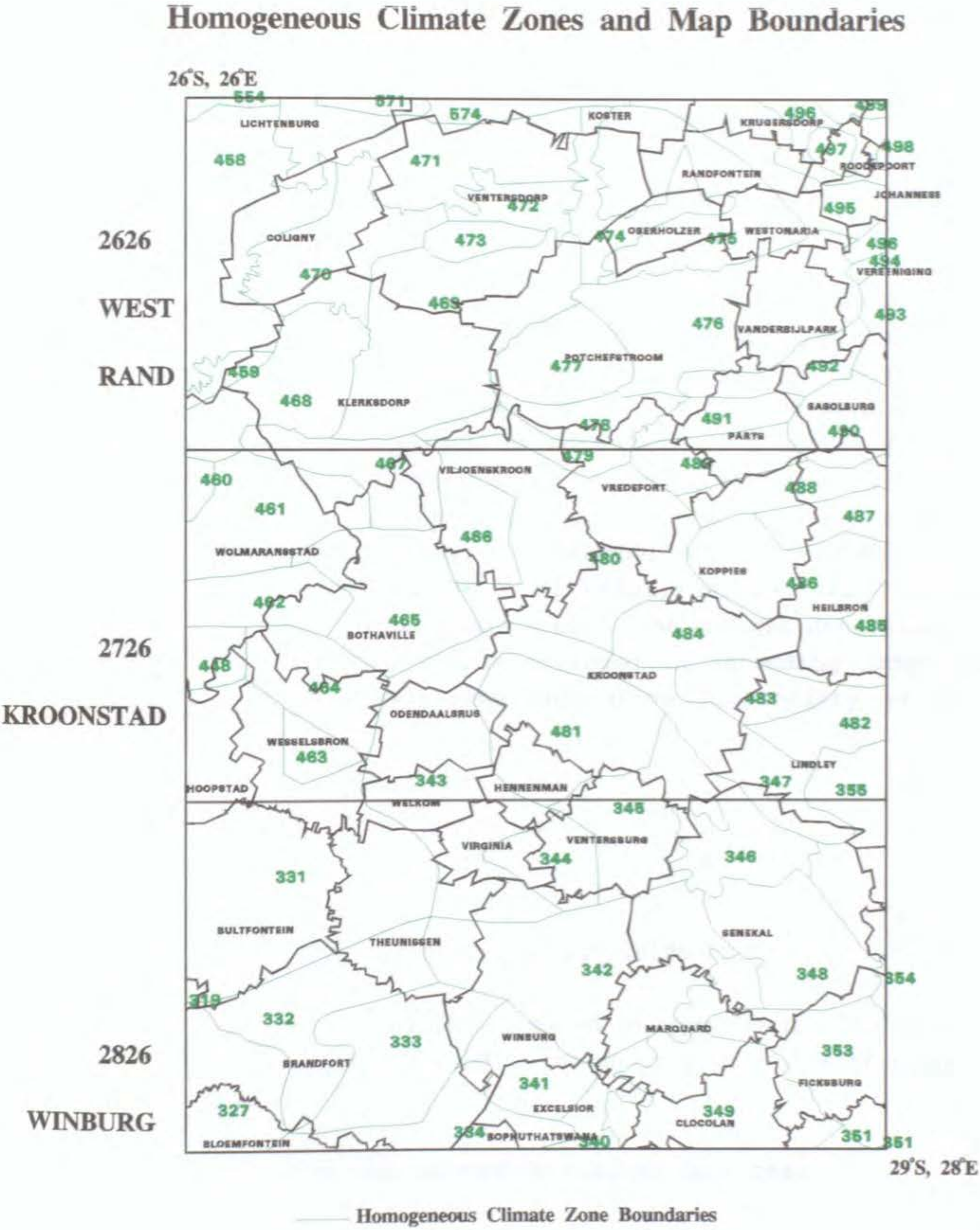

Figure 4.8 Homogeneous Climate Zones (HCZ's) within the bounds of the three 1:250 000 map sheets

One hundred yearly scenarios of daily weather data were constructed for each HCZ by matching generated rainfall with daily values of the other elements on a monthly basis. Random selection of months of ISCW data with which to match the rainfall, was undertaken from the full record of the closest ISCW weather station.

The number of soil types within each homogeneous climate zone were determined. Thereafter the number of different planting dates, based on magisterial district within the homogeneous climate zone, were determined. The model was executed for 100 years using all combinations of soil type and planting date for a given homogeneous climate zone. A single homogeneous climate zone therefore had several such combinations, for each of which the CDF had been determined. The number of unique combinations varied from 174 for the 2826 map sheet, 212 for the 2726 map sheet and 255 for the 2626 map sheet. The CDF was determined by ranking the simulated yields obtained in ascending order and calculating their associated cumulative probability of non-exceedence as:

$$\frac{i}{n + 1} * 100$$

where:
i = rank position
n = total number of simulated yields

The median yield of each CDF is given in Appendix A. The spatial distribution of median yield is shown in Figure 5.8 of Chapter 5.

4.6.2 Establishing the surrogate weather data base

The method of creating the below average, average and above average rainfall scenarios for completing the season had to be decided upon. There were 100 generated daily rainfall data sets, each covering one calendar year, for each HCZ, from which to select the surrogate series. One approach would have been to rank the annual totals and select below average, median and above average rainfall years. This was decided against as the annual total gives no indication of the distribution of the rainfall throughout the year. Although a year could be selected as below average in terms of total rainfall, for example, the distribution could be such that one or more of the individual months could have extremely high rainfall totals. Were these months to occur during, say, the critical flowering stage of the crop a completely false prognosis of the drought situation would be obtained from this particular below average scenario.

It was decided rather to use an approach similar to that of Du Pisani (1987) and Fouché (1992) to construct surrogate rainfall data sets. The three scenarios were constructed by determining the cumulative distribution function of total monthly rainfall for each month of the 100 years of generated data. For a particular HCZ for instance, one hundred Januaries were analyzed to determine the CDF for January, and so on. Twelve CDF's were therefore obtained for each HCZ.

In each CDF, below average rainfall was defined as the monthly total associated with the 10% probability of non-exceedence, (1st decile) average rainfall as the monthly total associated with the 50% probability of non-exceedence, and above average rainfall as the monthly total associated with the 90% probability of non-exceedence (10th decile). The number of raindays associated with the monthly totals were also taken into consideration to ensure that excessive amounts of rainfall did not occur on a single day in the month. Record was kept of the years from which the months meeting these criteria came.

A year of surrogate data was constructed by combining the appropriate months. The below average rainfall year for HCZ 333, for example; comprised data from January 1947, February 1931, March 1968, April 1985, May 1973, June 1922, July 1918, August 1986, September 1952, October 1979, November 1934, and December

1910. The process was repeated until each HCZ had below average, average, and above average surrogate data sets. The advantage of this approach is that for each month of surrogate data used to complete the season, rainfall values associated with fixed probabilities of non-exceedence are used. This eliminates the possibility of including months with abnormally high or low values in any of the three scenarios.

The spatially distributed surrogate weather data base used for each map sheet was then established. Weather data files were created using the random access method described in 4.2.2. above. The HCZ within which each cell lay was determined and the surrogate data of that HCZ was then assigned to the cell.

4.7 TESTING OF THE DROUGHT MONITORING SYSTEM

The drought monitoring system was tested for three maize production seasons. The seasons chosen represented above normal conditions (1988/89) and severe drought (1991/92) (Laing pers. comm.[3]). Furthermore, the 1992/93 season was used as appropriate METEOSAT weather satellite data were available for computing spatially distributed irradiance.

The drought monitoring system was executed by concatenating fortnightly increments of observed data and completing the season with the three scenarios of surrogate data. Simulated yields were compared with their appropriate CDF and drought index maps together with tabulations of classified area, produced. Maps and tabular output from the system are shown in Section 5.5 of Chapter 5.

The accuracy of the system was determined by comparing the average yield per magisterial district for all three the seasons, with yield data obtained from the Department of Agriculture

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[3]M. Laing, Deputy Director, Climate Information, South African Weather Bureau

(Kruger pers. comm.[4]). Individual farm yields recorded for the 1992/93 season, supplied by farmers in the Orange Free State, were compared with their corresponding simulated yields at each of the locations. These comparisons are shown in Section 5.6 of Chapter 5.

Genetic characteristics of the cultivar PANNAR 473, which is suitable for production in all regions within the three map sheets, were used for the genetic coefficients required in the model. The coefficients used are given in Table 4.4. Management information such as planting dates, plant population densities and row width spacing were altered according to magisterial district (van Biljon pers. comm.[5]) The management data used for each map sheet is given in Table 4.5.

Table 4.4 Genetic coefficients of PANNAR 473

Critical heat units: Vegetative Stage	776
Critical heat units: Flowering Stage	140
Critical heat units: Reproductive Stage	576
Kernel filling efficiency (mg day^{-1})	8.5
Maximum area of the largest leaf (m^2)	0.08
Potential kernel count per cob	500
Potential maximum number of cobs per plant	1.26
Potential minimum number of cobs per plant	1.00
Potential kernel mass (g)	0.3658

[4]J.P. Kruger, Assistant Director, Directorate of Agricultural Economic Tendencies, Department of Agriculture.

[5]Dr J. van Biljon, Senior Lecturer, Department of Agronomy, University of the Orange Free State

Table 4.5 Crop management inputs for each magisterial district on each map sheet

		2626					2726					2826		
MAG NAME	PDAY	PMONTH	NPL	ROWWID	MAG NAME	PDAY	PMONTH	NPL	ROWWID	MAG NAME	PDAY	PMONTH	NPL	ROWWID
COLIGNY	25	11	18000	1.90	BOTHAVILLE	16	11	18000	1.90	BETHLEHEM	22	10	25000	0.91
HEILBRON	01	11	20000	1.20	HEILBRON	01	11	20000	1.90	BLOEMFONTEIN	01	12	12000	2.25
JOHANNESBURG	05	11	25000	1.20	HENNENMAN	17	11	15000	1.90	BOSHOF	05	12	12000	2.25
KLERKSDORP	20	11	18000	1.20	HOOPSTAD	28	11	12000	1.90	BOPHUTHATSWANA	01	12	12000	2.25
KOSTER	20	11	18000	1.20	KLERKSDORP	20	11	18000	1.90	BRANDFORT	28	11	13000	2.25
KRUGERSDORP	10	11	25000	0.91	KOPPIES	08	11	20000	1.50	BULTFONTEIN	01	12	12000	2.25
LICHTENBURG	28	11	18000	1.20	KROONSTAD	15	11	18000	1.52	CLOCOLAN	08	11	22000	0.91
OBERHOLZER	08	11	25000	1.20	LINDLEY	01	11	22000	1.20	EXCELSIOR	18	11	20000	0.91
PARYS	10	11	20000	1.20	ODENDAALSRUS	18	11	17000	1.52	FICKSBURG	26	10	22000	0.91
POTCHEFSTROOM	15	11	18000	1.20	PARYS	10	11	20000	1.20	HENNENMAN	17	11	15000	1.52
RANDBURG	05	11	25000	1.20	SASOLBURG	05	11	22000	1.20	HOOPSTAD	28	11	12000	2.25
RANDFONTEIN	08	11	25000	1.20	SENEKAL	08	11	22000	0.91	KROONSTAD	15	11	18000	1.52
ROODEPOORT	05	11	25000	1.20	VENTERSBURG	16	11	14000	1.20	LADYBRAND	08	11	22000	0.91
SASOLBURG	05	11	22000	1.20	VILJOENSKROON	15	11	18000	1.20	LINDLEY	01	11	22000	1.52
VANDERBIJLPARK	08	11	23000	1.20	VREDEFORT	13	11	20000	1.20	MARQUARD	10	11	22000	0.91
VENTERSDORP	18	11	18000	1.90	WELKOM	20	11	14000	1.20	SENEKAL	12	11	22000	0.91
VEREENIGING	01	11	23000	1.20	WESSELSBRON	25	11	14000	1.20	THEUNISSEN	25	11	14000	2.25
VILJOENSKROON	15	11	18000	1.90	WOLMARANSSTAD	24	11	14000	1.20	VENTERSBURG	16	11	14000	1.52
VREDEFORT	13	11	20000	1.20						VIRGINIA	20	11	16000	2.25
WESTONARIA	07	11	25000	1.20						WELKOM	20	11	14000	1.52
WOLMARANSSTAD	24	11	14000	1.90						WESSELSBRON	25	11	14000	1.52
										WINBURG	18	11	18000	1.52

MAG NAME = Magisterial District Name
PDAY = Planting Day
PMONTH = Planting Month
NPL = Plant population (ha^{-1})
ROWWID = Row spacing (m)

5. RESULTS AND DISCUSSION

The sections in the chapter, in which the results are recorded and discussed are:

5.1) the validation of the PUTU maize model,
5.2) the creation of the spatially distributed soil data base,
5.3) the testing of techniques for the establishment of a spatially distributed weather data base,
5.4) the establishment of the cumulative distribution functions,
5.5) the demonstration of the drought monitoring system, and,
5.6) the testing of the accuracy of the system.

5.1 MAIZE MODEL VALIDATION

The statistical analysis of measured and simulated maize yields obtained at the locations listed in Table 4.1 is given in Table 5.1. The definitions of the statistics calculated are given in Section 4.2.1 of Chapter 4.

Table 5.1 Statistical analysis of measured and simulated yields

STATISTIC	
Number of pairs (n)	23
Root Mean Square Error (RMSE)	907 kg ha^{-1}
Systematic RMSE	516 kg ha^{-1} 32%
Unsystematic RMSE	745 kg ha^{-1} 68%
Mean absolute error	746 kg ha^{-1} 18%
Coefficient of determination (r^2)	0.906
Willmott Index of Agreement	0.969

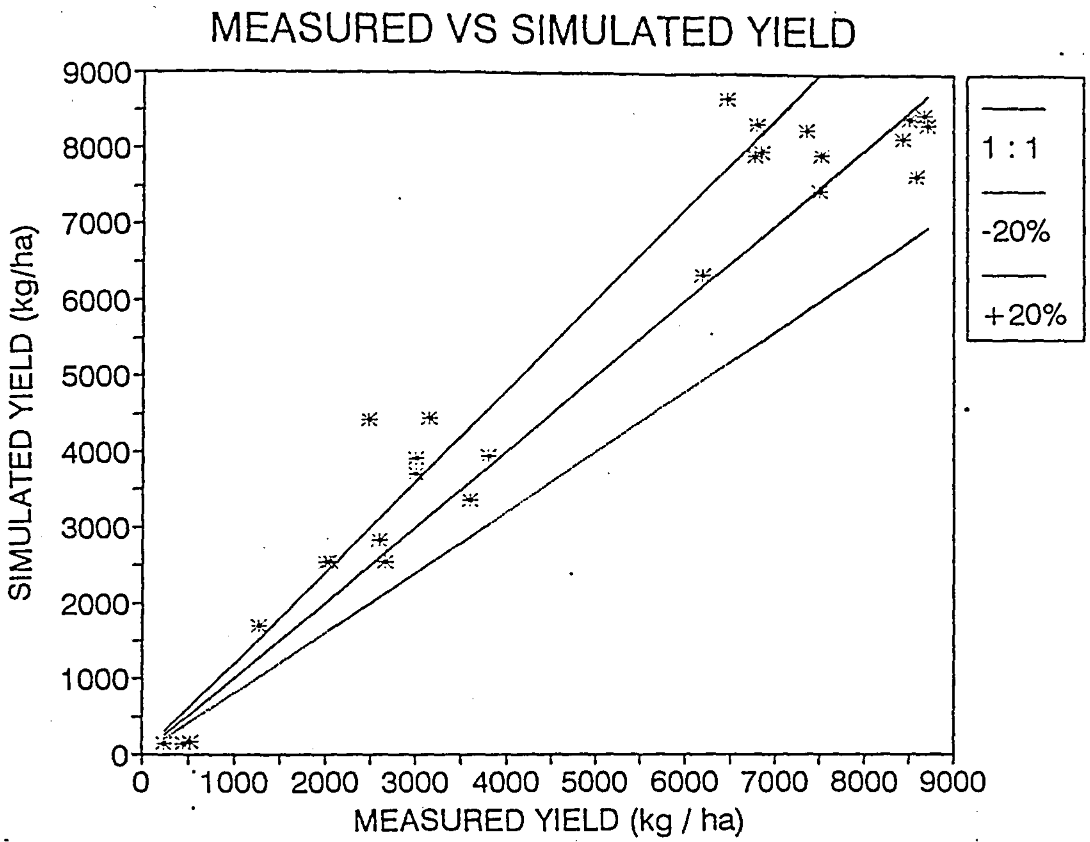

Figure 5.1 Scatter plot of simulated versus measured yield

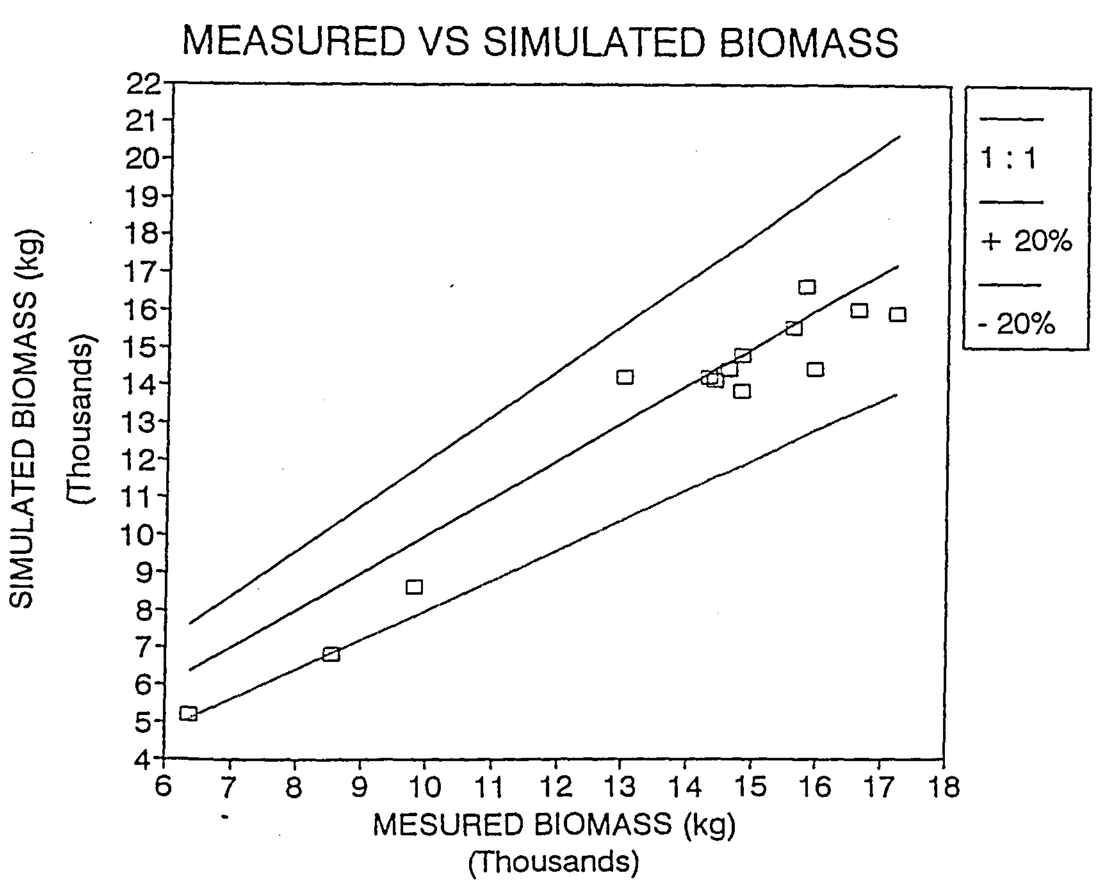

Figure 5.2 Scatter plot of simulated versus measured biomass

From Table 5.1 it can be seen that a high coefficient of determination and index of agreement was obtained. Furthermore the value of the unsystematic RMSE is considerably higher than that of the systematic RMSE, and relatively close to the RMSE. This indicates that there is no consistent bias in the model and that good agreement exists between measured and simulated values.

Certain discrepancies were however found in some of the measured data used. For instance, at Glen during the 1985/86 production season; the same soil, cultivar and planting date was used in two experiments. Only the available soil water content at planting differs by 37 mm (301 as opposed to 338 mm). No irrigation was applied to either experiments yet the measured yields of these experiments differ by 138% (534 and 1271 kg ha^{-1}, respectively), a highly unlikely, if not impossible, situation. It is likely that another unaccounted for external factor, such as poor fertility or pest or disease problems, resulted in these large differences between measured yield. The PUTU maize model on the other hand simulated identical yields (2138 kg ha^{-1}) for the two experiments which were considerably higher than both measured yields.

It was concluded that the validation showed that the model could be used with confidence in a drought monitoring system.

5.2 CREATION OF THE SPATIALLY DISTRIBUTED SOIL DATA BASE

A separate, random access soil data file, was established for each 1:250 000 map sheet following the procedure described in Section 4.4 of Chapter 4. Representative soil forms of each land type on the 1:250 000 map sheet were identified, and allocated numbers. However in establishing gridded data for the 2′ x 2′ cells it was found that certain land types were too small to occupy an entire 2′ x 2′ cell. These soil forms were therefore not used in the gridded data. This results in non-sequential numbering of the soil forms in the subsequent tables and figures. Cells where land types contain 80% or more rock or where large dams occur are labelled as "No soil used".

Fifty soil forms were used for the 2626 map sheet, 40 for the 2726 map sheet and 23 for the 2826 map sheet. The soil forms are listed in Table 5.2, according to the South African binomial classification system (MacVicar *et al.*, 1977) used in the land type surveys. The spatial distribution of the soil forms are shown in Figures 5.1(a&b) to 5.3(a&b), respectively. Properties of the soil forms are listed in Tables 5.3 to 5.5, respectively. A regional perspective of effective depth and plant available water (DUL - LL) is shown in Figures 5.4 and 5.5, respectively.

Table 5.2 Soil forms used in the three 1:250 000 map sheets

Form names

Av = Avalon	Ar = Arcadia
Bo = Bonheim	Bv = Bainsvlei
Cv = Clovelly	Gc = Glencoe
Hu = Hutton	Rg = Rensburg
Sw = Swartland	Va = Valsrivier
We = Westleigh	

Hu33 = 33 is the series number of the Hutton form
p114 = modal profile number 114 (MacVicar *et al.*, 1977)

Map sheet

2626	2726	2826
.1 Ar20p195.a	.1 Ar20p195.a	.1 Av26p502.a
.2 Ar20p213.a	.2 Ar20p195.b	.3 Av36p190.a
.3 Av34p178.a	.3 Av31p168.a	.4 Bo21p470.a
.4 Av36p120.a	.4 Av34p174.a	.5 Bo41p484.a
.5 Av36p228.a	.5 Av34p174.b	.6 Bv36p181.a
.6 Av36p228.b	.6 Av34p178.a	.7 Bv36p465.a
.7 Av36p228.c	.8 Av36p120.b	.8 Cv26p000.a
.8 Cv36p172.a	.9 Av36p120.c	.9 Cv36p485.a
.9 Gc20p153.a	.10 Av36p173.a	.10 Hu26p208.a
.10 Gc24p226.a	.11 Av36p173.b	.11 Hu33p176.a
.11 Hu16p227.a	.12 Av36p190.a	.13 Hu36p162.c
.12 Hu26p113.a	.13 Bo40p184.a	.14 Hu36p456.a
.13 Hu26p194.a	.14 Bo41p187.a	.15 Sw41p189.a
.14 Hu26p194.b	.15 Bv36p181.a	.16 Sw41p491.a
.15 Hu26p194.c	.16 Bv36p183.a	.17 Va41p460.a
.16 Hu26p194.d	.17 Cv33p175.a	.18 Va41p461.a
.17 Hu26p202.a	.18 Cv34p170.a	.19 Va41p464.a
.18 Hu26p208.a	.19 Cv36p172.a	.20 Va41p475.a
.19 Hu26p208.b	.20 Cv36p485.a	.21 Va41p486.b
.20 Hu26p208.c	.22 Hu26p194.a	.22 We12p479.a
.21 Hu26p210.a	.24 Hu33p176.a	.23 We13p492.a
.22 Hu26p211.a	.25 Hu36p162.a	.24 We13p494.a
.23 Hu26p211.b	.26 Hu36p162.b	.25 We13p496.a
.24 Hu26p211.c	.27 Hu36p162.c	.26 No soil used
.25 Hu26p211.d	.28 Hu36p171.a	
.26 Hu26p217.a	.29 Hu36p171.b	
.27 Hu26p224.a	.30 Hu36p171.c	
.28 Hu26p224.b	.32 Hu36p203.a	
.29 Hu26p224.c	.33 Hu36p203.b	
.30 Hu26p224.d	.34 Hu36p203.c	
.31 Hu26p225.a	.36 Hu36p456.a	
.32 Hu26p748.a	.37 Hu37p204.a	
.33 Hu27p150.a	.39 Sw41p189.a	
.34 Hu33p745.a	.40 Sw41p491.a	
.35 Hu36p146.a	.41 Va41p486.a	
.36 Hu36p171.a	.42 Va41p486.b	
.37 Hu36p171.b	.43 We13p188.a	
.38 Hu36p171.c	.44 We13p492.a	
.39 Hu36p201.a	.45 We13p494.a	
.40 Hu36p203.a	.46 We13p758.a	
.41 Hu36p203.b	.47 No soil used	
.43 Hu36p203.d		
.44 Hu36p203.e		
.45 Hu36p203.f		
.47 Hu36p203.h		
.48 Hu37p204.a		
.49 Rg20p114.a		
.50 Rg20p114.b		
.52 We12p112.a		
.53 We13p758.a		
.54 No soil used		

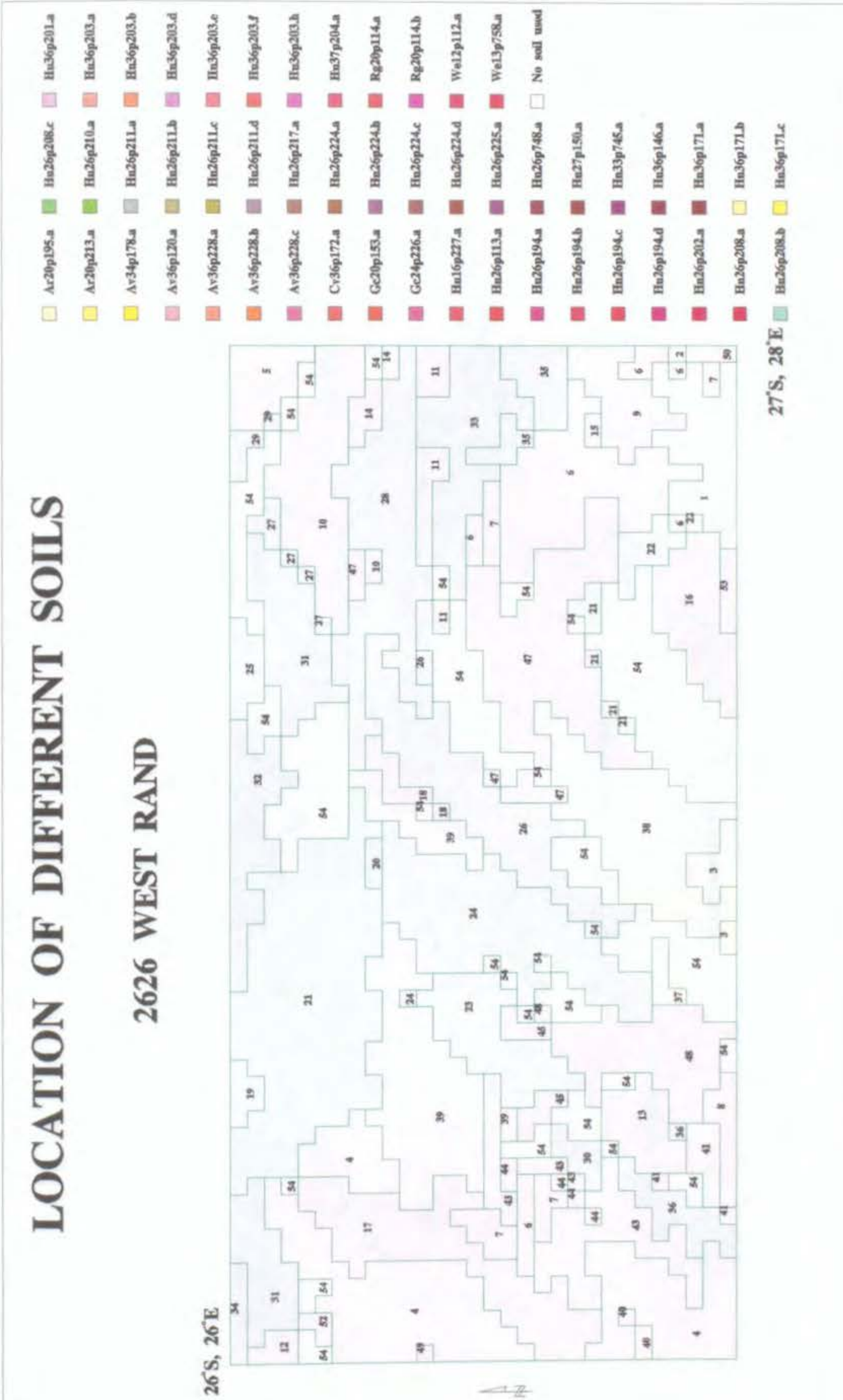

Figure 5.1a Distribution of soil forms on the 2626 WEST RAND map sheet

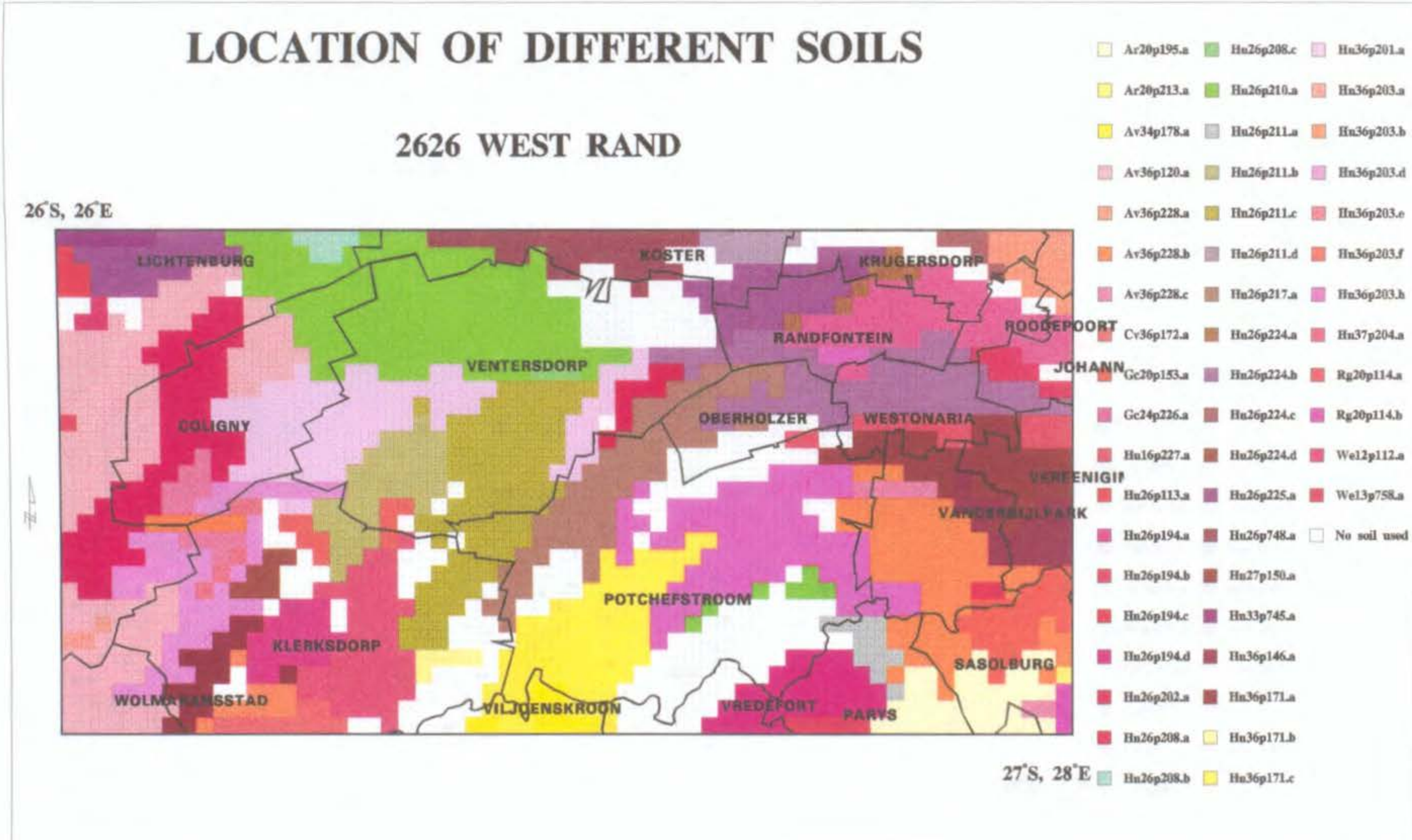

Figure 5.1b Soil form numbers (Table 5.2) for the 2626 WEST RAND map sheet.

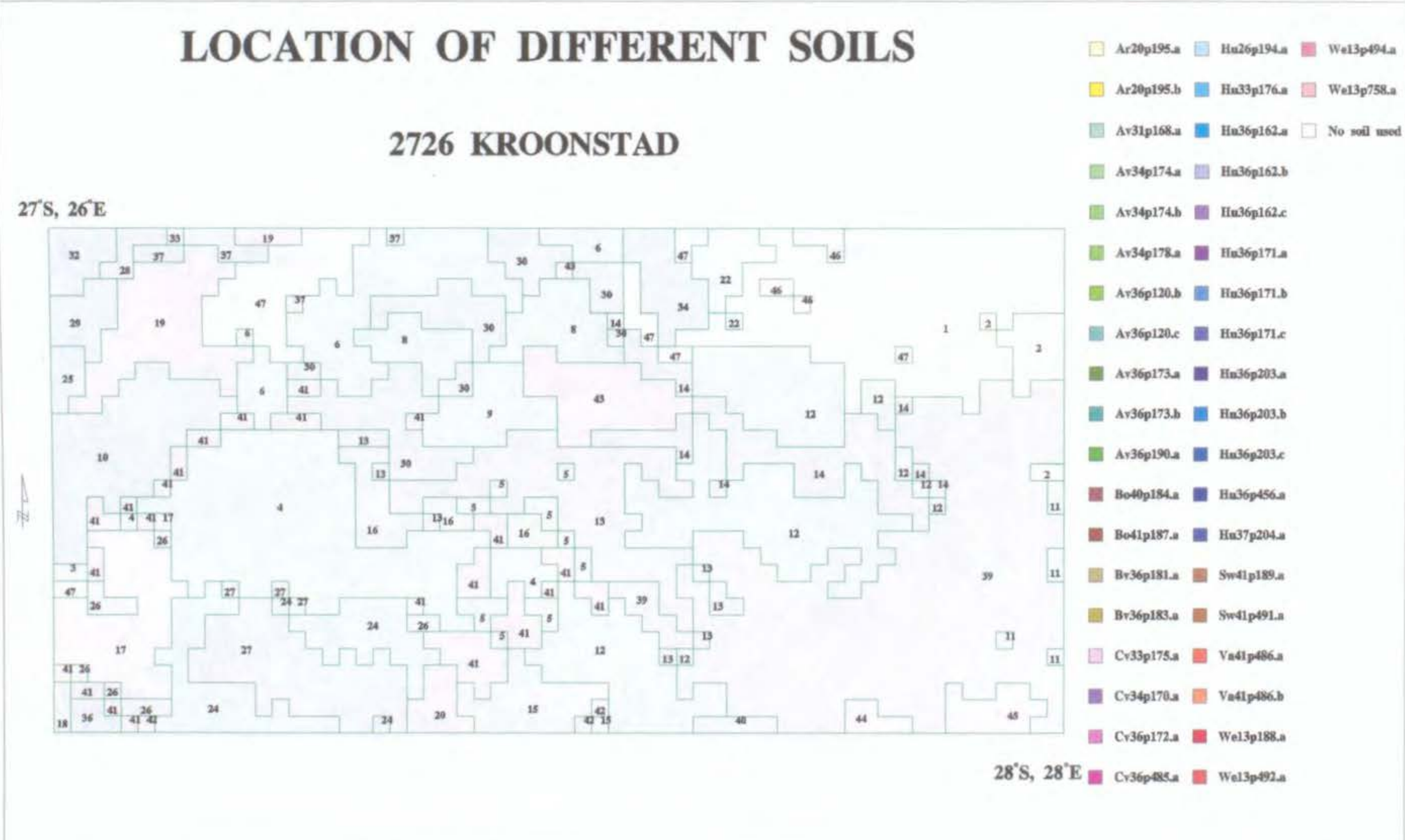

Figure 5.2a Distribution of soil forms on the 2726 KROONSTAD map sheet

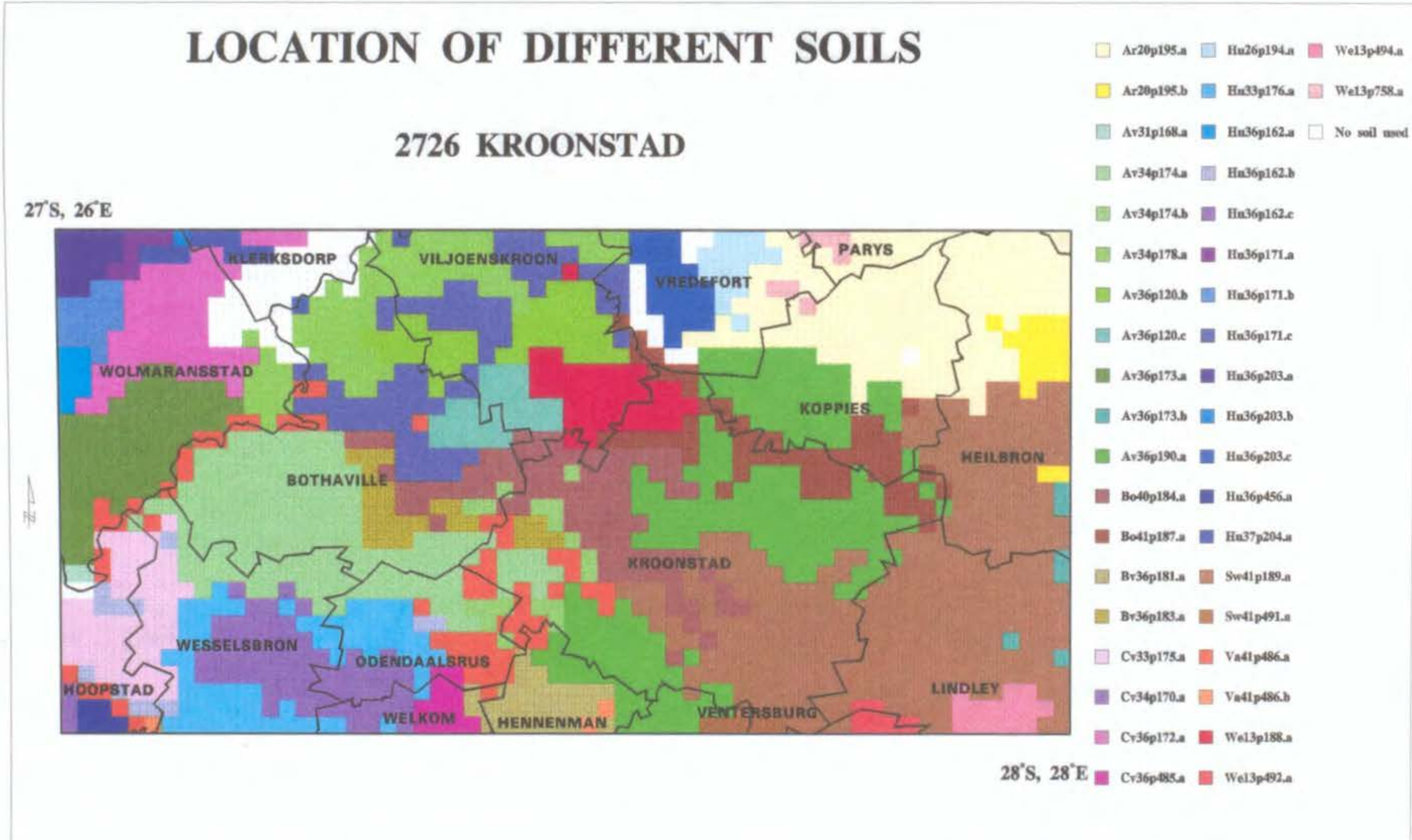

Figure 5.2b Soil form numbers (Table 5.2) for the 2726 KROONSTAD map sheet.

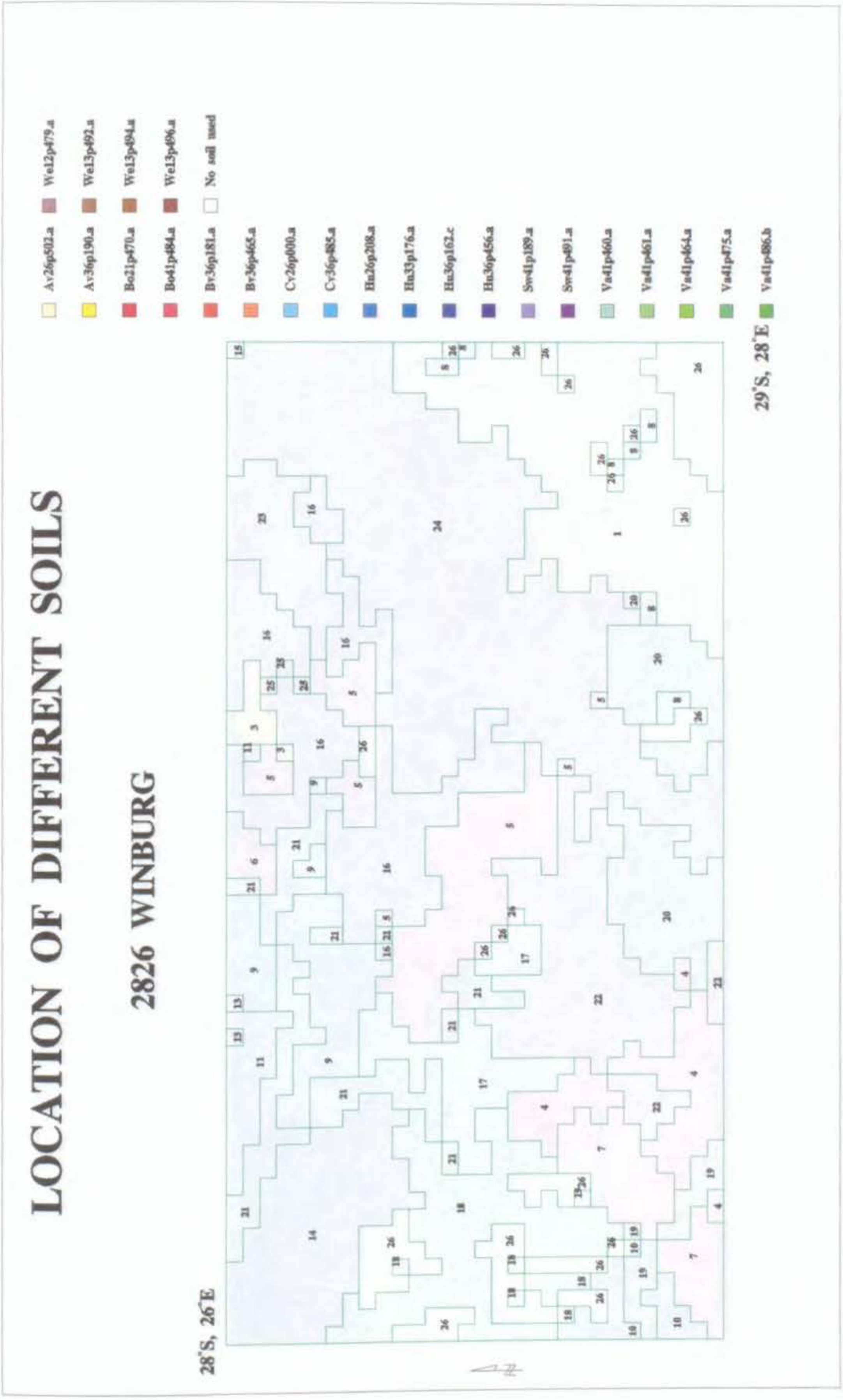

Figure 5.3a Distribution of soil forms on the 2826 WINBURG map sheet

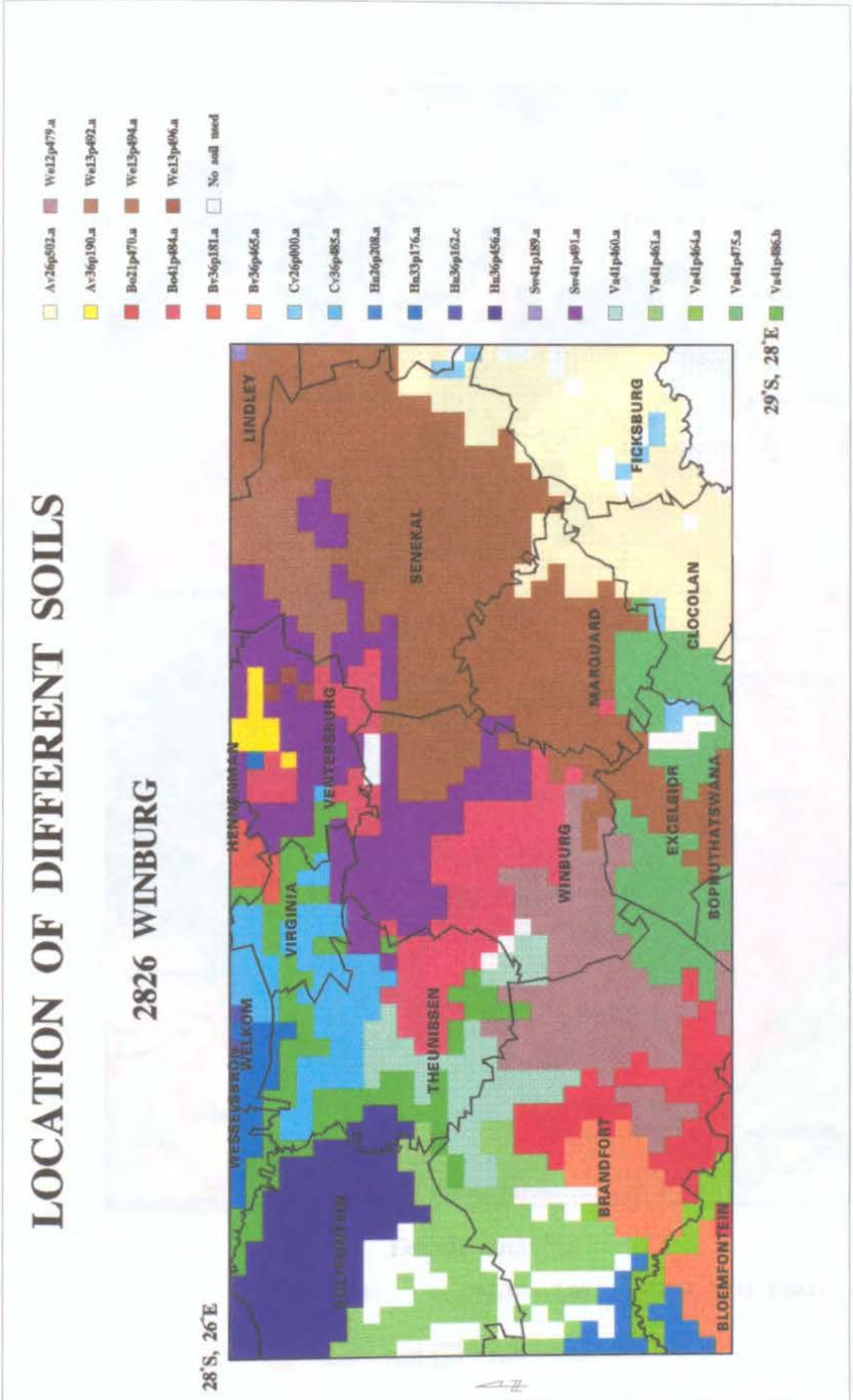

Figure 5.3b Soil form numbers (Table 5.2) for the 2826 WINBURG map sheet.

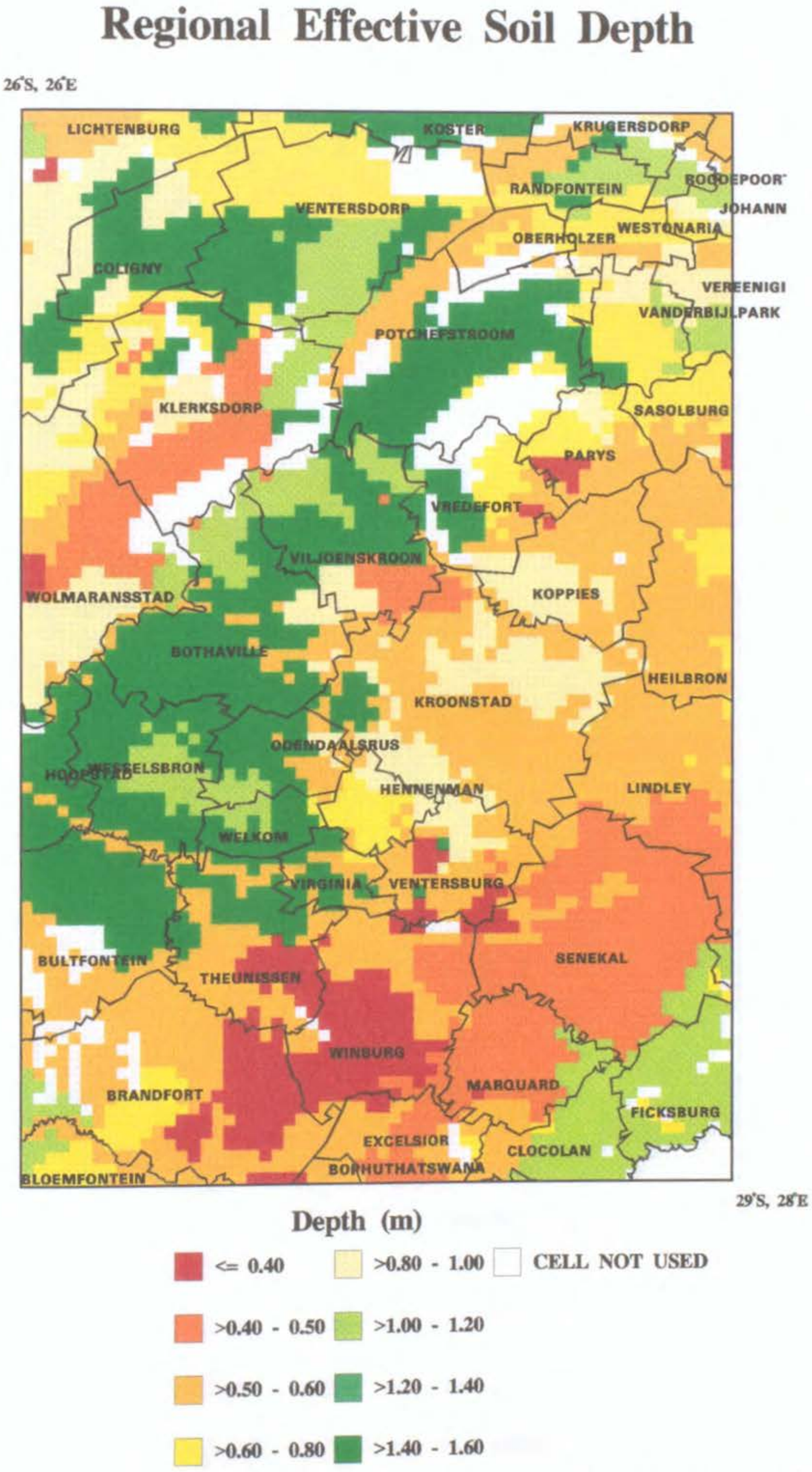

Figure 5.4 Effective soil depth for the region encompassed by all three map sheets

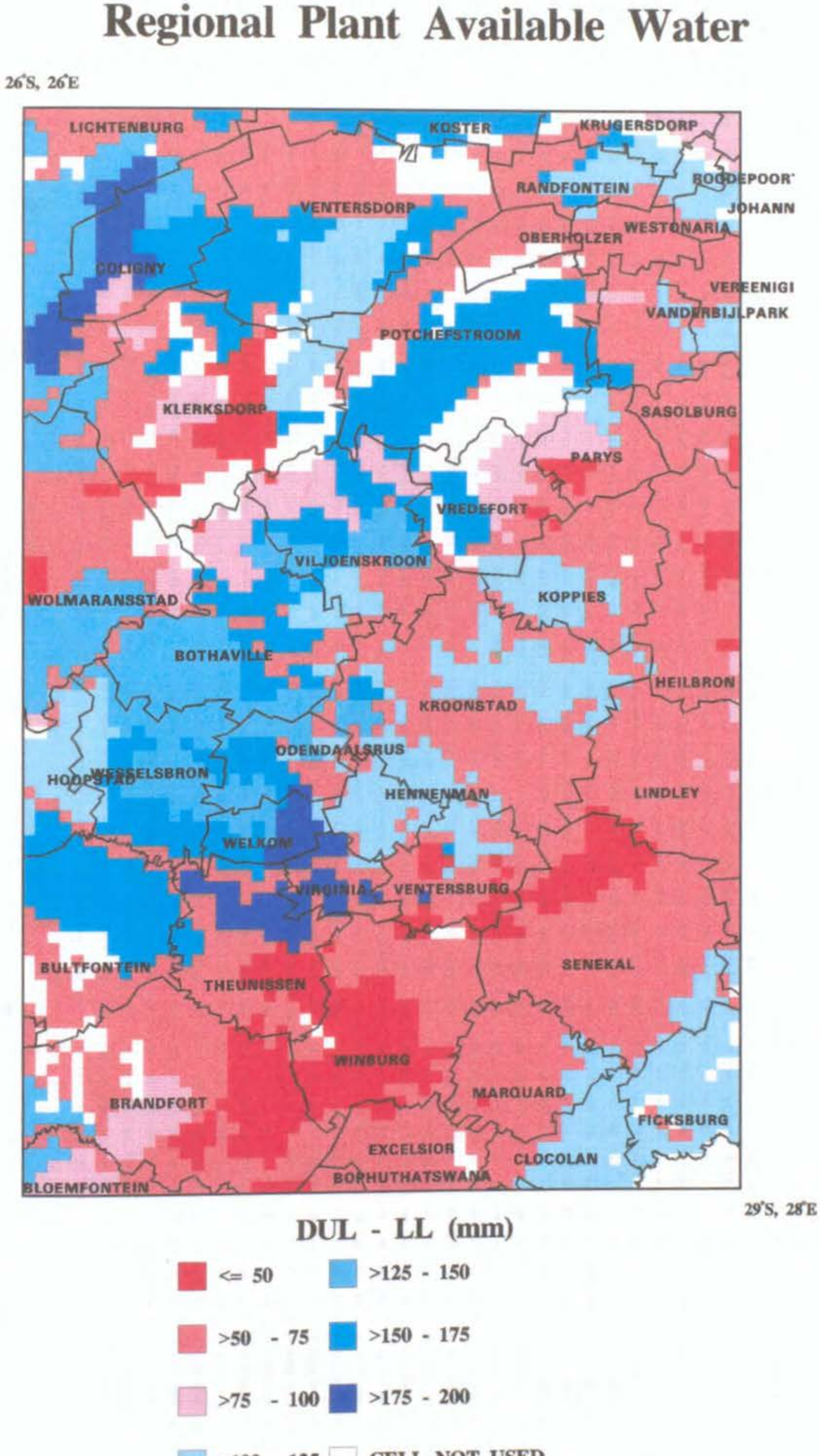

Figure 5.5 Plant available water in the region encompassed by all three map sheets

Table 5.3 Properties of the soil forms used in the 2626 WEST RAND Map sheet

Soil Type	Effect. Depth (ED)	Clay (%) Layer No. 1	2	3	4	5	6	7	8	9	Total Water in ED	DUL ($mm\ m^{-1}$) Layer No. 1	2	3	4	5	6	7	8	9
.1 Ar20p195.a	.60	50.	50.	50.	50.	50.	50.	50.	50.	50.	54.	386.	386.	386.	386.	379.	379.	379.	379.	379.
.2 Ar20p213.a	.70	55.	55.	55.	55.	55.	55.	55.	55.	55.	57.	415.	415.	418.	406.	406.	406.	406.	406.	406.
.3 Av34p178.a	1.05	5.	5.	10.	10.	20.	20.	20.	20.	20.	92.	99.	99.	121.	121.	186.	186.	186.	186.	186.
.4 Av36p120.a	.95	15.	15.	25.	25.	25.	25.	25.	25.	25.	127.	163.	158.	266.	266.	267.	267.	267.	267.	267.
.5 Av36p228.a	.60	15.	15.	15.	15.	15.	15.	15.	15.	15.	75.	163.	163.	232.	232.	157.	157.	157.	157.	157.
.6 Av36p228.b	.70	20.	20.	30.	30.	30.	30.	30.	30.	30.	62.	245.	245.	298.	298.	288.	288.	288.	288.	288.
.7 Av36p228.c	.95	15.	15.	25.	25.	25.	25.	25.	25.	25.	86.	163.	163.	276.	276.	266.	266.	266.	266.	266.
.8 Cv36p172.a	.50	15.	20.	20.	20.	20.	20.	20.	20.	20.	50.	180.	247.	247.	192.	192.	192.	192.	192.	192.
.9 Gc20p153.a	.80	5.	5.	5.	5.	5.	5.	5.	5.	5.	54.	97.	97.	98.	98.	98.	98.	98.	98.	98.
.10 Gc24p226.a	1.20	9.	9.	10.	10.	14.	14.	14.	14.	14.	121.	123.	123.	129.	129.	161.	161.	161.	161.	161.
.11 Hu16p227.a	.60	20.	20.	25.	25.	25.	25.	25.	25.	25.	72.	246.	246.	269.	269.	278.	278.	278.	278.	278.
.12 Hu26p113.a	1.20	18.	18.	20.	20.	20.	20.	20.	20.	20.	142.	182.	182.	193.	193.	193.	193.	193.	182.	182.
.13 Hu26p194.a	1.00	15.	15.	25.	25.	25.	25.	25.	25.	25.	91.	161.	161.	269.	269.	269.	270.	270.	270.	270.
.14 Hu26p194.b	.90	25.	25.	35.	35.	35.	35.	35.	35.	35.	100.	267.	267.	312.	312.	312.	312.	312.	312.	312.
.15 Hu26p194.c	1.20	20.	20.	25.	25.	25.	25.	25.	25.	25.	137.	189.	189.	269.	269.	269.	270.	270.	270.	270.
.16 Hu26p194.d	.80	20.	20.	30.	30.	30.	30.	30.	30.	30.	82.	189.	189.	291.	291.	291.	291.	291.	291.	291.
.17 Hu26p202.a	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	188.	159.	159.	194.	194.	194.	194.	194.	194.	194.
.18 Hu26p208.a	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	159.	162.	162.	247.	247.	247.	247.	247.	247.	247.
.19 Hu26p208.b	1.50	20.	20.	30.	30.	30.	30.	30.	30.	30.	163.	190.	190.	289.	289.	289.	289.	289.	289.	289.
.20 Hu26p208.c	.75	15.	15.	20.	20.	20.	20.	20.	20.	20.	69.	162.	162.	247.	247.	247.	247.	247.	247.	247.
.21 Hu26p210.a	.70	20.	20.	25.	25.	25.	25.	25.	25.	25.	70.	246.	246.	268.	268.	268.	268.	268.	268.	268.
.22 Hu26p211.a	1.00	15.	15.	25.	25.	25.	25.	25.	25.	25.	109.	162.	162.	267.	267.	266.	266.	266.	266.	266.
.23 Hu26p211.b	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	166.	162.	162.	246.	246.	186.	186.	186.	186.	186.
.24 Hu26p211.c	1.10	15.	15.	25.	25.	25.	25.	25.	25.	25.	114.	162.	162.	267.	267.	266.	266.	266.	266.	266.
.25 Hu26p211.d	1.50	20.	20.	25.	25.	25.	25.	25.	25.	25.	156.	190.	190.	267.	267.	266.	266.	266.	266.	266.
.26 Hu26p217.a	.60	15.	15.	20.	20.	20.	20.	20.	20.	20.	62.	162.	162.	246.	246.	186.	186.	186.	186.	186.
.27 Hu26p224.a	1.50	20.	20.	25.	25.	25.	25.	25.	25.	25.	163.	188.	188.	266.	266.	266.	269.	269.	269.	269.
.28 Hu26p224.b	.70	25.	25.	35.	35.	35.	35.	35.	35.	35.	67.	267.	267.	309.	309.	309.	312.	312.	312.	312.
.29 Hu26p224.c	1.00	25.	25.	35.	35.	35.	35.	35.	35.	35.	93.	267.	267.	309.	309.	309.	312.	312.	312.	312.
.30 Hu26p224.d	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	166.	159.	159.	178.	178.	178.	247.	247.	247.	247.
.31 Hu26p225.a	.60	20.	20.	20.	20.	20.	20.	20.	20.	20.	61.	246.	246.	249.	249.	251.	251.	251.	251.	251.
.32 Hu26p748.a	1.50	25.	25.	30.	30.	30.	30.	30.	30.	30.	158.	267.	267.	289.	289.	289.	289.	289.	289.	289.
.33 Hu27p150.a	.90	20.	20.	25.	25.	25.	25.	25.	25.	25.	73.	246.	246.	269.	269.	269.	272.	272.	272.	272.

Soil Type	LL ($mm\ m^{-1}$) Layer No. 1	2	3	4	5	6	7	8	9	Water per layer (mm) Layer No. 1	2	3	4	5	6	7	8	9
.1 Ar20p195.a	287.	287.	287.	287.	266.	266.	266.	266.	266.	15.	15.	15.	10.	17.	17.	17.	17.	17.
.2 Ar20p213.a	334.	334.	343.	309.	309.	309.	309.	309.	309.	16.	16.	15.	10.	19.	19.	19.	19.	19.
.3 Av34p178.a	33.	33.	40.	40.	62.	62.	62.	62.	62.	7.	10.	16.	16.	31.	12.	31.	31.	31.
.4 Av36p120.a	56.	54.	165.	165.	162.	162.	162.	162.	162.	18.	18.	30.	30.	30.	32.	32.	32.	32.
.5 Av36p228.a	69.	69.	127.	127.	54.	54.	54.	54.	54.	14.	14.	26.	21.	21.	21.	21.	21.	21.
.6 Av36p228.b	162.	162.	193.	193.	186.	186.	186.	186.	186.	12.	12.	26.	11.	20.	20.	20.	20.	20.
.7 Av36p228.c	69.	69.	171.	171.	165.	165.	165.	165.	165.	14.	14.	26.	26.	5.	20.	20.	20.	20.
.8 Cv36p172.a	61.	144.	144.	63.	63.	63.	63.	63.	63.	18.	15.	10.	6.	19.	19.	19.	19.	19.
.9 Gc20p153.a	34.	34.	33.	33.	33.	33.	33.	33.	33.	9.	9.	12.	12.	6.	5.	6.	6.	6.
.10 Gc24p226.a	49.	49.	45.	45.	57.	57.	57.	57.	57.	11.	9.	15.	15.	22.	26.	11.	11.	11.
.11 Hu16p227.a	168.	168.	174.	174.	162.	162.	162.	162.	162.	8.	8.	14.	19.	23.	29.	29.	29.	12.
.12 Hu26p113.a	66.	66.	63.	63.	63.	63.	63.	59.	59.	14.	15.	20.	20.	20.	20.	26.	9.	28.
.13 Hu26p194.a	58.	58.	165.	165.	165.	162.	162.	162.	162.	15.	21.	16.	16.	23.	1.	15.	15.	15.
.14 Hu26p194.b	169.	169.	208.	208.	208.	204.	204.	204.	204.	15.	20.	16.	16.	23.	12.	15.	15.	15.
.15 Hu26p194.c	67.	67.	165.	165.	165.	162.	162.	162.	162.	18.	24.	16.	16.	23.	15.	15.	10.	15.
.16 Hu26p194.d	67.	67.	186.	186.	186.	183.	183.	183.	183.	18.	24.	16.	16.	7.	15.	15.	15.	15.
.17 Hu26p202.a	53.	53.	62.	62.	62.	62.	62.	62.	62.	11.	11.	24.	24.	24.	24.	24.	24.	24.
.18 Hu26p208.a	57.	57.	141.	141.	141.	141.	141.	141.	141.	10.	10.	21.	21.	21.	21.	21.	21.	11.
.19 Hu26p208.b	66.	66.	183.	183.	183.	183.	183.	183.	183.	12.	12.	21.	21.	21.	21.	21.	21.	11.
.20 Hu26p208.c	57.	57.	141.	141.	141.	141.	141.	141.	141.	10.	10.	21.	21.	5.	21.	21.	21.	21.
.21 Hu26p210.a	152.	152.	165.	165.	165.	165.	165.	165.	165.	9.	9.	26.	26.	15.	15.	15.	15.	15.
.22 Hu26p211.a	57.	57.	165.	165.	162.	162.	162.	162.	162.	16.	16.	15.	20.	16.	16.	10.	16.	16.
.23 Hu26p211.b	57.	57.	144.	144.	62.	62.	62.	62.	62.	16.	16.	15.	20.	25.	25.	25.	19.	6.
.24 Hu26p211.c	57.	57.	165.	165.	162.	162.	162.	162.	162.	16.	16.	15.	20.	16.	16.	16.	16.	16.
.25 Hu26p211.d	66.	66.	165.	165.	162.	162.	162.	162.	162.	19.	19.	15.	20.	21.	21.	21.	16.	5.
.26 Hu26p217.a	57.	57.	144.	144.	62.	62.	62.	62.	62.	16.	16.	15.	15.	19.	19.	19.	19.	19.
.27 Hu26p224.a	68.	68.	168.	168.	168.	165.	165.	165.	165.	18.	18.	20.	20.	18.	21.	21.	18.	10.
.28 Hu26p224.b	172.	172.	212.	212.	212.	208.	208.	208.	208.	14.	14.	19.	19.	17.	21.	21.	18.	16.
.29 Hu26p224.c	172.	172.	212.	212.	212.	208.	208.	208.	208.	14.	14.	19.	19.	17.	8.	21.	18.	16.
.30 Hu26p224.d	59.	59.	63.	63.	63.	144.	144.	144.	144.	15.	15.	23.	23.	21.	21.	21.	18.	10.
.31 Hu26p225.a	150.	150.	143.	143.	140.	140.	140.	140.	140.	14.	14.	16.	16.	17.	17.	17.	17.	17.
.32 Hu26p748.a	167.	167.	183.	183.	183.	183.	183.	183.	183.	10.	10.	21.	21.	21.	21.	21.	21.	11.
.33 Hu27p150.a	165.	165.	177.	177.	177.	168.	168.	168.	168.	12.	13.	23.	23.	2.	16.	16.	16.	16.

Table 5.3 ctd

Soil Type	Effect. Depth (ED)	Clay (%) Layer No.									Total Water in ED	DUL (mm m^{-1}) Layer No.								
.34 Hu33p745.a	.60	10.	10.	15.	15.	15.	15.	15.	15.	15.	66.	148.	148.	185.	185.	185.	185.	185.	185.	185.
.35 Hu36p146.a	1.20	20.	20.	29.	29.	29.	29.	29.	29.	29.	108.	246.	246.	288.	288.	291.	291.	291.	291.	291.
.36 Hu36p171.a	.60	15.	15.	25.	25.	25.	25.	25.	25.	25.	69.	163.	163.	267.	267.	267.	265.	265.	265.	265.
.37 Hu36p171.b	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	159.	163.	163.	192.	192.	192.	182.	182.	182.	182.
.38 Hu36p171.c	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	159.	163.	163.	192.	192.	192.	182.	182.	182.	182.
.39 Hu36p201.a	1.50	15.	15.	25.	25.	25.	25.	25.	25.	25.	158.	182.	182.	271.	271.	274.	274.	274.	274.	274.
.40 Hu36p203.a	.75	15.	15.	25.	25.	25.	25.	25.	25.	25.	68.	168.	168.	267.	267.	267.	267.	267.	267.	267.
.41 Hu36p203.b	.50	20.	20.	25.	25.	25.	25.	25.	25.	25.	51.	246.	246.	267.	267.	267.	267.	267.	267.	267.
.43 Hu36p203.d	.75	15.	15.	20.	20.	20.	20.	20.	20.	20.	68.	168.	168.	246.	246.	246.	246.	246.	246.	246.
.44 Hu36p203.e	.50	15.	15.	25.	25.	25.	25.	25.	25.	25.	52.	168.	168.	267.	267.	267.	267.	267.	267.	267.
.45 Hu36p203.f	.75	15.	15.	25.	25.	25.	25.	25.	25.	25.	68.	168.	168.	267.	267.	267.	267.	267.	267.	267.
.47 Hu36p203.h	1.50	15.	15.	25.	25.	25.	25.	25.	25.	25.	157.	168.	168.	267.	267.	267.	267.	267.	267.	267.
.48 Hu37p204.a	.45	15.	15.	35.	35.	35.	35.	35.	35.	35.	39.	156.	156.	317.	317.	317.	317.	317.	317.	317.
.49 Rg20p114.a	.60	50.	50.	50.	50.	50.	50.	50.	50.	50.	72.	379.	379.	379.	375.	375.	375.	375.	375.	375.
.50 Rg20p114.b	.40	50.	50.	50.	50.	50.	50.	50.	50.	50.	37.	379.	379.	379.	375.	375.	375.	375.	375.	375.
.52 We12p112.a	.40	15.	15.	25.	25.	25.	25.	25.	25.	25.	52.	152.	152.	266.	266.	266.	266.	266.	266.	266.
.53 We13p758.a	.40	20.	20.	20.	35.	35.	35.	35.	35.	35.	31.	247.	247.	245.	314.	314.	309.	309.	309.	309.
.54 No soil used																				

Soil Type	LL (mm m^{-1}) Layer No.									Water per layer (mm) Layer No.								
.34 Hu33p745.a	49.	49.	63.	63.	63.	63.	63.	63.	63.	15.	15.	18.	18.	18.	18.	18.	18.	18.
.35 Hu36p146.a	162.	162.	203.	203.	196.	196.	196.	196.	196.	13.	13.	12.	12.	24.	24.	9.	19.	19.
.36 Hu36p171.a	56.	56.	162.	162.	162.	159.	159.	159.	159.	11.	16.	16.	16.	10.	16.	16.	16.	16.
.37 Hu36p171.b	56.	56.	63.	63.	63.	59.	59.	59.	59.	11.	16.	19.	19.	19.	18.	18.	18.	18.
.38 Hu36p171.c	56.	56.	63.	63.	63.	59.	59.	59.	59.	11.	16.	19.	19.	19.	18.	18.	18.	18.
.39 Hu36p201.a	66.	66.	174.	174.	168.	168.	168.	168.	168.	12.	12.	17.	17.	26.	26.	26.	20.	20.
.40 Hu36p203.a	59.	59.	165.	165.	165.	162.	162.	162.	162.	11.	11.	20.	20.	5.	21.	21.	21.	21.
.41 Hu36p203.b	145.	145.	165.	165.	165.	162.	162.	162.	162.	10.	10.	20.	10.	20.	21.	21.	21.	21.
.43 Hu36p203.d	59.	59.	144.	144.	144.	141.	141.	141.	141.	11.	11.	20.	20.	5.	21.	21.	21.	21.
.44 Hu36p203.e	59.	59.	165.	165.	165.	162.	162.	162.	162.	11.	11.	20.	10.	20.	21.	21.	21.	21.
.45 Hu36p203.f	59.	59.	165.	165.	165.	162.	162.	162.	162.	11.	11.	20.	20.	5.	21.	21.	21.	21.
.47 Hu36p203.h	59.	59.	165.	165.	165.	162.	162.	162.	162.	11.	11.	20.	20.	20.	21.	21.	21.	11.
.48 Hu37p204.a	61.	61.	244.	244.	244.	244.	244.	244.	244.	10.	11.	11.	6.	11.	11.	11.	11.	11.
.49 Rg20p114.a	283.	283.	286.	272.	272.	272.	272.	272.	272.	14.	24.	16.	18.	21.	15.	15.	15.	15.
.50 Rg20p114.b	286.	286.	286.	272.	272.	272.	272.	272.	272.	14.	23.	16.	21.	21.	15.	15.	15.	15.
.52 We12p112.a	58.	58.	168.	168.	168.	168.	168.	168.	168.	12.	12.	14.	14.	14.	14.	14.	14.	14.
.53 We13p758.a	157.	157.	160.	215.	215.	204.	204.	204.	204.	14.	14.	4.	12.	13.	16.	16.	16.	16.
.54 No soil used																		

Table 5.4 Properties of the soil forms used in the 2726 KROONSTAD map sheet

Soil Type	Effect. Depth (ED)	Clay (%) Layer No.									Total Water in ED	DUL (mm m⁻¹) Layer No.									LL (mm m⁻¹) Layer No.									Water per layer (mm) Layer No.								
		1	2	3	4	5	6	7	8	9		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.1 Ar20p195.a	.60	50.	50.	50.	50.	50.	50.	50.	50.	50.	54.	386.	386.	386.	386.	379.	379.	379.	379.	379.	287.	287.	287.	287.	266.	266.	266.	266.	266.	15.	15.	15.	10.	17.	17.	17.	17.	17.
.2 Ar20p195.b	.70	50.	50.	50.	50.	50.	50.	50.	50.	50.	45.	386.	386.	386.	386.	379.	379.	379.	379.	379.	287.	287.	287.	287.	266.	266.	266.	266.	266.	15.	15.	15.	0.	17.	17.	17.	17.	17.
.3 Av31p168.a	1.50	3.	3.	6.	6.	6.	6.	6.	6.	6.	97.	82.	82.	98.	98.	104.	104.	98.	98.	98.	28.	28.	33.	33.	35.	35.	33.	33.	33.	8.	8.	20.	20.	21.	21.	20.	20.	20.
.4 Av34p174.a	1.50	10.	10.	15.	15.	15.	15.	15.	15.	15.	128.	142.	142.	164.	164.	164.	140.	140.	140.	140.	47.	47.	55.	55.	55.	60.	60.	60.	60.	14.	19.	16.	27.	27.	16.	8.	32.	32.
.5 Av34p174.b	1.00	15.	15.	20.	20.	20.	20.	20.	20.	20.	124.	170.	170.	192.	192.	192.	168.	168.	168.	168.	56.	56.	63.	63.	63.	70.	70.	70.	70.	17.	23.	19.	32.	32.	20.	39.	39.	39.
.6 Av34p178.a	1.05	5.	5.	10.	10.	20.	20.	20.	20.	20.	92.	99.	99.	121.	121.	186.	186.	186.	186.	186.	33.	33.	40.	40.	62.	62.	62.	62.	62.	7.	10.	16.	16.	31.	12.	31.	31.	31.
.8 Av36p120.b	1.50	10.	10.	20.	20.	20.	20.	20.	20.	20.	138.	135.	130.	185.	185.	246.	246.	246.	246.	246.	47.	45.	63.	63.	141.	141.	141.	141.	141.	15.	14.	37.	37.	32.	4.	32.	32.	32.
.9 Av36p120.c	1.00	15.	15.	25.	25.	25.	25.	25.	25.	25.	122.	163.	158.	266.	266.	267.	267.	267.	267.	267.	56.	54.	165.	165.	162.	162.	162.	162.	162.	18.	18.	30.	30.	25.	32.	32.	32.	32.
.10 Av36p173.a	1.00	10.	10.	20.	20.	20.	20.	20.	20.	20.	129.	142.	142.	247.	247.	247.	181.	181.	192.	192.	47.	47.	144.	144.	141.	60.	60.	63.	63.	14.	14.	21.	21.	26.	33.	40.	45.	45.
.11 Av36p173.b	.80	15.	15.	20.	20.	20.	20.	20.	20.	20.	91.	170.	170.	247.	247.	247.	181.	181.	192.	192.	56.	56.	144.	144.	141.	60.	60.	63.	63.	17.	17.	21.	21.	16.	39.	40.	45.	45.
.12 Av36p190.a	1.00	15.	15.	30.	30.	30.	30.	30.	30.	30.	105.	162.	162.	289.	289.	289.	289.	289.	289.	289.	57.	57.	190.	190.	183.	183.	183.	183.	183.	17.	17.	15.	16.	16.	16.	8.	16.	16.
.13 Bo40p184.a	.60	20.	20.	35.	35.	35.	35.	35.	35.	35.	66.	182.	182.	309.	309.	310.	310.	310.	310.	310.	66.	66.	204.	204.	204.	204.	204.	204.	204.	17.	19.	20.	10.	16.	16.	16.	16.	21.
.14 Bo41p187.a	.60	25.	25.	40.	40.	40.	40.	40.	40.	40.	63.	272.	272.	338.	335.	335.	335.	335.	335.	335.	169.	169.	237.	225.	225.	225.	225.	225.	225.	15.	15.	15.	16.	16.	16.	16.	16.	16.
.15 Bv36p181.a	.75	15.	15.	20.	20.	20.	20.	20.	20.	20.	104.	147.	147.	174.	174.	186.	186.	192.	192.	192.	50.	50.	60.	60.	62.	62.	63.	63.	63.	12.	11.	17.	14.	27.	24.	26.	26.	32.
.16 Bv36p183.a	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	172.	152.	152.	185.	185.	246.	246.	258.	258.	258.	52.	52.	63.	63.	136.	136.	136.	136.	136.	15.	15.	18.	18.	22.	22.	24.	24.	12.
.17 Cv33p175.a	1.50	7.	7.	10.	10.	10.	10.	10.	10.	10.	120.	104.	104.	121.	121.	126.	126.	126.	126.	126.	34.	34.	40.	40.	41.	41.	41.	41.	41.	14.	14.	19.	19.	10.	17.	17.	9.	17.
.18 Cv34p170.a	1.50	8.	8.	11.	11.	11.	11.	11.	11.	11.	124.	109.	109.	125.	125.	125.	125.	125.	125.	125.	37.	37.	42.	42.	42.	42.	42.	42.	42.	14.	14.	21.	21.	21.	21.	12.	21.	21.
.19 Cv36p172.a	.50	15.	20.	20.	20.	20.	20.	20.	20.	20.	50.	180.	247.	247.	192.	192.	192.	192.	192.	192.	61.	144.	144.	63.	63.	63.	63.	63.	63.	18.	15.	10.	6.	19.	19.	19.	19.	19.
.20 Cv36p485.a	1.50	10.	10.	20.	20.	20.	20.	20.	20.	20.	178.	128.	128.	192.	192.	192.	192.	192.	192.	192.	46.	46.	63.	63.	63.	63.	63.	63.	63.	13.	13.	25.	25.	19.	19.	26.	26.	13.
.22 Hu26p194.a	.80	20.	20.	30.	30.	30.	30.	30.	30.	30.	82.	189.	189.	291.	291.	291.	291.	291.	291.	291.	67.	67.	186.	186.	186.	183.	183.	183.	183.	18.	24.	16.	16.	7.	15.	15.	15.	15.
.24 Hu33p176.a	1.50	10.	10.	15.	15.	15.	15.	15.	15.	15.	161.	131.	131.	158.	158.	153.	153.	153.	153.	153.	44.	44.	53.	53.	51.	51.	51.	51.	51.	13.	10.	16.	15.	15.	22.	26.	26.	18.
.25 Hu36p162.a	.40	10.	10.	20.	20.	20.	20.	20.	20.	20.	35.	116.	116.	185.	179.	179.	179.	179.	179.	179.	48.	48.	63.	61.	61.	61.	61.	61.	61.	8.	9.	18.	18.	18.	18.	18.	18.	18.
.26 Hu36p162.b	1.50	10.	10.	15.	15.	15.	15.	15.	15.	15.	122.	116.	116.	157.	151.	151.	151.	151.	151.	151.	48.	48.	54.	52.	52.	52.	52.	52.	52.	8.	9.	15.	15.	15.	20.	20.	20.	0.
.27 Hu36p162.c	1.20	15.	15.	20.	20.	20.	20.	20.	20.	20.	140.	145.	145.	185.	179.	179.	179.	179.	179.	179.	58.	58.	63.	61.	61.	61.	61.	61.	61.	10.	11.	18.	18.	18.	18.	18.	18.	12.
.28 Hu36p171.a	.60	15.	15.	25.	25.	25.	25.	25.	25.	25.	69.	163.	163.	267.	267.	267.	265.	265.	265.	265.	56.	56.	162.	162.	162.	159.	159.	159.	159.	11.	16.	16.	16.	10.	16.	16.	16.	16.
.29 Hu36p171.b	.60	10.	10.	15.	15.	15.	15.	15.	15.	15.	66.	135.	135.	164.	164.	164.	154.	154.	154.	154.	47.	47.	55.	55.	55.	50.	50.	50.	50.	9.	13.	16.	16.	11.	16.	16.	16.	16.
.30 Hu36p171.c	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	159.	163.	163.	192.	192.	192.	182.	182.	182.	182.	56.	56.	63.	63.	63.	59.	59.	59.	59.	11.	16.	19.	19.	19.	18.	18.	18.	18.
.32 Hu36p203.a	.75	15.	15.	25.	25.	25.	25.	25.	25.	25.	68.	168.	168.	267.	267.	267.	267.	267.	267.	267.	59.	59.	165.	165.	165.	162.	162.	162.	162.	11.	11.	20.	20.	5.	21.	21.	21.	21.
.33 Hu36p203.b	.50	20.	20.	25.	25.	25.	25.	25.	25.	25.	51.	246.	246.	267.	267.	267.	267.	267.	267.	267.	145.	145.	165.	165.	165.	162.	162.	162.	162.	10.	10.	20.	10.	20.	21.	21.	21.	21.
.34 Hu36p203.c	1.50	15.	15.	20.	20.	20.	20.	20.	20.	20.	157.	168.	168.	246.	246.	246.	246.	246.	246.	246.	59.	59.	144.	144.	144.	141.	141.	141.	141.	11.	11.	20.	20.	20.	21.	21.	21.	11.
.36 Hu36p456.a	1.50	10.	10.	20.	20.	20.	20.	20.	20.	20.	166.	125.	125.	181.	188.	188.	188.	188.	188.	188.	42.	42.	60.	60.	60.	60.	60.	60.	60.	15.	15.	22.	22.	22.	22.	22.	22.	5.
.37 Hu37p204.a	.45	15.	15.	35.	35.	35.	35.	35.	35.	35.	39.	156.	156.	317.	317.	317.	317.	317.	317.	317.	61.	61.	244.	244.	244.	244.	244.	244.	244.	10.	11.	11.	6.	11.	11.	11.	11.	11.
.39 Sw41p189.a	.60	20.	20.	35.	35.	35.	35.	35.	35.	35.	69.	247.	247.	315.	315.	315.	315.	315.	315.	315.	155.	155.	227.	227.	212.	212.	212.	212.	212.	10.	10.	10.	10.	15.	14.	15.	15.	15.
.40 Sw41p491.a	.60	20.	40.	40.	40.	40.	40.	40.	40.	40.	51.	247.	340.	340.	341.	341.	341.	341.	341.	341.	152.	246.	246.	233.	233.	233.	233.	233.	233.	10.	10.	10.	16.	3.	16.	16.	16.	16.

Table 5.4 ctd

Soil Type	Effect. Depth (ED)	Clay (%)									Total Water in ED	DUL (mm m^{-1})									LL (mm m^{-1})									Water per layer (mm)								
		Layer No.										Layer No.									Layer No.									Layer No.								
.41 Va41p486.a	.60	15.	15.	35.	35.	35.	35.	35.	35.	35.	61.	176.	176.	313.	313.	309.	309.	309.	309.	309.	65.	65.	219.	219.	204.	204.	204.	204.	204.	13.	14.	14.	19.	16.	16.	16.	16.	16.
.42 Va41p486.b	.60	20.	20.	40.	40.	40.	40.	40.	40.	40.	57.	247.	247.	335.	335.	330.	330.	330.	330.	330.	150.	150.	242.	242.	225.	225.	225.	225.	225.	12.	13.	14.	19.	16.	16.	16.	16.	16.
.43 We13p188.a	.50	20.	20.	35.	35.	35.	35.	35.	35.	35.	59.	176.	176.	309.	310.	310.	308.	308.	308.	308.	58.	58.	208.	208.	208.	201.	201.	201.	201.	12.	12.	10.	15.	10.	21.	21.	21.	21.
.44 We13p492.a	.50	20.	20.	40.	40.	40.	40.	40.	40.	40.	40.	246.	246.	334.	330.	330.	330.	330.	330.	330.	150.	150.	237.	218.	218.	218.	218.	218.	218.	17.	17.	6.	17.	17.	17.	17.	17.	17.
.45 We13p494.a	.50	15.	15.	45.	45.	45.	45.	45.	45.	45.	57.	188.	188.	357.	363.	363.	363.	363.	363.	363.	68.	68.	259.	273.	273.	273.	273.	273.	273.	18.	24.	15.	14.	14.	14.	14.	14.	14.
.46 We13p758.a	.40	20.	20.	20.	35.	35.	35.	35.	35.	35.	31.	247.	247.	245.	314.	314.	309.	309.	309.	309.	157.	157.	160.	215.	215.	204.	204.	204.	204.	14.	14.	4.	12.	13.	16.	16.	16.	16.
.47 No soil used																																						

Table 5.5 Properties of soils forms used in the 2826 WINBURG Map sheet

	Soil Type	Effect. Depth (ED)	Clay (%) Layer No. 1	2	3	4	5	6	7	8	9	Total Water in ED	DUL (mm m^{-1}) Layer No. 1	2	3	4	5	6	7	8	9	LL (mm m^{-1}) Layer No. 1	2	3	4	5	6	7	8	9	Water per layer (mm) Layer No. 1	2	3	4	5	6	7	8	9
.1	Av26p502.a	1.10	15.	15.	25.	25.	25.	25.	25.	25.	25.	122.	166.	166.	268.	268.	268.	269.	269.	269.	269.	60.	60.	162.	162.	162.	162.	162.	162.	162.	16.	16.	16.	16.	16.	16.	16.	11.	16.
.3	Av36p190.a	1.00	15.	15.	30.	30.	30.	30.	30.	30.	30.	105.	162.	162.	289.	289.	289.	289.	289.	289.	289.	57.	57.	190.	190.	183.	183.	183.	183.	183.	17.	17.	15.	16.	16.	16.	8.	16.	16.
.4	Bo21p470.a	.60	40.	40.	45.	45.	45.	45.	45.	45.	45.	53.	335.	335.	355.	355.	355.	355.	355.	355.	355.	242.	242.	257.	257.	257.	257.	257.	257.	257.	9.	9.	15.	15.	5.	15.	15.	15.	15.
.5	Bo41p484.a	.40	55.	55.	55.	55.	55.	55.	55.	55.	55.	44.	403.	403.	399.	399.	399.	399.	399.	399.	399.	309.	309.	300.	300.	300.	300.	300.	300.	300.	9.	9.	15.	10.	15.	15.	15.	15.	15.
.6	Bv36p181.a	.75	15.	15.	20.	20.	20.	20.	20.	20.	20.	104.	147.	147.	174.	174.	186.	186.	192.	192.	192.	50.	50.	60.	60.	62.	62.	63.	63.	63.	12.	11.	17.	14.	27.	24.	26.	26.	32.
.7	Bv36p465.a	.80	15.	15.	25.	25.	25.	25.	25.	25.	25.	90.	152.	152.	265.	265.	267.	267.	267.	267.	267.	52.	52.	156.	156.	156.	156.	156.	156.	156.	15.	15.	16.	16.	17.	11.	17.	17.	17.
.8	Cv26p000.a	.70	10.	10.	15.	15.	15.	15.	15.	15.	15.	62.	127.	127.	149.	149.	149.	166.	166.	166.	166.	47.	47.	54.	54.	54.	53.	53.	53.	53.	12.	12.	11.	13.	13.	23.	23.	23.	23.
.9	Cv36p485.a	1.50	10.	10.	20.	20.	20.	20.	20.	20.	20.	178.	128.	128.	192.	192.	192.	192.	192.	192.	192.	46.	46.	63.	63.	63.	63.	63.	63.	63.	13.	13.	25.	25.	19.	19.	26.	26.	13.
.10	Hu26p208.a	1.20	15.	15.	25.	25.	25.	25.	25.	25.	25.	127.	162.	162.	268.	268.	268.	268.	268.	268.	268.	57.	57.	162.	162.	162.	162.	162.	162.	162.	10.	10.	21.	21.	21.	21.	21.	21.	21.
.11	Hu33p176.a	1.50	10.	10.	15.	15.	15.	15.	15.	15.	15.	161.	131.	131.	158.	158.	153.	153.	153.	153.	153.	44.	44.	53.	53.	51.	51.	51.	51.	51.	13.	10.	16.	15.	15.	22.	26.	26.	18.
.13	Hu36p162.c	1.20	15.	15.	20.	20.	20.	20.	20.	20.	20.	140.	145.	145.	185.	179.	179.	179.	179.	179.	179.	58.	58.	63.	61.	61.	61.	61.	61.	61.	10.	11.	18.	18.	18.	18.	18.	18.	12.
.14	Hu36p456.a	1.50	10.	10.	20.	20.	20.	20.	20.	20.	20.	166.	125.	125.	181.	188.	188.	188.	188.	188.	188.	42.	42.	60.	60.	60.	60.	60.	60.	60.	15.	15.	22.	22.	22.	22.	22.	22.	5.
.15	Sw41p189.a	.60	20.	20.	35.	35.	35.	35.	35.	35.	35.	69.	247.	247.	315.	315.	315.	315.	315.	315.	315.	155.	155.	227.	227.	212.	212.	212.	212.	212.	10.	10.	10.	10.	15.	14.	15.	15.	15.
.16	Sw41p491.a	.60	20.	40.	40.	40.	40.	40.	40.	40.	40.	51.	247.	340.	340.	341.	341.	341.	341.	341.	341.	152.	246.	246.	233.	233.	233.	233.	233.	233.	10.	10.	10.	16.	3.	16.	16.	16.	16.
.17	Va41p460.a	.60	20.	20.	50.	50.	50.	50.	50.	50.	50.	64.	178.	178.	375.	375.	371.	371.	371.	371.	371.	63.	63.	277.	277.	263.	263.	263.	263.	263.	17.	17.	20.	10.	16.	16.	16.	16.	16.
.18	Va41p461.a	.60	15.	15.	45.	45.	45.	45.	45.	45.	45.	58.	149.	149.	353.	353.	351.	351.	351.	351.	351.	54.	54.	255.	255.	242.	242.	242.	242.	242.	14.	14.	20.	10.	16.	16.	16.	16.	16.
.19	Va41p464.a	.60	25.	50.	50.	50.	50.	50.	50.	50.	50.	54.	270.	379.	379.	377.	377.	377.	377.	377.	377.	183.	278.	282.	272.	272.	272.	272.	272.	272.	9.	20.	19.	5.	16.	16.	16.	16.	16.
.20	Va41p475.a	.60	15.	15.	50.	50.	50.	50.	50.	50.	50.	65.	183.	183.	380.	380.	374.	374.	374.	374.	374.	59.	59.	286.	286.	268.	268.	268.	268.	268.	19.	19.	14.	14.	16.	16.	16.	16.	16.
.21	Va41p486.b	.60	20.	20.	40.	40.	40.	40.	40.	40.	40.	57.	247.	247.	335.	335.	330.	330.	330.	330.	330.	150.	150.	242.	242.	225.	225.	225.	225.	225.	12.	13.	14.	19.	16.	16.	16.	16.	16.
.22	We12p479.a	.40	15.	15.	30.	30.	30.	30.	30.	30.	30.	39.	173.	173.	291.	291.	291.	291.	291.	291.	291.	60.	60.	190.	190.	190.	190.	190.	190.	190.	17.	17.	5.	15.	15.	15.	15.	15.	15.
.23	We13p492.a	.50	20.	20.	40.	40.	40.	40.	40.	40.	40.	40.	246.	246.	334.	330.	330.	330.	330.	330.	330.	150.	150.	237.	218.	218.	218.	218.	218.	218.	17.	17.	6.	17.	17.	17.	17.	17.	17.
.24	We13p494.a	.50	15.	15.	45.	45.	45.	45.	45.	45.	45.	57.	188.	188.	357.	363.	363.	363.	363.	363.	363.	68.	68.	259.	273.	273.	273.	273.	273.	273.	18.	24.	15.	14.	14.	14.	14.	14.	14.
.25	We13p496.a	.50	15.	15.	45.	45.	45.	45.	45.	45.	45.	50.	227.	227.	358.	358.	358.	358.	358.	358.	358.	121.	121.	264.	264.	264.	264.	264.	264.	264.	16.	16.	12.	6.	14.	14.	14.	14.	14.
.26	No soil used																																						

5.3 TESTING OF TECHNIQUES USED IN ESTABLISHING SPATIALLY DISTRIBUTED WEATHER DATA BASE

5.3.1 Interpolation techniques for daily temperature values

The De Launay tessellation (Watson, 1982; Lee and Lin (1986)), trend surface analysis (Davis, 1973; Schulze, 1981) and ordinary kriging (van Tonder, 1982) interpolation techniques were compared for obtaining spatially distributed daily maximum and minimum temperatures, as described in Section 4.5.2 of Chapter 4.

Temperature data from the 1992/1993 summer growing season (September to May) were used to evaluate the techniques. Alternate months were used starting with September '92 and ending with May '93. All 89 ISCW weather stations (Fig 3.5) were used for initial evaluation, with no separation done on the basis of geographic location. Linear regression analysis was performed between measured and interpolated values. Measured and interpolated pairs were compared at five day intervals in every month. The results of the regression analyses are shown in Table 5.6.

Table 5.6 Coefficients of determination (r^2) from linear regression analysis of measured and interpolated temperatures

Maximum temperature interpolation				
MONTH	n	KRIG	TREND	DELAU
JAN	732	0.80490	0.65412	0.65194
MAR	732	0.63689	0.45805	0.40929
MAY	732	0.68741	0.57509	0.51560
NOV	732	0.79524	0.57755	0.51406
SEP	732	0.52488	0.63390	0.41309
Minimum temperature interpolation				
MONTH	n	KRIG	TREND	DELAU
JAN	732	0.61301	0.45497	0.46316
MAR	732	0.34224	0.23638	0.25009
MAY	732	0.71576	0.56367	0.49066
NOV	732	0.69769	0.58498	0.51825
SEP	732	0.66601	0.42604	0.45850

Interpolation technique:
KRIG = ORDINARY KRIGING
TREND = TREND SURFACE ANALYSIS
DELAU = DE LAUNAY TESSELLATION

From Table 5.6 it can be seen that ordinary kriging proved to be the best interpolation technique for both maximum and minimum temperatures, except for the temperature maxima in September. It was therefore decided to evaluate the kriging method further by grouping the ISCW stations according to the 1:250 000 topographical map sheet within which they lay (Fig 3.5). This was done for two reasons: i) the drought monitoring system uses the 1:250 000 map sheet as base unit, and, (ii) the effect of topography could then more easily be evaluated. The 2928 DRAKENSBERG map sheet for instance covers a very mountainous area.

Pearson product-moment correlation analysis and paired t-testing was used in the statistical evaluation of the measured and interpolated pairs on the various map sheets. The results of these analyses are shown in Tables 5.7 and 5.8, respectively.

Table 5.7 Statistical analysis of measured maximum temperatures and values interpolated by ordinary kriging per 1:250 000 map sheet

MAP = 1:250 000 Map sheet
MMEAS = MEAN OF MEASURED DATA
MINTER = MEAN OF INTERPOLATED DATA
CORR = CORRELATION COEFFICIENT

MAP	MNTH	n	MMEAS	MINTER	CORR
2428	JAN	40	31.06	31.10	0.92560
2430	JAN	31	28.65	28.66	0.65840
2526	JAN	24	31.05	30.72	0.84630
2528	JAN	32	31.16	29.80	0.93350
2530	JAN	63	28.85	28.42	0.89970
2626	JAN	71	30.80	31.00	0.86400
2628	JAN	40	27.53	28.36	0.89270
2630	JAN	8	24.30	27.93	0.94980
2726	JAN	40	31.91	31.74	0.93470
2728	JAN	16	30.21	28.76	0.87380
2730	JAN	32	28.14	28.83	0.90480
2826	JAN	60	32.14	32.06	0.96060
2828	JAN	64	28.40	28.20	0.92970
2830	JAN	40	28.85	27.82	0.83930
2926	JAN	16	31.74	32.59	0.92750
2928	JAN	76	25.62	26.81	0.84770
2930	JAN	79	26.81	27.65	0.94960
2428	MAR	40	26.75	27.13	0.89390
2430	MAR	32	27.36	25.10	0.75050
2526	MAR	16	27.49	26.03	0.97820
2528	MAR	32	26.26	24.69	0.96580
2530	MAR	57	26.25	25.30	0.87580
2628	MAR	32	22.51	23.60	0.98230
2630	MAR	8	22.02	24.32	0.96240
2726	MAR	8	27.15	27.18	0.98050
2730	MAR	32	25.14	26.13	0.84280
2826	MAR	24	27.81	27.35	0.98300
2828	MAR	31	26.19	25.53	0.87830
2830	MAR	40	26.94	26.34	0.68680
2926	MAR	8	25.63	26.67	0.27440
2928	MAR	77	23.90	25.64	0.77840
2930	MAR	80	25.54	27.11	0.66400
2428	NOV	40	27.87	27.58	0.86040
2430	NOV	32	28.16	26.61	0.80550
2526	NOV	31	26.26	25.69	0.95090
2528	NOV	32	27.46	26.04	0.94860
2530	NOV	62	27.29	27.15	0.77450
2626	NOV	72	25.36	25.31	0.90600
2628	NOV	40	23.70	24.54	0.88140
2630	NOV	8	22.80	25.38	0.94510
2726	NOV	40	25.43	25.07	0.96140
2728	NOV	16	24.27	23.80	0.84430
2730	NOV	32	25.18	25.67	0.86510
2826	NOV	62	24.04	24.85	0.88840
2828	NOV	69	23.67	24.59	0.87830
2830	NOV	40	25.91	25.18	0.87090
2926	NOV	16	23.53	24.40	0.91840
2928	NOV	73	22.32	23.95	0.93080
2930	NOV	80	23.93	24.97	0.95990
2428	SEP	40	30.76	30.28	0.39790
2430	SEP	32	28.14	28.54	0.84910
2526	SEP	32	30.04	29.31	0.69120
2528	SEP	32	30.20	28.52	0.81540
2530	SEP	61	27.10	28.74	0.89840
2626	SEP	71	28.88	28.36	0.57680
2628	SEP	40	27.33	27.01	0.78120
2630	SEP	8	24.16	27.08	0.91210
2726	SEP	40	29.38	28.43	0.78500
2728	SEP	16	27.83	26.61	0.82780
2730	SEP	32	25.99	24.67	0.51660
2826	SEP	64	26.66	27.24	0.90490
2828	SEP	66	25.05	24.30	0.56250
2830	SEP	38	26.72	24.43	0.74840
2926	SEP	16	25.70	26.41	0.85210
2928	SEP	80	22.94	22.45	0.34270
2930	SEP	78	24.66	24.76	0.88380
2428	MAY	40	26.48	26.58	0.91100
2430	MAY	32	26.92	26.20	0.72930
2526	MAY	24	24.81	25.24	0.83240
2528	MAY	32	25.79	25.40	0.91890
2530	MAY	62	26.02	25.81	0.73950
2626	MAY	72	24.33	24.32	0.93060
2628	MAY	40	22.29	22.85	0.79950
2630	MAY	8	21.58	23.62	0.88340
2726	MAY	40	24.49	23.83	0.97860
2728	MAY	16	23.04	21.75	0.91340
2730	MAY	30	23.76	24.28	0.56670
2826	MAY	64	22.51	22.51	0.97410
2828	MAY	55	22.18	22.08	0.87800
2830	MAY	40	24.45	24.56	0.83430
2926	MAY	15	21.19	21.81	0.93530
2928	MAY	80	21.57	21.98	0.55540
2930	MAY	77	23.42	24 73	0.69830

Table 5.8 Statistical analysis of measured minimum temperatures and values interpolated by ordinary kriging per 1:250 000 map sheet

MAP = 1:250 000 Map sheet
MMEAS = MEAN OF MEASURED DATA
MINTER = MEAN OF INTERPOLATED DATA
CORR = CORRELATION COEFFICIENT

MAP	MNTH	n	MMEAS	MINTER	CORR
2428	JAN	40	18.46	18.28	0.68130
2430	JAN	32	17.80	18.04	0.57240
2526	JAN	24	17.39	17.19	0.81600
2528	JAN	32	18.29	16.75	0.84010
2530	JAN	63	18.77	17.98	0.86420
2626	JAN	71	16.14	16.09	0.74400
2628	JAN	40	14.29	15.43	0.83200
2630	JAN	8	12.61	16.51	0.80670
2726	JAN	40	15.98	15.92	0.90460
2728	JAN	16	14.76	14.73	0.58330
2730	JAN	31	16.17	16.92	0.73140
2826	JAN	62	14.66	15.44	0.83780
2828	JAN	64	15.16	14.68	0.69080
2830	JAN	40	17.10	16.91	0.74480
2926	JAN	16	13.78	14.41	0.74880
2928	JAN	78	12.72	14.87	0.73020
2930	JAN	75	15.79	17.47	0.84760
2428	MAR	40	15.14	15.55	0.69970
2430	MAR	32	15.30	15.68	0.55810
2526	MAR	16	15.35	14.74	0.78360
2528	MAR	32	14.61	14.08	0.60220
2530	MAR	55	16.51	15.70	0.50070
2628	MAR	32	11.04	12.93	0.55900
2630	MAR	8	10.66	13.45	0.83280
2726	MAR	8	12.99	13.79	0.93350
2730	MAR	27	14.15	15.24	0.75750
2826	MAR	24	12.98	13.03	0.94440
2828	MAR	29	14.01	12.33	0.80050
2830	MAR	40	15.28	15.33	0.76990
2926	MAR	7	10.04	11.75	0.88800
2928	MAR	76	10.78	13.32	0.66510
2930	MAR	80	13.12	16.53	0.40280
2428	NOV	40	15.10	15.78	0.66240
2430	NOV	32	16.48	16.79	0.75110
2526	NOV	31	14.11	14.05	0.68140
2528	NOV	32	14.77	14.35	0.77770
2530	NOV	63	16.83	16.66	0.79170
2626	NOV	72	12.45	12.88	0.77830
2628	NOV	40	11.86	12.37	0.64420
2630	NOV	8	11.60	13.72	0.59360
2726	NOV	40	12.35	12.12	0.90900
2728	NOV	16	11.20	11.66	0.76390
2730	NOV	32	13.48	14.14	0.56570
2826	NOV	63	10.71	11.23	0.89670
2828	NOV	69	11.58	11.92	0.67940
2830	NOV	40	14.64	14.36	0.66930
2926	NOV	16	10.66	10.43	0.81890
2928	NOV	72	10.25	11.99	0.80420
2930	NOV	80	12.99	14.74	0.84580
2428	SEP	40	14.35	14.29	0.67840
2430	SEP	32	13.96	14.84	0.77840
2526	SEP	32	11.66	13.52	0.56500
2528	SEP	32	12.81	13.35	0.80290
2530	SEP	61	13.74	14.42	0.73780
2626	SEP	71	12.74	12.31	0.79680
2628	SEP	40	10.00	11.37	0.68810
2630	SEP	8	10.69	12.31	0.66710
2726	SEP	40	11.22	10.84	0.87710
2728	SEP	16	9.58	9.64	0.92000
2730	SEP	32	12.02	12.03	0.70190
2826	SEP	64	9.07	8.78	0.00000
2828	SEP	66	9.70	9.03	0.71680
2830	SEP	38	12.82	12.24	0.76710
2926	SEP	16	8.08	7.79	0.62870
2928	SEP	80	7.57	8.93	0.82490
2930	SEP	78	11.03	11.98	0.81310
2428	MAY	40	8.61	8.81	0.80440
2430	MAY	32	11.52	11.75	0.48570
2526	MAY	24	5.88	6.83	0.91390
2528	MAY	32	7.58	7.45	0.76640
2530	MAY	63	11.08	11.09	0.72170
2626	MAY	71	4.48	5.27	0.88850
2628	MAY	40	2.70	5.40	0.81580
2630	MAY	8	6.14	7.89	0.61840
2726	MAY	40	3.21	4.38	0.90450
2728	MAY	16	1.42	2.54	0.84970
2730	MAY	30	8.06	8.50	0.92250
2826	MAY	63	1.30	2.98	0.74550
2828	MAY	55	4.92	3.48	0.55920
2830	MAY	40	9.08	9.46	0.81570
2926	MAY	15	0.79	2.58	0.08760
2928	MAY	80	5.13	6.85	0.57170
2930	MAY	76	9.37	10.75	0.67710

The frequency distribution of absolute difference between measured and interpolated values was determined for all 1:250 000 map sheets and for the three map sheets used in the study (Fig 5.6 & Fig 5.7). In all cases, at least 80% of the interpolated maxima were within three degrees of the measured values. In all cases, at least 75% of the interpolated minima were within three degrees of the measured values.

In order to examine absolute differences greater than 5 °C a table was drawn up listing the five SAWB weather stations closest to each of the ISCW weather stations. The temperature values recorded by the SAWB and ISCW were then compared. Thermohygrograph charts of the ISCW stations were obtained. In one instance at a station shared by the two institutions digits of the measured maximum value were swopped by the SAWB observer (ie 12 instead of 21). As the SAWB data are used in the interpolation process a 9 °C absolute difference occurred between the measured and observed values.

At ISCW station 19672, the thermohygrograph chart and original records differed considerably from the data base values used in the comparisons. It appears that data from another ISCW station had been overwritten on that of station 19672. The measured minimum temperature value used in the comparison was 3.1 °C and should have been 17 °C. This resulted in an absolute difference of 17 °C occurring when it was, in fact, only 2 °C.

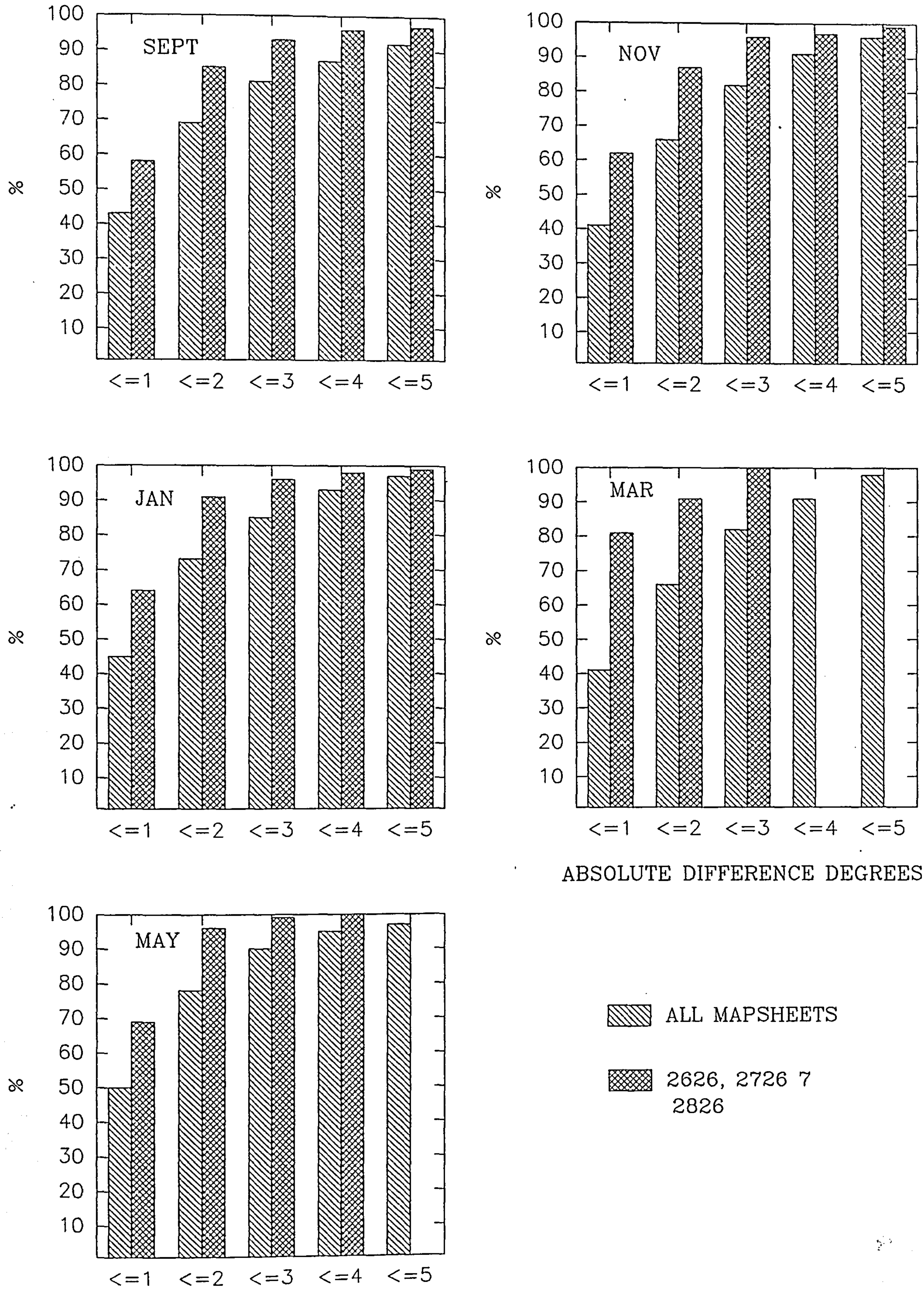

Figure 5.6 Frequency distribution of absolute difference between measured and interpolated maximum temperatures

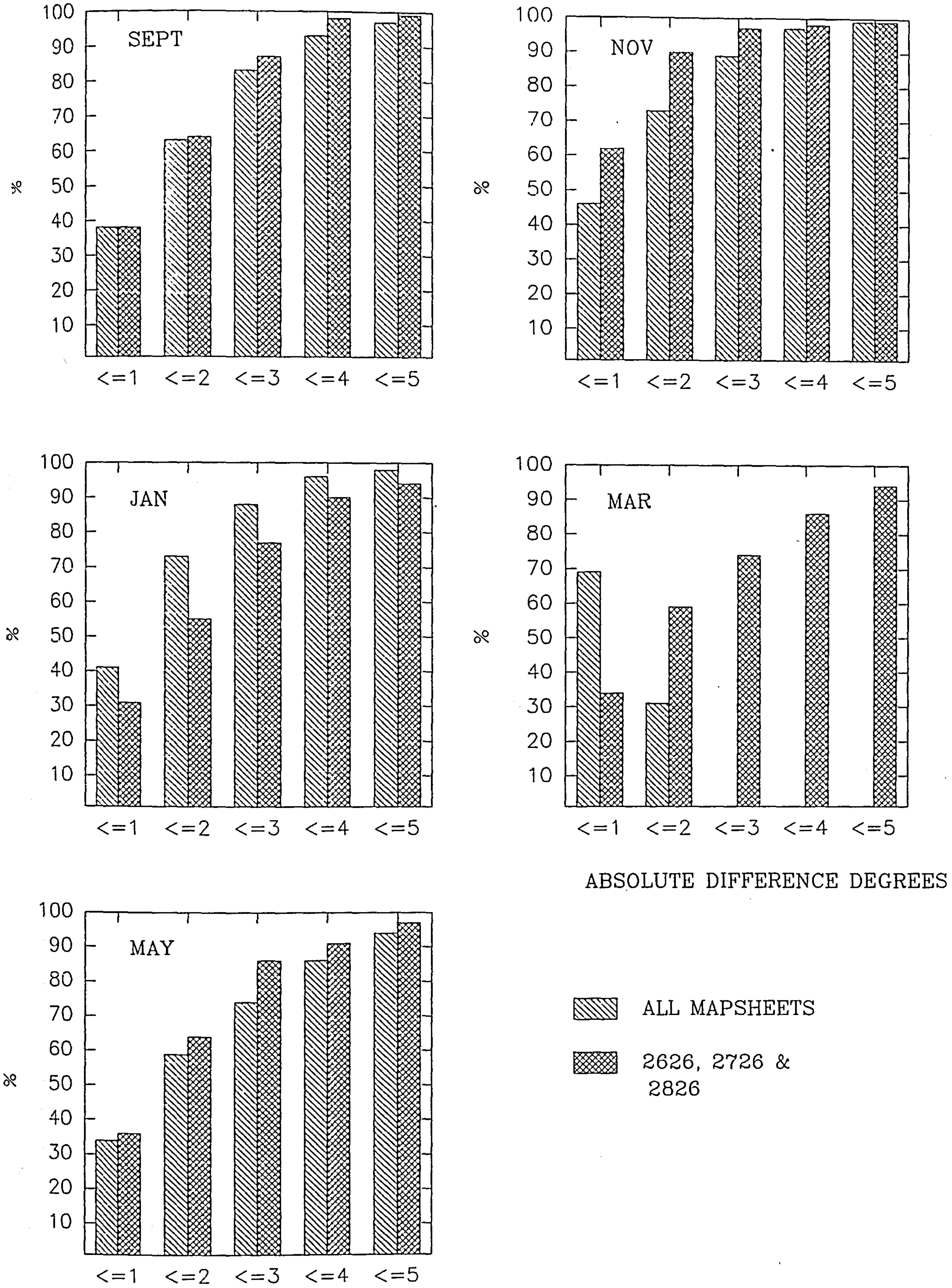

Figure 5.7 Frequency distribution of absolute difference between measured and interpolated minimum temperatures

It would appear that many of the large absolute differences especially between measured and interpolated minima, could be accounted for by the effect of topography. Topography was not taken into account in applying the ordinary kriging interpolation technique. Phenomena such as localised temperature inversions, if they occurred on a particular day, would therefore not have been detected.

5.3.2 Estimation of total radiant flux density from METEOSAT weather satellite imagery

Daily radiant flux density estimated from METEOSAT visible band data using the modified Nunez (1987 & 1990) model was compared with measured data from 16 weather stations (Fig 3.6, Table 5.9). The comparisons were made for the time period November 1992 to June 1993.

The result of statistical analysis performed on measured and satellite estimated irradiance is shown in Table 5.10. The frequency distribution of absolute difference is shown in Table 5.11. The small number of comparisons for January 1993 is due to failure of the archiving equipment for most of the month. An example of a daily irradiance map is shown in Figure 5.8.

Figure 5.8 Daily irradiance over South Africa, Lesotho and Swaziland on 5 January 1993, obtained from the empirical model applied to METEOSAT visible band data.

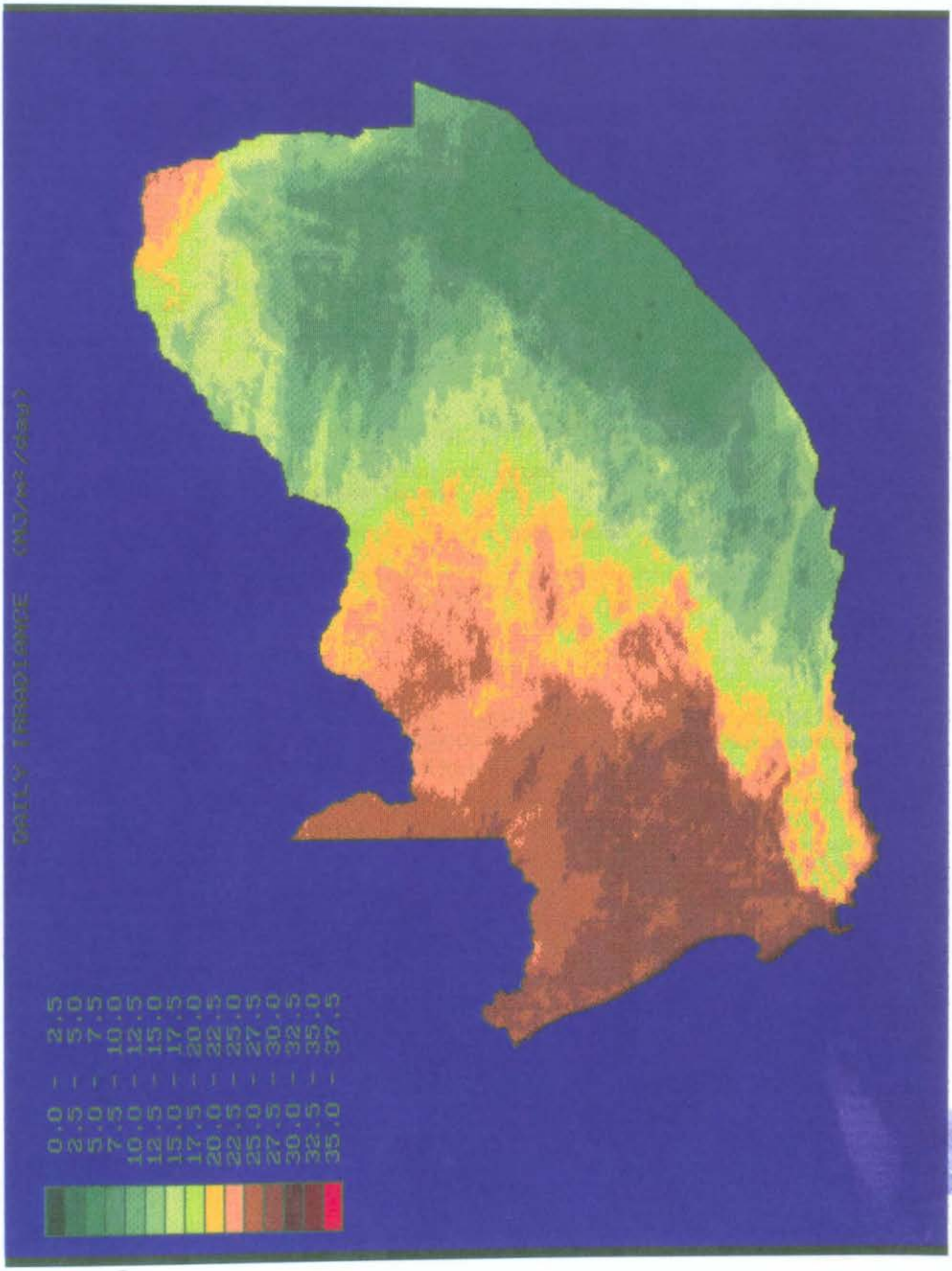

Table 5.9 Location of weather stations measuring daily radiation flux density

Station	Latitude	Longitude	Elevation
1 ISCW Rietrivier	29° 3'S	24° 38'E	1140 m
2 ISCW Ficksburg	28° 52'S	27° 51'E	1640 m
3 ISCW Glen	28° 57'S	26° 20'E	1304 m
4 ISCW Vaalharts	27° 57'S	24° 50'E	1175 m
5 ISCW De Keur	32° 58'S	19° 18'E	722 m
6 ISCW Langkloof	32° 58'S	19° 18'E	945 m
7 Dept Agmet UOFS	29° 6'S	26° 11'E	1424 m
8 SAWB Upington (*)	28° 24'S	21° 16'E	836 m
9 SAWB Cape Town (*)	33° 59'S	18° 36'E	18 m
10 SAWB Pretoria (*)	25° 44'S	28° 11'E	1330 m
11 ISCW Robertson	33° 50'S	19° 54'E	156 m
12 ISCW Langgewens	33° 17'S	18° 42'E	177 m
13 ISCW Elsenburg	33° 51'S	18° 50'E	177 m
14 Dept Agmet Karkloof	29° 23'S	30° 14'E	1093 m
15 Dept Agmet Winterton	28° 50'S	29° 32'E	1060 m
16 Dept Agmet Reitz	27° 48'S	28° 26'E	1615 m

<u>Weather Stations of:</u>

Dept Agmet = Department of Agrometeorology, University of the Orange Free State
ISCW = Institute for Soil Climate and water
SAWB = South African Weather Bureau

(*) = Weather stations used to obtain regression coefficients

Table 5.10 Comparison of daily total radiant flux density estimated from METEOSAT data with measurements at the earth's surface

Year	Month	No. of pairs	Intercept	Slope	r^2	Root mean square error ($MJ\ m^{-2}\ d^{-1}$)	Mean absolute difference ($MJ\ m^{-2}\ d^{1}$)
1992	January	274	7.06	0.84	0.88	2.57	2.32
	November	262	11.78	0.64	0.79	2.32	1.93
	December	361	6.13	0.79	0.74	2.35	1.96
1993	January	136	2.04	0.88	0.92	2.02	1.59
	February	343	3.09	0.85	0.94	1.85	1.52
	March	403	3.56	0.81	0.88	1.62	1.28
	April	380	3.99	0.73	0.90	1.67	1.35
	May	404	3.82	0.69	0.88	1.32	1.08
	June	361	3.81	0.65	0.88	1.31	1.08

Table 5.11 Frequency distribution of absolute difference (%) for R_s computed from METEOSAT data and R_s measured.

Range of absolute difference (%)	November 1992 (%)	December 1992 (%)	January 1993 (%)	February 1993 (%)	March 1993 (%)	April 1993 (%)	May 1993 (%)	June 1993 (%)
0 - 10	74.4	72.1	80.1	76.3	77.5	63.2	70.3	64.5
>10 - 20	21.6	23.9	18.2	17.1	18.3	23.1	22.0	29.1
>20 - 30	3.4	3.8	1.7	2.9	2.4	6.9	2.8	3.6
>30 - 40	0.6	0.2		1.0	0.3	3.2	1.5	1.1
>40 - 50				0.5	0.6	1.3	1.5	0.3
>50 - 60				1.5	0.4	0.5	0.3	0.8
>60 - 70				0.7	0.5		0.3	0.3
>70 - 80						1.3	0.7	0.3
>80 - 90						0.5	0.6	
>90 - 100								

From Tables 5.10 and 5.11 it is apparent that for all months, over 90% of estimated irradiance was within 20% of the measured value. In comparing estimated daily transmissivity with actual transmissivity it was found that the model tended to overestimate transmissivity under extremely cloudy conditions. This is evident in the high values obtained for the intercept in the regression analysis (Table 5.10). This may be due to the fact that there were relatively few cloudy days in December 1991 when the model was calibrated.

The technique has the advantage that it requires no additional data input other than atmospheric transmissivity to determine the empirical constants. It is easy to both establish and apply the regression model. The constants obtained in December 1991 did not have to be altered for use in other months. Slightly more than 20 minutes computer time is required to calculate daily irradiance over the entire country on a 2′ x 2′ basis.

5.4 DETERMINATION OF THE MAIZE YIELD CUMULATIVE DISTRIBUTION FUNCTIONS

Three steps were involved in the determination of the CDF's. The accuracy of the rainfall data generator was first evaluated to determine whether it provided realistic sets of rainfall data for each homogeneous climate zone. Secondly; the method of selection of temperature and sunshine duration data, to combine with the generated rainfall data was examined. More specifically, the need to distinguish between days on which rainfall occurred, or did not occur, was examined. Thirdly; the CDF's were determined using the data sets constructed.

5.4.1 Evaluation of the daily rainfall data generator

Daily rainfall data were generated for a 100 year period using the Zucchini and Adamson (1984) algorithm and parameters as described in Section 4.6.1 of Chapter 4. The process was repeated for each of the 66 homogeneous climate zones within the bounds of the three map sheets. The following statistics were determined for each set of generated data:

a) mean annual precipitation (MAP),
b) number of raindays per month,
c) mean monthly rainfall,
d) median monthly rainfall,
e) standard deviation,
f) coefficient of variation, and,
g) skewness.

These statistics were also obtained for measured data from the rainfall stations chosen by Dent *et al.* (1988) to represent each homogeneous climate zone. The comparison of MAP is shown in Table 5.12, while the remaining statistics are listed in Appendix B. Linear regression analysis was performed on each category of measured and generated data eg. Generated data MAP vs Measured data MAP. The coefficients of determination obtained for each category are given in Table 5.13.

Table 5.12 Comparison of Mean Annual Precipitation (MAP) obtained from measured and generated rainfall

HOMOGENEOUS CLIMATE ZONE	MAP MEASURED DATA	MAP GENERATED DATA
319	367.7	383.13
327	473.6	465.88
331	491.7	503.16
332	546.7	532.77
333	475.4	495.48
334	539.7	531.03
340	615.4	612.99
341	506.9	533.27
342	506.9	583.67
343	499.8	493.92
344	547.3	541.56
345	626.6	598.59
346	529.3	503.19
347	477.2	482.15
348	617.5	619.77
349	669.5	654.96
351	776.5	819.71
353	739.9	759.17
354	790.1	790.98
355	689.0	651.97
448	441.3	435.42
458	602.3	596.64
459	550.4	581.49
460	515.6	521.26
461	514.1	519.58
462	484.3	494.95
463	463.5	455.61
464	545.1	562.54
465	524.3	518.79
466	598.2	578.75
467	548.7	542.85
468	578.1	592.31
469	589.0	589.68
470	558.7	564.96
471	483.0	461.15
472	639.2	636.31
473	483.6	473.76
474	575.9	582.70
475	656.3	619.91
476	608.2	627.82
477	620.2	615.67
478	645.0	657.34
479	597.2	595.42
480	527.9	533.59
481	593.0	566.95
482	656.4	654.77
483	553.1	554.00
484	597.6	595.03
485	687.4	685.14
486	587.4	585.21
487	612.6	627.34
488	562.2	542.16
489	663.0	684.17
490	643.7	640.11
491	583.4	576.41
492	694.2	689.43
493	685.5	685.26
494	630.2	613.36
495	688.1	702.48
496	699.6	691.45
497	799.4	781.43
498	817.2	837.69
499	680.5	687.07
554	601.9	604.86
571	668.9	643.63
574	603.4	580.00

Table 5.13 Coefficients of determination (r^2) values from linear regression analysis of measured and generated rainfall data statistics obtained for 66 Homogeneous Climate Zones

STATISTIC	n	r^2
Mean Annual Precipitation	792	0.959
Number of raindays per month	792	0.973
Mean monthly rainfall	792	0.976
Median monthly rainfall	792	0.965
Standard deviation	792	0.868
Coefficient of variation	792	0.866
Skewness in monthly totals	792	0.466

From Table 5.13 it can be seen that there is a high degree of agreement between the statistics obtained for the measured rainfall data and those from the generated data. The poorest agreement occurred between skewness values. Differences in skewness can be attributed to an inability in the rainfall data generator to simulate unusually high values such as those which may occur with cloud bursts or flash floods. The r^2 for skewness, although lower than the other categories, is still highly significant at the 95% confidence level.

5.4.2 Selection of weather elements for combining with generated rainfall data

Correlation analysis was performed on weather data from all 28 ISCW weather stations within the three map sheets (Fig 3.7). The correlation between daily rainfall and maximum temperature, daily rainfall and minimum temperature, and daily rainfall and sunshine duration, was determined. The trend at all 28 stations was identical with low correlations occurring for each comparison.

The correlation coefficients obtained at one of the ISCW Stations is shown in Table 5.14.

Table 5.14 Correlation coefficients (r) between rainfall and other elements at one ISCW station in the study area

MONTH	RAINFALL & MAXIMUM TEMP.	RAINFALL & MINIMUM TEMP.	RAINFALL & SUNSHINE DURATION
JANUARY	0.2293	0.1871	0.3788
FEBRUARY	0.2005	0.2069	0.3696
MARCH	0.2020	0.1667	0.3585
APRIL	0.0938	0.2631	0.4171
MAY	0.1010	0.2486	0.3918
JUNE	0.1241	0.1975	0.3818
JULY	0.1546	0.2133	0.3938
AUGUST	0.2093	0.1962	0.4327
SEPTEMBER	0.2563	0.1609	0.4352
OCTOBER	0.2343	0.1749	0.4369
NOVEMBER	0.2358	0.1649	0.4217
DECEMBER	0.1828	0.1836	0.4134
ALL MONTHS	0.1853	0.1970	0.4026

The low correlation values meant that little benefit would have accrued in constructing weather data input files, using rain/ no-rain as a criterion for data selection. Thus, for each HCZ, the generated rainfall data were combined with daily temperature data and sunshine duration on a month by month basis, with the months chosen at random from the full data record of the ISCW station closest to the rainfall station representing the HCZ.

5.4.3 Median yields determined from the cumulative distribution functions

CDF's were determined using the procedure described in Section 4.6.1 of Chapter 4. Six hundred and thirty nine such median yields are listed in Appendix A. The median yields, in Appendix A, are recorded together with their associated homogeneous climate zone, soil type and planting date, which is based on magisterial district. The spatial distribution of the median yields is shown in Fig 5.8.

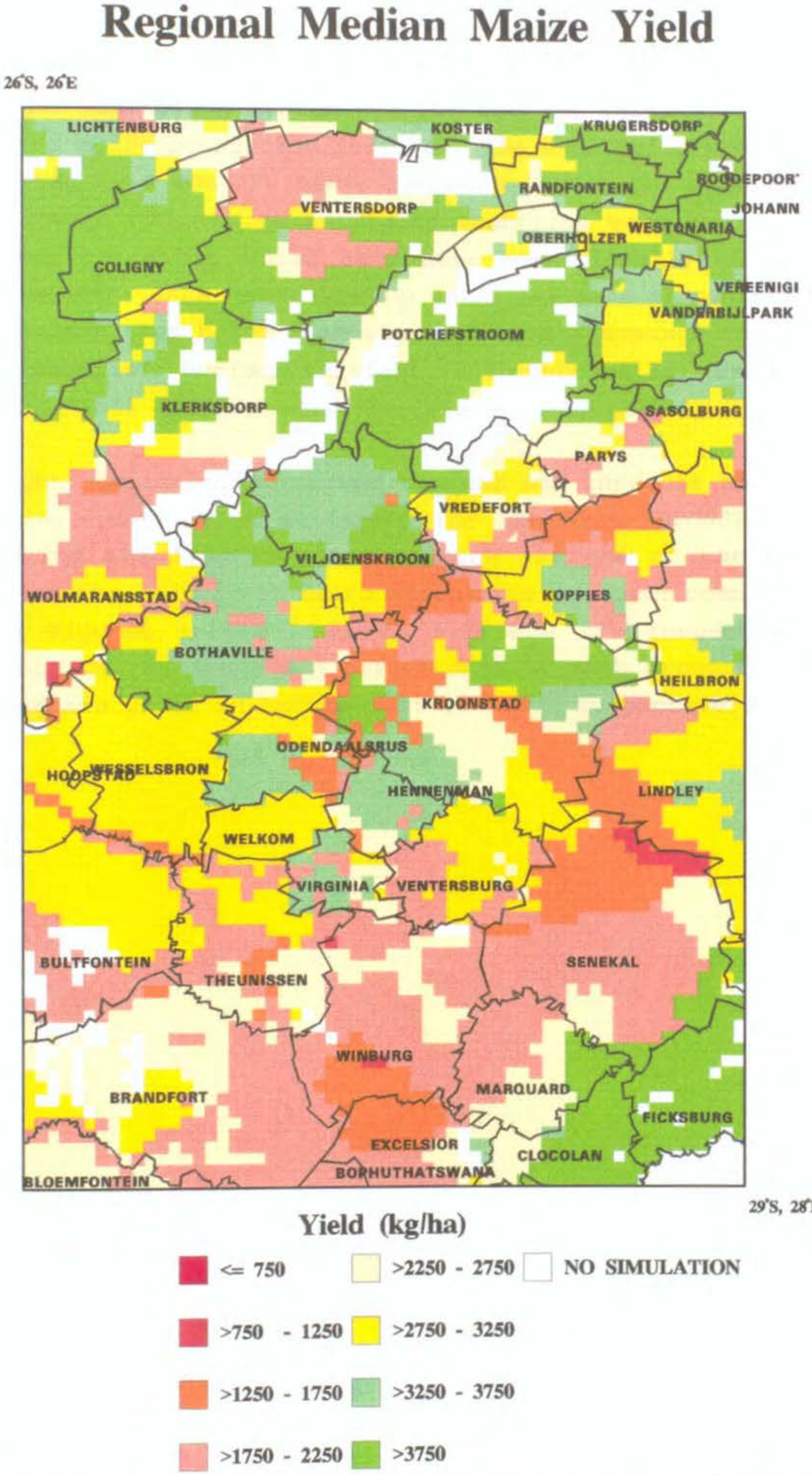

Figure 5.9 Median maize yield obtained from cumulative distribution functions determined for the study area

5.5 OPERATION OF THE DROUGHT MONITORING SYSTEM

The Drought Monitoring System was run for the 1988/89, 1991/92 and 1992/93 maize production seasons. The monitoring procedure was repeated on a monthly basis for each season for each 1:250 000 map sheet. All three surrogate scenarios were used. The system was run as it would have been operationally; i.e the observed weather data being used up until the date of monitoring and the season then being completed with below average rainfall (10th percentile), average rainfall (50th percentile) and above average rainfall (90th percentile) years, respectively.

The drought monitoring performed for one map sheet is shown as an example. Monitoring performed for the 2726 KROONSTAD map sheet during the 1991/92 season, which was one of the worst droughts of the century in South Africa (Laing, pers comm.[1]), is shown in Figures 5.10(a - c) to 5.14(a - c), respectively. Tabulations of the areas and percentages of each drought class on the map are given in Tables 5.15 to 5.19, respectively.

[1]M. Laing, Deputy Director, Climate Information, South African Weather Bureau.

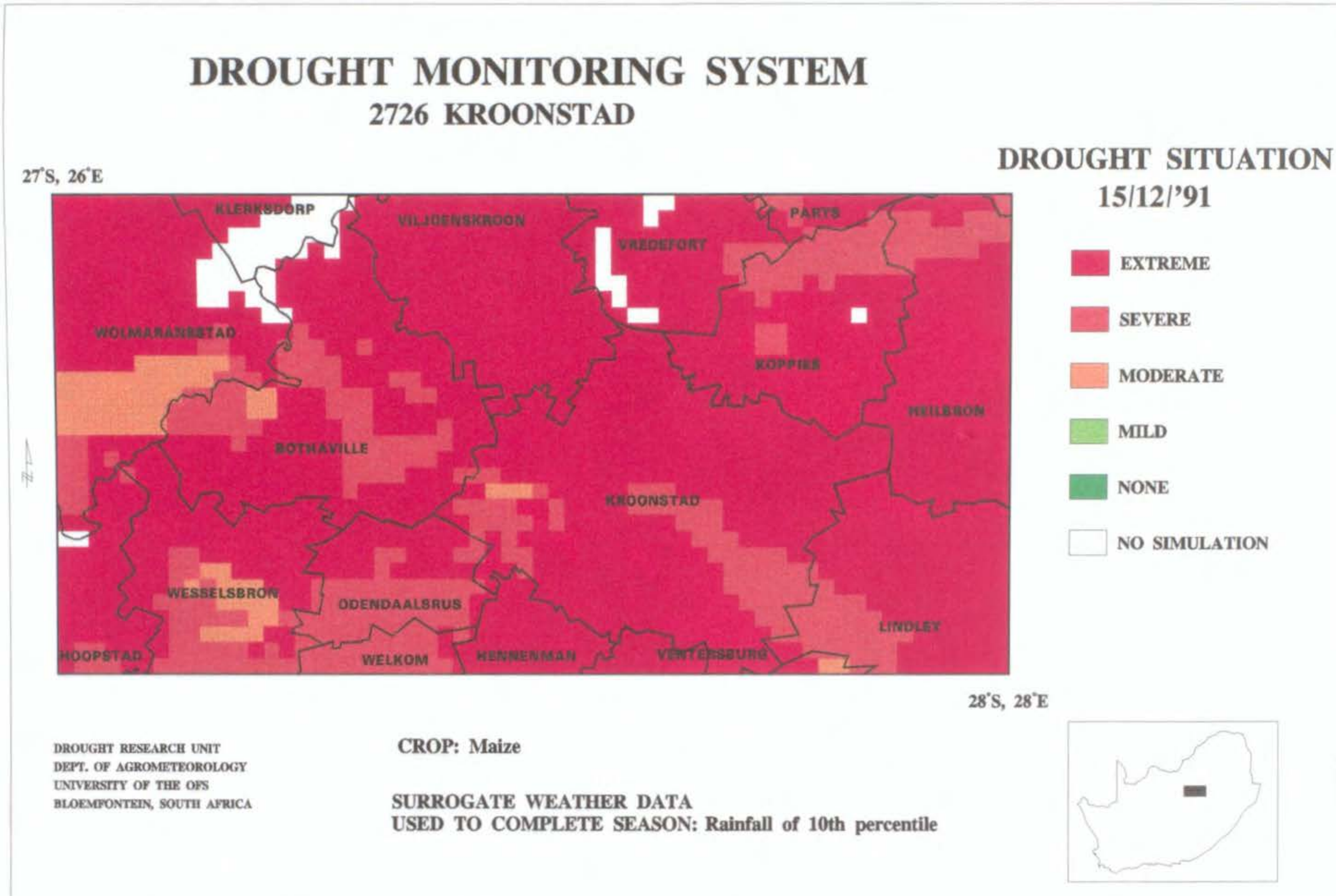

Figure 5.10a Drought map for 2726 KROONSTAD on 15/12/1991. Season completed with below average rainfall year.

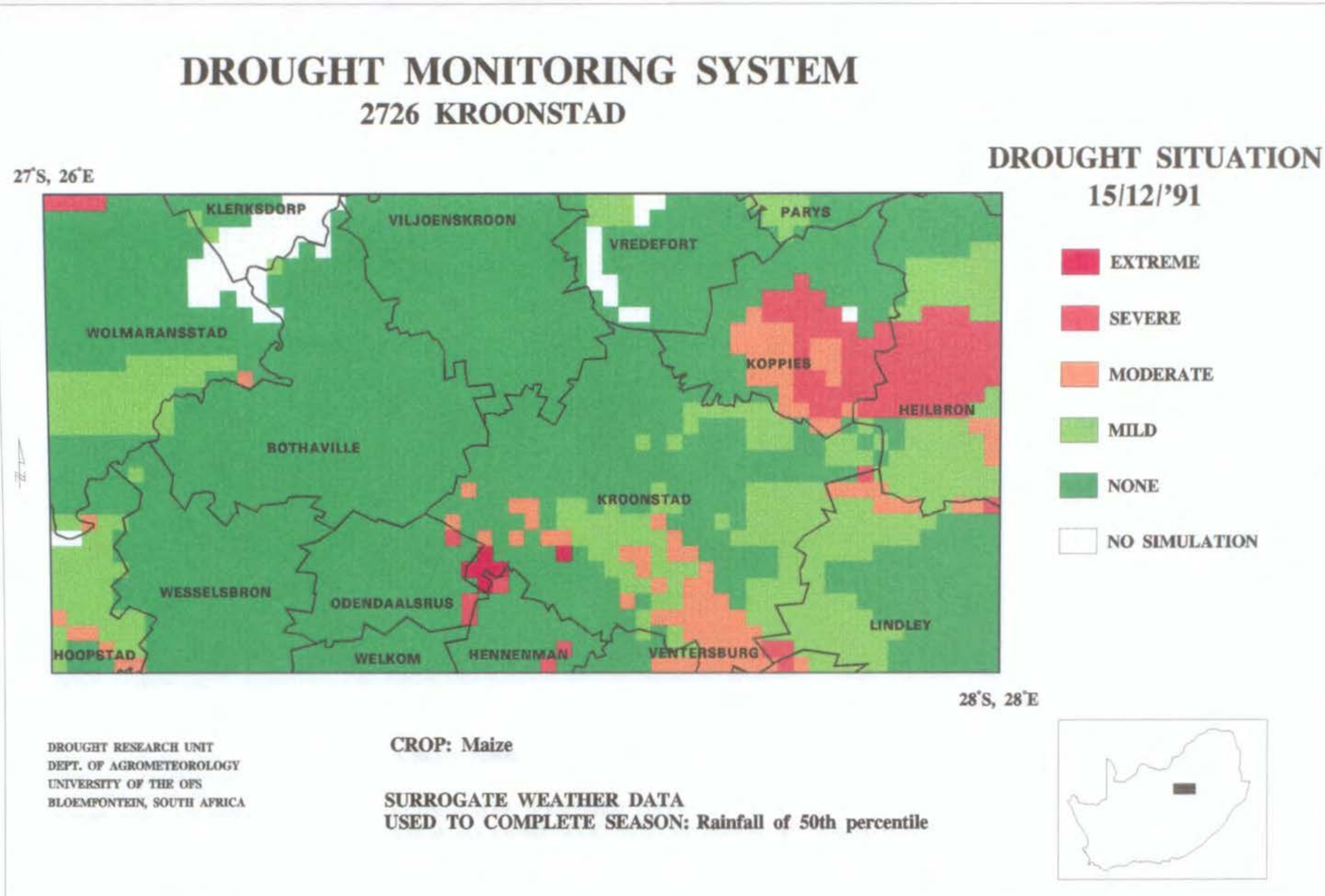

Figure 5.10b Drought map for 2726 KROONSTAD on 15/12/1991. Season completed with average rainfall year.

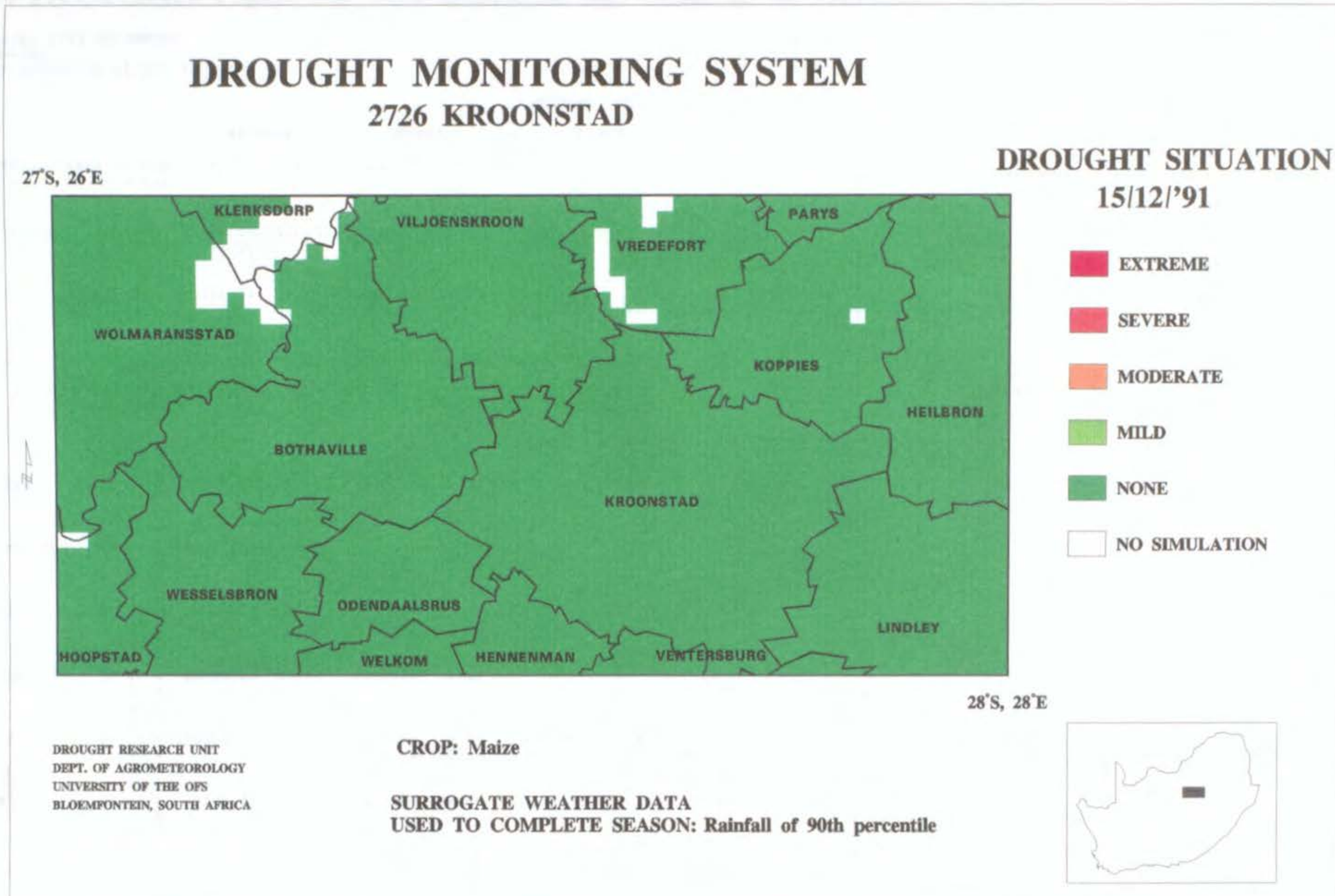

Figure 5.10c Drought map for 2726 KROONSTAD on 15/12/1991. Season completed with above average rainfall year.

Table 5.15 Drought report for 2726 KROONSTAD map sheet on 15/12/1991

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/12/'91

			DROUGHT CLASS											
			EXTREME		SEVERE		MODERATE		MILD		NONE		NO SIMULATION	
MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
ODENDAALSRUS	100	10 %	38993.07	44.45	48735.32	55.55	-	-	-	-	-	-	-	-
		50 %	684.01	.78	3061.12	3.49	240.66	.27	-	-	83743.02	95.46	-	-
		90 %	-	-	-	-	-	-	-	-	87729.27	100.00	-	-
KOPPIES	100	10 %	115468.02	74.42	38463.91	24.79	-	-	-	-	-	-	1219.45	.79
		50 %	-	-	41368.76	26.66	30903.57	19.92	1260.26	.81	80397.05	51.82	1219.45	.79
		90 %	-	-	-	-	-	-	-	-	153934.41	99.21	1219.45	.79
BOTHAVILLE	100	10 %	194692.38	69.63	72851.86	26.06	5385.69	1.93	-	-	-	-	6670.01	2.39
		50 %	-	-	-	-	41.78	.01	3858.83	1.38	269032.41	96.22	6667.97	2.38
		90 %	-	-	-	-	-	-	-	-	272931.91	97.62	6667.97	2.38
KROONSTAD	99	10 %	346522.25	82.89	67895.62	16.24	3645.89	.87	-	-	-	-	-	-
		50 %	5798.03	1.39	671.61	.16	52640.53	12.59	107892.73	25.81	251073.59	60.05	-	-
		90 %	-	-	-	-	-	-	-	-	418063.69	100.00	-	-
WESSELSBRON	89	10 %	91184.01	58.72	44705.82	28.79	19405.39	12.50	-	-	-	-	-	-
		50 %	-	-	-	-	212.00	.14	2754.73	1.77	152327.61	98.09	-	-
		90 %	-	-	-	-	-	-	-	-	155294.61	100.00	-	-
VILJOENSKROON	87	10 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
		50 %	-	-	-	-	-	-	32.25	.02	182301.41	99.80	340.77	.19
		90 %	-	-	-	-	-	-	-	-	182333.59	99.81	340.77	.19
HENNENMAN	80	10 %	45974.84	99.13	403.00	.87	-	-	-	-	-	-	-	-
		50 %	799.23	1.72	4157.61	8.96	-	-	-	-	41420.86	89.31	-	-
		90 %	-	-	-	-	-	-	-	-	46377.71	100.00	-	-
VREDEFORT	77	10 %	85324.23	80.69	7029.79	6.65	-	-	-	-	-	-	13395.68	12.67
		50 %	-	-	-	-	-	-	7859.29	7.43	84494.67	79.90	13395.68	12.67
		90 %	-	-	-	-	-	-	-	-	92353.99	87.33	13395.68	12.67
LINDLEY	59	10 %	135216.41	80.46	32633.60	19.42	214.46	.13	-	-	-	-	-	-
		50 %	-	-	3903.14	2.32	10019.02	5.96	61490.49	36.59	92651.94	55.13	-	-
		90 %	-	-	-	-	-	-	-	-	168064.70	100.00	-	-
WELKOM	54	10 %	3270.62	10.71	27271.07	89.29	-	-	-	-	-	-	-	-
		50 %	-	-	-	-	-	-	-	-	30542.11	100.00	-	-
		90 %	-	-	-	-	-	-	-	-	30538.37	100.00	-	-
HEILBRON	47	10 %	148012.50	85.96	24183.74	14.04	-	-	-	-	-	-	-	-
		50 %	-	-	56505.65	32.82	6374.71	3.70	71124.79	41.31	38188.59	22.18	-	-
		90 %	-	-	-	-	-	-	-	-	172196.70	100.00	-	-

Table 5.15 ctd

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/12/'91

MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	DROUGHT CLASS: EXTREME		SEVERE		MODERATE		MILD		NONE		NO SIMULATION	
			ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
WOLMARANSSTAD	47	10 %	147373.91	68.10	23266.40	10.75	45758.29	21.15	-	-	-	-	-	-
		50 %	-	-	4888.00	2.26	1600.23	.74	49593.33	22.92	160317.28	74.08	-	-
		90 %	-	-	-	-	-	-	-	-	216399.92	100.00	-	-
PARYS	22	10 %	15293.78	72.93	5675.93	27.07	-	-	-	-	-	-	-	-
		50 %	-	-	-	-	-	-	9066.29	43.23	11903.72	56.77	-	-
		90 %	-	-	-	-	-	-	-	-	20966.80	100.00	-	-
HOOPSTAD	19	10 %	58521.90	87.25	6975.13	10.40	-	-	-	-	-	-	1574.00	2.35
		50 %	-	-	-	-	7668.73	11.43	40095.25	59.78	17733.83	26.44	1574.00	2.35
		90 %	-	-	-	-	-	-	-	-	65496.75	97.65	1574.00	2.35
VENTERSBURG	14	10 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	-	-	-	-	3573.52	20.10	2259.30	12.71	11942.37	67.19	-	-
		90 %	-	-	-	-	-	-	-	-	17783.23	100.00	-	-
KLERKSDORP	12	10 %	15391.94	36.68	-	-	-	-	-	-	-	-	26572.51	63.32
		50 %	-	-	-	-	-	-	2185.67	5.21	13206.26	31.47	26571.23	63.32
		90 %	-	-	-	-	-	-	-	-	15391.94	36.68	26571.23	63.32
SASOLBURG	2	10 %	512.47	24.70	1562.46	75.30	-	-	-	-	-	-	-	-
		50 %	-	-	-	-	-	-	-	-	2074.95	100.00	-	-
		90 %	-	-	-	-	-	-	-	-	2074.95	100.00	-	-
SENEKAL	2	10 %	3092.81	43.52	1806.26	25.41	2208.28	31.07	-	-	-	-	-	-
		50 %	-	-	1149.57	16.17	1943.26	27.34	4014.57	56.48	-	-	-	-
		90 %	-	-	-	-	-	-	-	-	7107.37	100.00	-	-

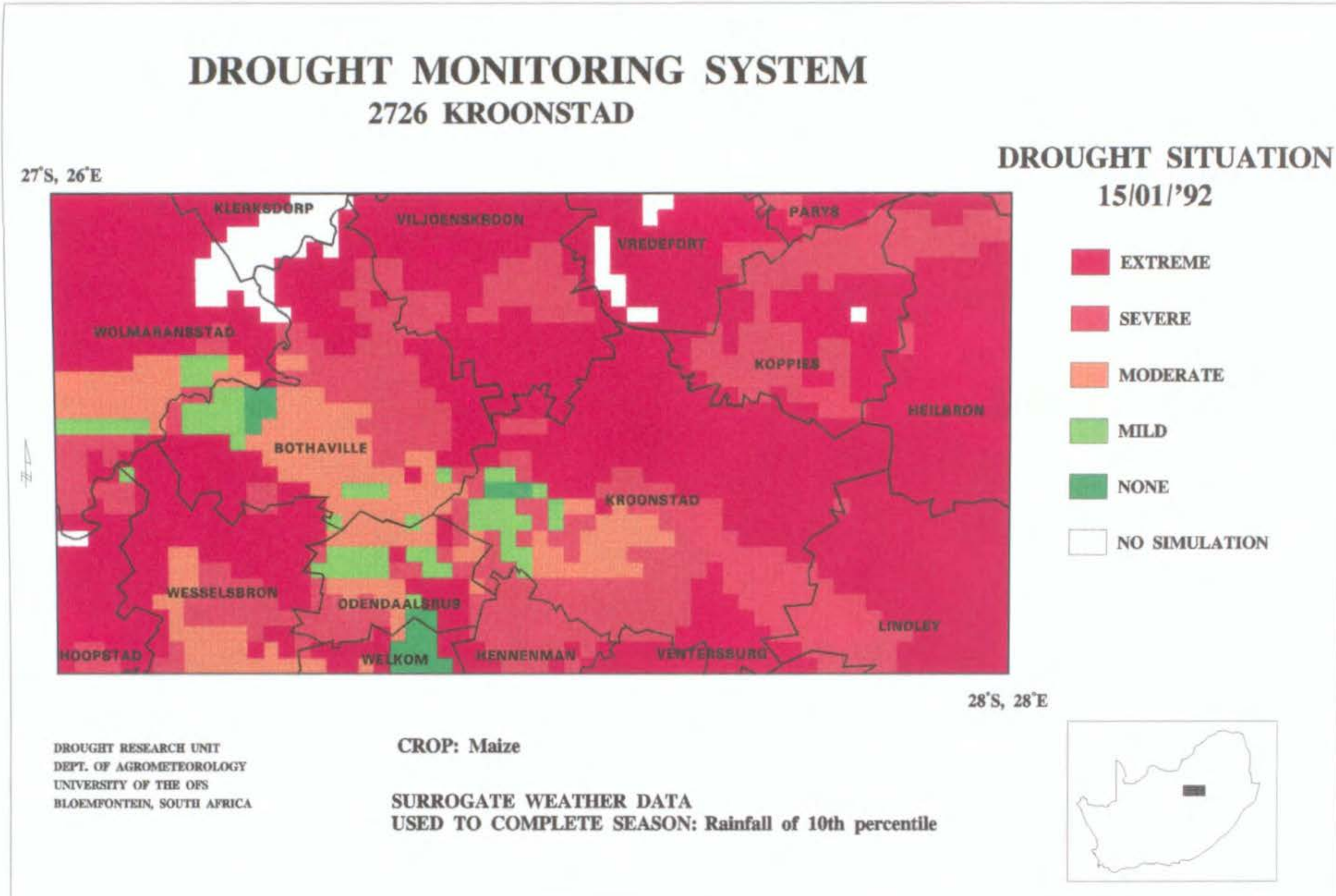

Figure 5.11a Drought map for 2726 KROONSTAD on 15/01/1992. Season completed with below average rainfall year.

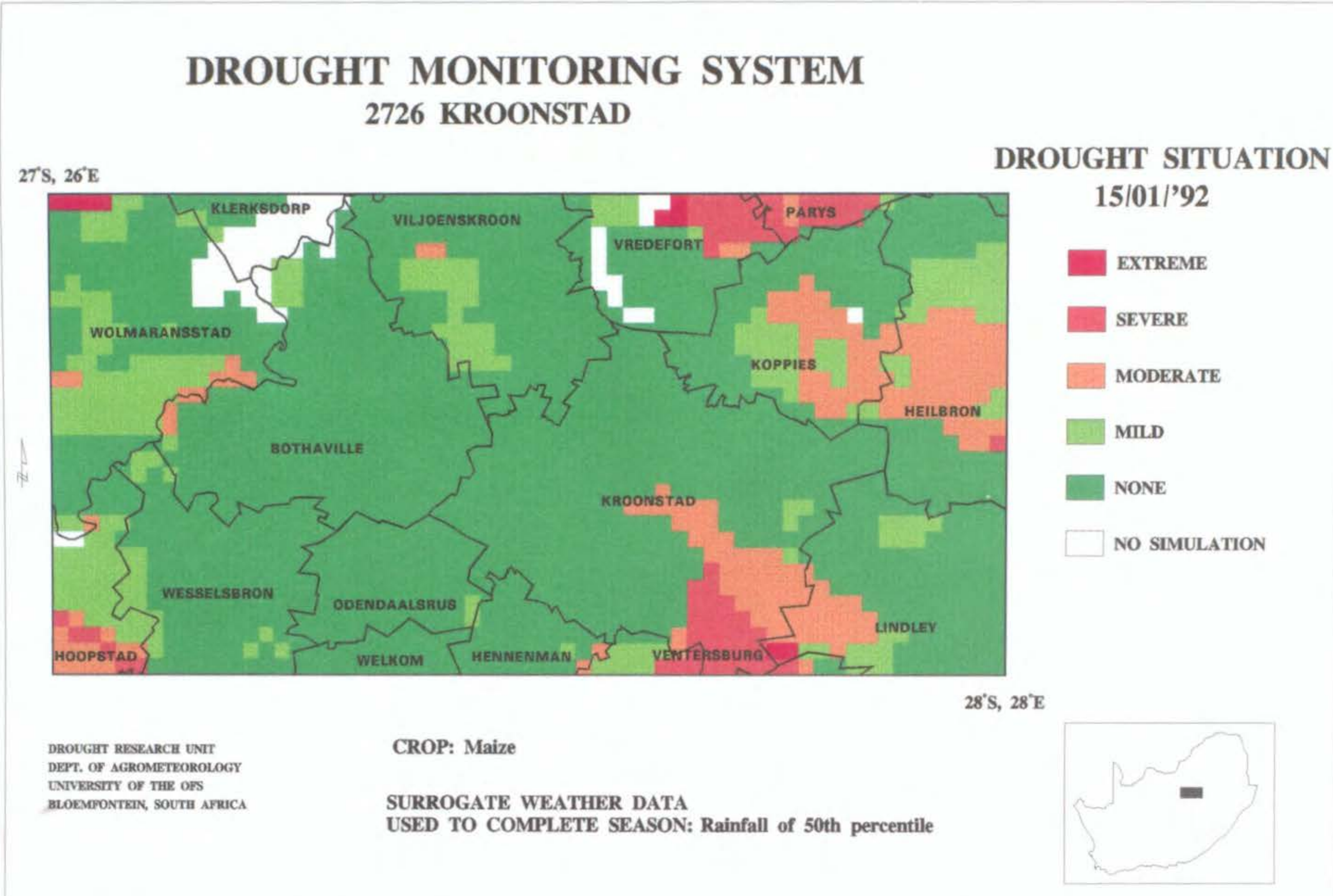

Figure 5.11b Drought map for 2726 KROONSTAD on 15/01/1992. Season completed with average rainfall year.

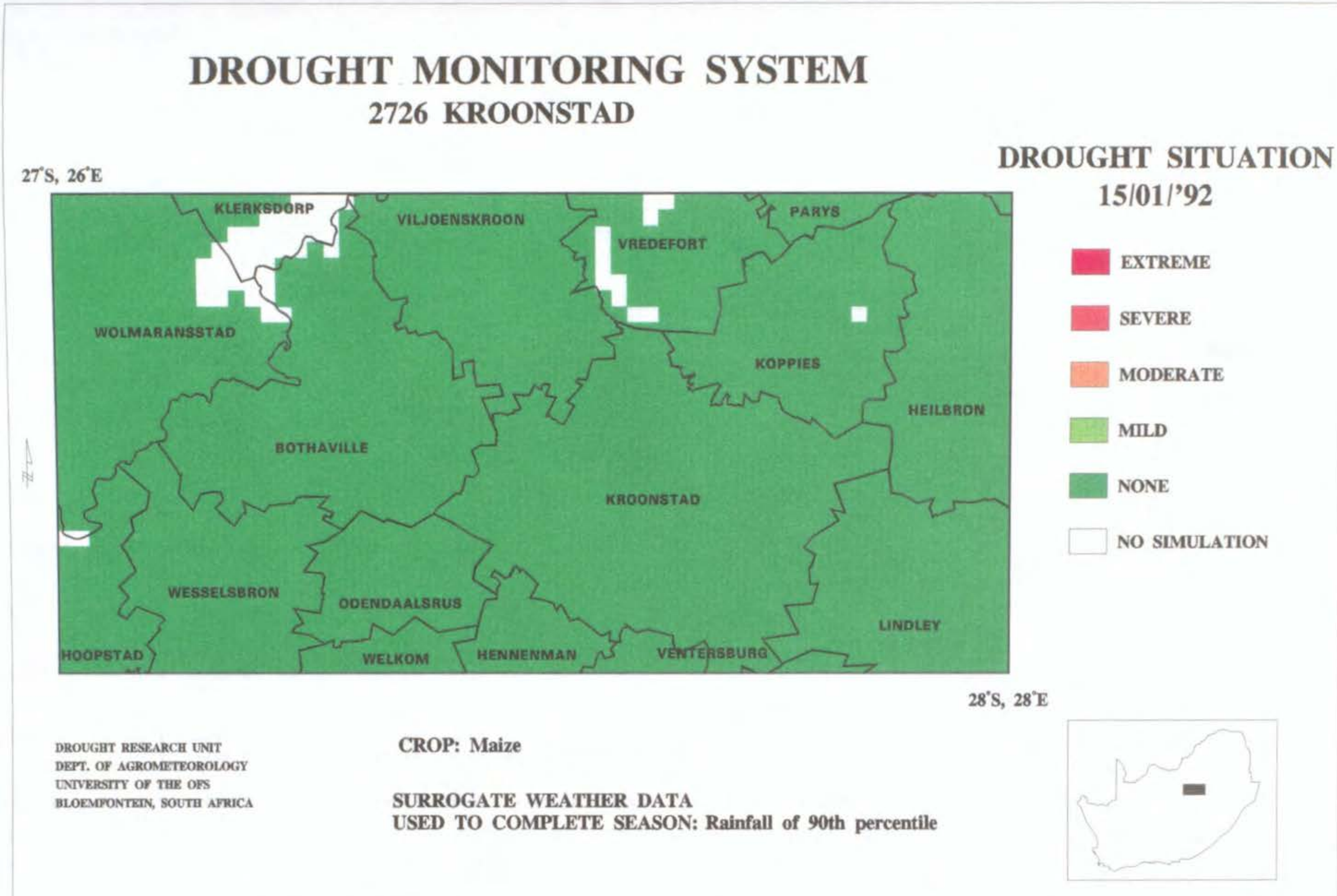

Figure 5.11c Drought map for 2726 KROONSTAD on 15/01/1992. Season completed with above average rainfall year.

Table 5.16 Drought report for 2726 KROONSTAD map sheet on 15/01/1992

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/01/'92

			DROUGHT CLASS											
			EXTREME		SEVERE		MODERATE		MILD		NONE		NO SIMULATION	
MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
ODENDAALSRUS	100	10 %	15934.70	18.16	25100.44	28.61	27420.63	31.25	17122.55	19.52	2154.33	2.46	-	-
		50 %	-	-	-	-	-	-	1901.31	2.17	85827.62	97.83	-	-
		90 %	-	-	-	-	-	-	-	-	87729.27	100.00	-	-
KOPPIES	100	10 %	73915.77	47.64	80016.24	51.57	-	-	-	-	-	-	1219.45	.79
		50 %	-	-	449.69	.29	41189.93	26.55	27361.44	17.64	84933.06	54.74	1219.45	.79
		90 %	-	-	-	-	-	-	-	-	153934.41	99.21	1219.45	.79
BOTHAVILLE	100	10 %	96197.25	34.40	78918.07	28.22	71947.87	25.73	19853.95	7.10	6018.40	2.15	6667.97	2.38
		50 %	-	-	-	-	4371.57	1.56	9911.29	3.54	258650.30	92.51	6667.97	2.38
		90 %	-	-	-	-	-	-	-	-	272931.91	97.62	6667.97	2.38
KROONSTAD	99	10 %	230842.22	55.22	130170.19	31.14	34351.66	8.22	19051.78	4.56	3645.89	.87	-	-
		50 %	120.10	.03	28207.09	6.75	46345.42	11.09	4946.81	1.18	338442.28	80.96	-	-
		90 %	-	-	-	-	-	-	-	-	418063.69	100.00	-	-
WESSELSBRON	89	10 %	88817.50	57.20	32761.27	21.10	32457.54	20.90	1251.90	.81	-	-	-	-
		50 %	-	-	212.00	.14	228.47	.15	20042.81	12.91	134813.03	86.81	-	-
		90 %	-	-	-	-	-	-	-	-	155294.61	100.00	-	-
VILJOENSKROON	87	10 %	139030.48	76.11	43301.53	23.70	-	-	-	-	-	-	340.77	.19
		50 %	-	-	-	-	2441.45	1.34	28644.14	15.68	151248.03	82.80	340.77	.19
		90 %	-	-	-	-	-	-	-	-	182333.59	99.81	340.77	.19
HENNENMAN	80	10 %	9477.15	20.43	36519.55	78.74	-	-	383.38	.83	-	-	-	-
		50 %	-	-	-	-	1768.50	3.81	1827.45	3.94	42784.02	92.25	-	-
		90 %	-	-	-	-	-	-	-	-	46377.71	100.00	-	-
VREDEFORT	77	10 %	84721.60	80.11	7634.03	7.22	-	-	-	-	-	-	13395.68	12.67
		50 %	3664.88	3.47	17502.43	16.55	2378.29	2.25	8518.62	8.06	60290.08	57.01	13395.68	12.67
		90 %	-	-	-	-	-	-	-	-	92353.99	87.33	13395.68	12.67
LINDLEY	59	10 %	134475.22	80.01	33589.28	19.99	-	-	-	-	-	-	-	-
		50 %	2258.85	1.34	549.35	.33	22119.95	13.16	18948.59	11.27	124187.77	73.89	-	-
		90 %	-	-	-	-	-	-	-	-	168064.70	100.00	-	-
WELKOM	54	10 %	13878.59	45.44	1364.73	4.47	4125.09	13.51	-	-	11171.21	36.58	-	-
		50 %	-	-	-	-	-	-	-	-	30542.11	100.00	-	-
		90 %	-	-	-	-	-	-	-	-	30538.37	100.00	-	-
HEILBRON	47	10 %	145719.52	84.62	26476.67	15.38	-	-	-	-	-	-	-	-
		50 %	-	-	1216.64	.71	58775.81	34.13	37848.91	21.98	74352.49	43.18	-	-
		90 %	-	-	-	-	-	-	-	-	172196.70	100.00	-	-

Table 5.16 ctd

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/01/'92

			DROUGHT CLASS											
			EXTREME		SEVERE		MODERATE		MILD		NONE		NO SIMULATION	
MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
WOLMARANSSTAD	47	10 %	142409.03	65.81	24282.59	11.22	36244.09	16.75	13400.11	6.19	62.76	.03	-	-
		50 %	4888.00	2.26	-	-	8230.16	3.80	74973.85	34.65	128301.44	59.29	-	-
		90 %	-	-	-	-	-	-	-	-	216399.92	100.00	-	-
PARYS	22	10 %	15293.78	72.93	5675.93	27.07	-	-	-	-	-	-	-	-
		50 %	-	-	16245.35	77.47	2443.51	11.65	694.59	3.31	1586.23	7.56	-	-
		90 %	-	-	-	-	-	-	-	-	20966.80	100.00	-	-
HOOPSTAD	19	10 %	52818.88	78.75	12037.94	17.95	-	-	640.97	.96	-	-	1574.00	2.35
		50 %	-	-	6872.61	10.25	15104.58	22.52	33313.16	49.67	10207.23	15.22	1574.00	2.35
		90 %	-	-	-	-	-	-	-	-	65496.75	97.65	1574.00	2.35
VENTERSBURG	14	10 %	15214.00	85.55	2569.08	14.45	-	-	-	-	-	-	-	-
		50 %	-	-	4556.04	25.62	1147.42	6.45	9510.54	53.48	2569.08	14.45	-	-
		90 %	-	-	-	-	-	-	-	-	17783.23	100.00	-	-
KLERKSDORP	12	10 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
		50 %	-	-	-	-	-	-	2341.79	5.58	13053.45	31.10	26571.23	63.32
		90 %	-	-	-	-	-	-	-	-	15391.94	36.68	26571.23	63.32
SASOLBURG	2	10 %	512.47	24.70	1562.46	75.30	-	-	-	-	-	-	-	-
		50 %	-	-	-	-	-	-	-	-	2074.95	100.00	-	-
		90 %	-	-	-	-	-	-	-	-	2074.95	100.00	-	-
SENEKAL	2	10 %	3092.81	43.52	4014.57	56.48	-	-	-	-	-	-	-	-
		50 %	44.68	.63	1836.78	25.84	1414.52	19.90	1603.08	22.56	2208.28	31.07	-	-
		90 %	-	-	-	-	-	-	-	-	7107.37	100.00	-	-

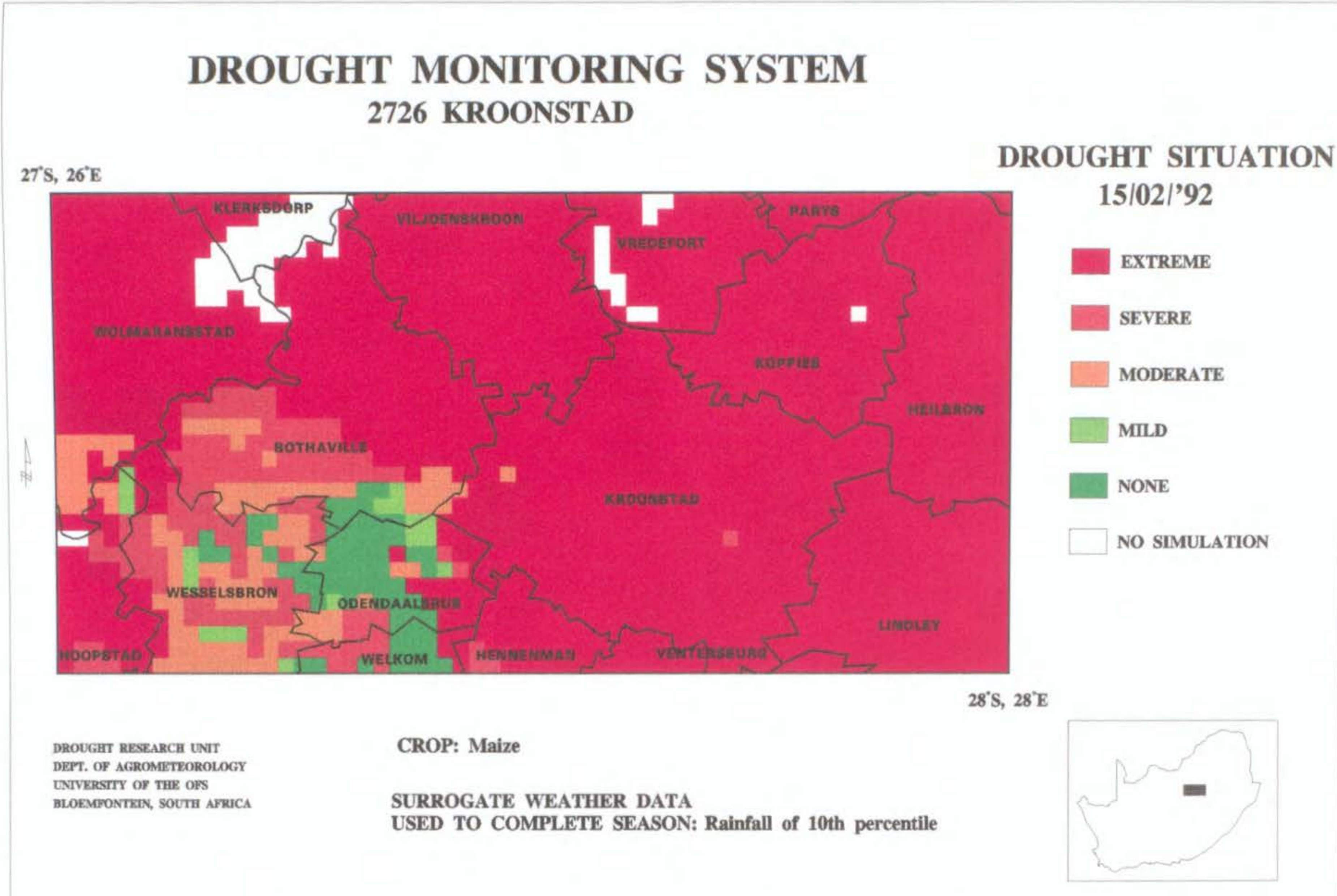

Figure 5.12a Drought map for 2726 KROONSTAD on 15/02/1992. Season completed with below average rainfall year.

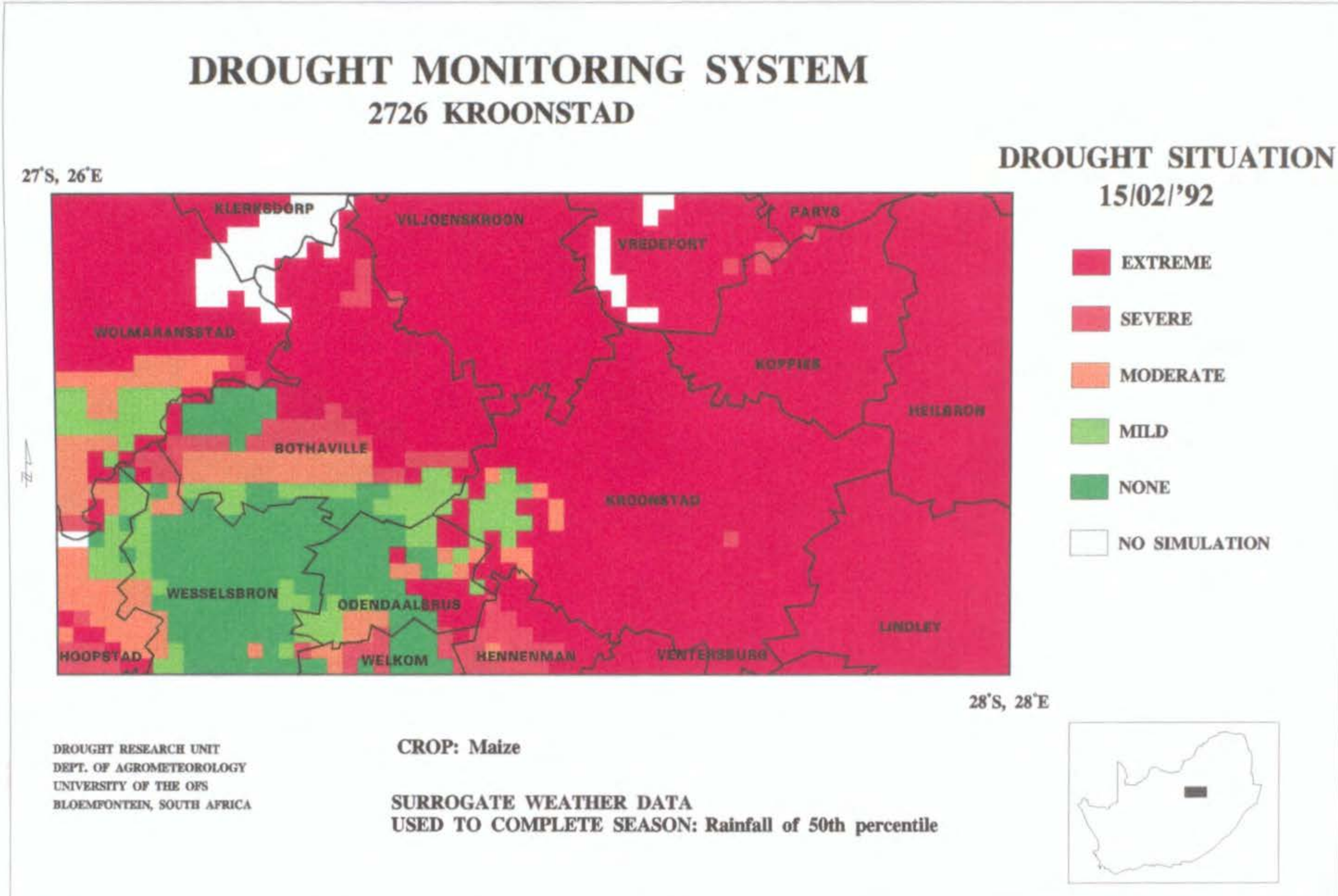

Figure 5.12b Drought map for 2726 KROONSTAD on 15/02/1992. Season completed with average rainfall year.

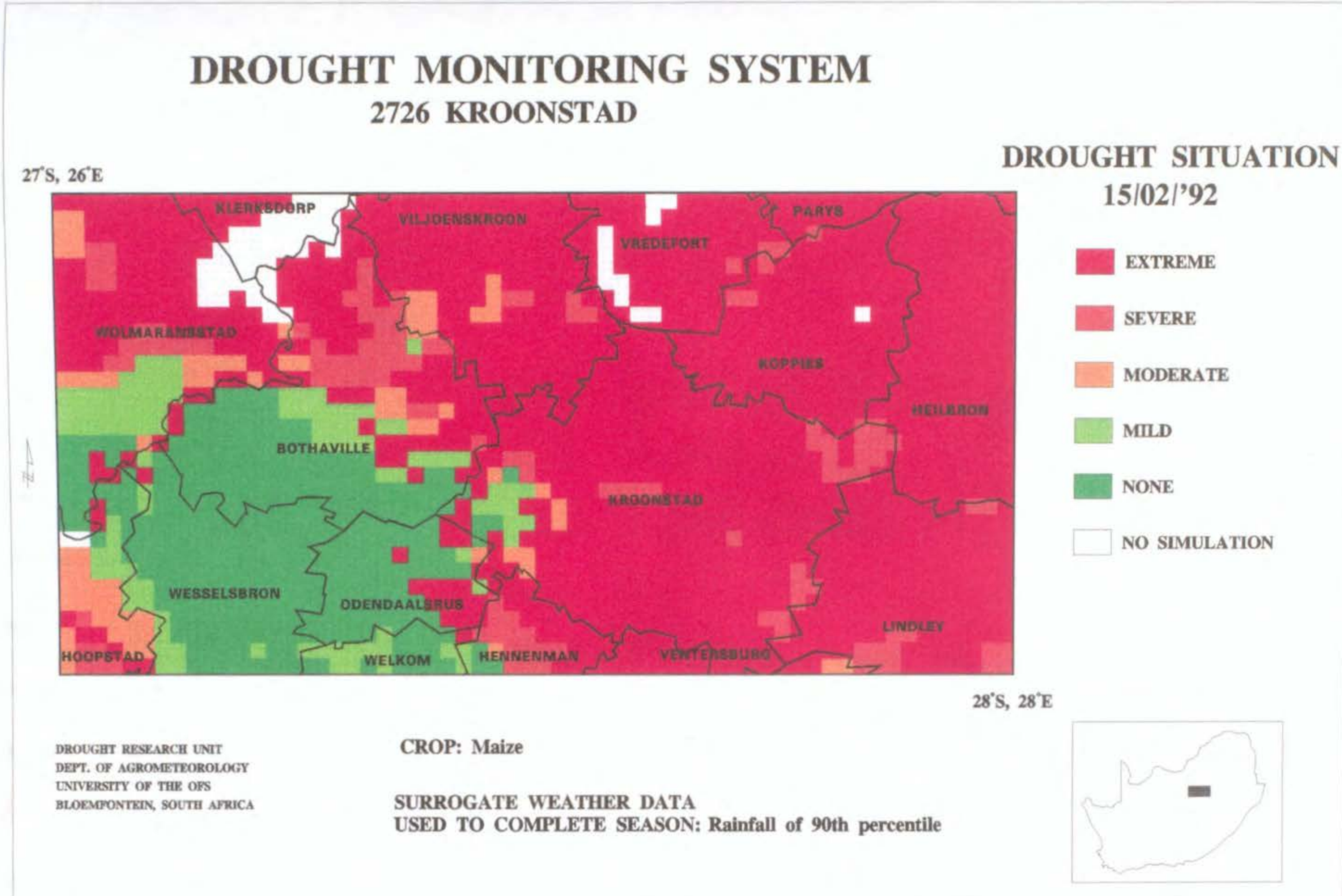

Figure 5.12c Drought map for 2726 KROONSTAD on 15/02/1992. Season completed with above average rainfall year.

Table 5.17 Drought report for 2726 KROONSTAD map sheet on 15/02/1992

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/02/'92

			DROUGHT CLASS											
			EXTREME		SEVERE		MODERATE		MILD		NONE		NO SIMULATION	
MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
ODENDAALSRUS	100	10 %	22878.31	26.08	8895.49	10.14	10880.65	12.40	6304.56	7.19	38769.76	44.19	-	-
		50 %	18354.51	20.92	1061.56	1.21	11853.22	13.51	16342.59	18.63	40115.63	45.73	-	-
		90 %	18354.51	20.92	311.00	.35	1094.97	1.25	2673.16	3.05	65294.74	74.43	-	-
KOPPIES	100	10 %	153934.41	99.21	-	-	-	-	-	-	-	-	1219.45	.79
		50 %	151785.09	97.83	2149.38	1.39	-	-	-	-	-	-	1219.45	.79
		90 %	148588.30	95.77	5341.76	3.44	-	-	-	-	-	-	1219.45	.79
BOTHAVILLE	100	10 %	163576.80	58.50	64672.15	23.13	31622.87	11.31	4612.64	1.65	8445.20	3.02	6670.01	2.39
		50 %	146151.11	52.27	37344.50	13.36	29505.79	10.55	26548.83	9.50	33382.92	11.94	6667.97	2.38
		90 %	88551.70	31.67	37433.48	13.39	12257.41	4.38	31003.92	11.09	103686.70	37.08	6667.97	2.38
KROONSTAD	99	10 %	413921.59	99.01	1214.24	.29	2915.79	.70	12.06	-	-	-	-	-
		50 %	391362.22	93.61	1218.53	.29	8237.25	1.97	17245.53	4.13	-	-	-	-
		90 %	360496.88	86.23	32088.23	7.68	8237.25	1.97	11282.68	2.70	5962.85	1.43	-	-
WESSELSBRON	89	10 %	18533.16	11.93	54801.57	35.29	57768.63	37.20	9059.50	5.83	15131.65	9.74	-	-
		50 %	2344.44	1.51	5332.97	3.43	13057.22	8.41	19064.93	12.28	115497.48	74.37	-	-
		90 %	2180.39	1.40	-	-	1026.85	.66	15813.39	10.18	136275.38	87.75	-	-
VILJOENSKROON	87	10 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
		50 %	181675.00	99.45	658.60	.36	-	-	-	-	-	-	340.77	.19
		90 %	163711.00	89.62	7411.24	4.06	11211.44	6.14	-	-	-	-	340.77	.19
HENNENMAN	80	10 %	42743.43	92.16	3634.27	7.84	-	-	-	-	-	-	-	-
		50 %	23375.88	50.40	21406.81	46.16	1595.12	3.44	-	-	-	-	-	-
		90 %	23375.88	50.40	16232.75	35.00	1595.12	3.44	1539.79	3.32	3634.27	7.84	-	-
VREDEFORT	77	10 %	92353.99	87.33	-	-	-	-	-	-	-	-	13395.68	12.67
		50 %	89056.24	84.21	3297.76	3.12	-	-	-	-	-	-	13395.68	12.67
		90 %	89017.68	84.18	3336.27	3.15	-	-	-	-	-	-	13395.68	12.67
LINDLEY	59	10 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	150542.62	89.57	17307.76	10.30	214.46	.13	-	-	-	-	-	-
WELKOM	54	10 %	4245.55	13.90	10989.23	35.98	8.48	.03	-	-	15296.30	50.09	-	-
		50 %	975.08	3.19	10706.71	35.06	3553.36	11.64	8.48	.03	15296.30	50.09	-	-
		90 %	975.08	3.19	418.58	1.37	-	-	12620.52	41.33	16525.11	54.11	-	-
HEILBRON	47	10 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	170673.20	99.12	1523.53	.88	-	-	-	-	-	-	-	-

Table 5.17 ctd

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/02/'92

MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	DROUGHT CLASS: EXTREME ha	EXTREME %	SEVERE ha	SEVERE %	MODERATE ha	MODERATE %	MILD ha	MILD %	NONE ha	NONE %	NO SIMULATION ha	NO SIMULATION %
WOLMARANSSTAD	47	10 %	199170.38	92.04	144.73	.07	17083.75	7.89	-	-	-	-	-	-
		50 %	149102.53	68.90	4370.25	2.02	39076.19	18.06	23703.09	10.95	144.73	.07	-	-
		90 %	120269.20	55.58	19511.07	9.02	22692.32	10.49	34735.05	16.05	19189.06	8.87	-	-
PARYS	22	10 %	20966.80	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	20310.60	96.87	656.15	3.13	-	-	-	-	-	-	-	-
		90 %	20310.60	96.87	656.15	3.13	-	-	-	-	-	-	-	-
HOOPSTAD	19	10 %	46587.80	69.46	12285.54	18.32	3552.84	5.30	3071.58	4.58	-	-	1574.00	2.35
		50 %	9342.91	13.93	10159.70	15.15	30417.94	45.35	12510.25	18.65	3067.02	4.57	1574.00	2.35
		90 %	9344.57	13.93	7267.17	10.83	28244.19	42.11	10605.61	15.81	10036.26	14.96	1574.00	2.35
VENTERSBURG	14	10 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
KLERKSDORP	12	10 %	15391.94	36.68	-	-	-	-	-	-	-	-	26572.51	63.32
		50 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
		90 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
SASOLBURG	2	10 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
SENEKAL	2	10 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	4150.56	58.40	748.50	10.53	2208.28	31.07	-	-	-	-	-	-

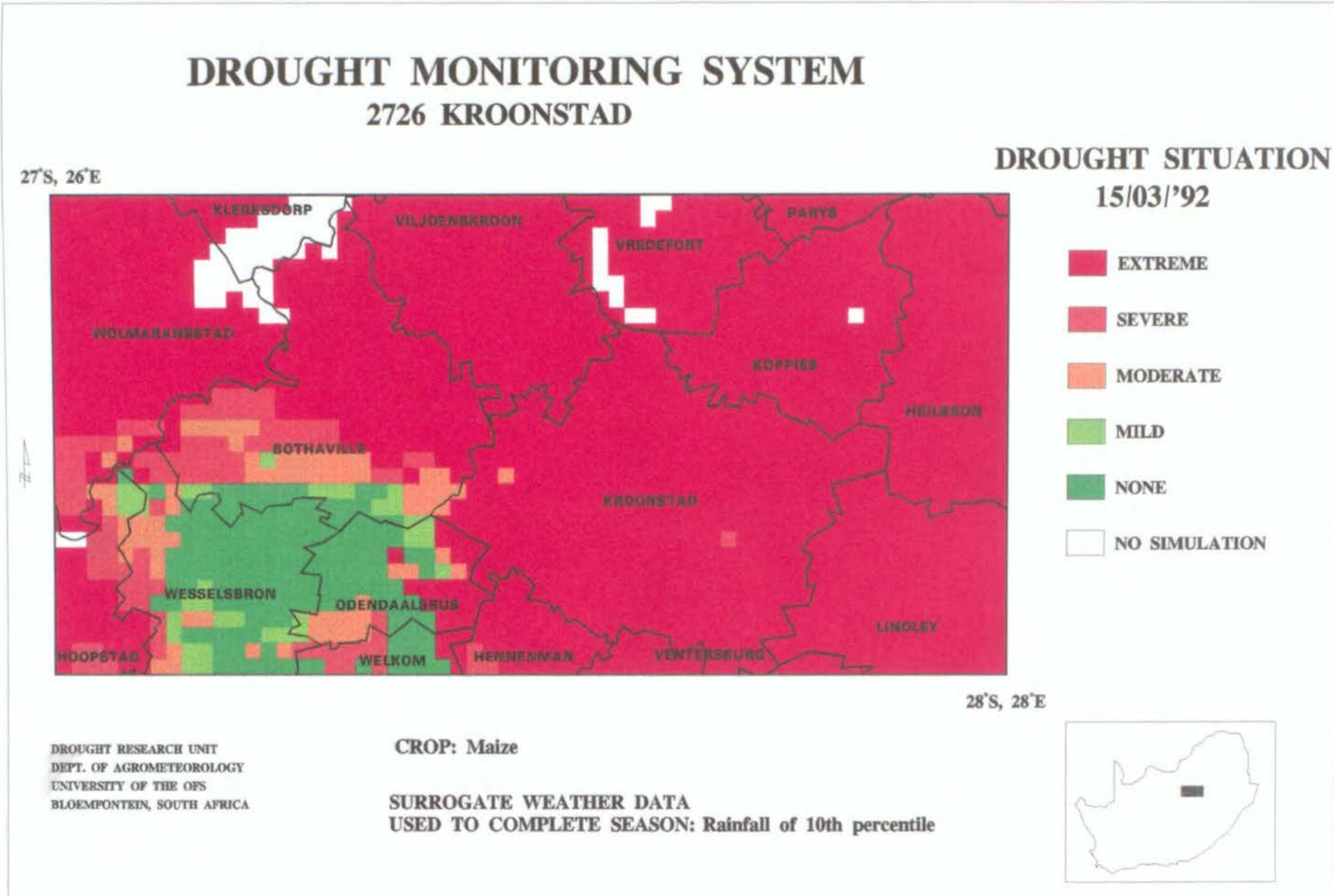

Figure 5.13a Drought map for 2726 KROONSTAD on 15/03/1992. Season completed with below average rainfall year.

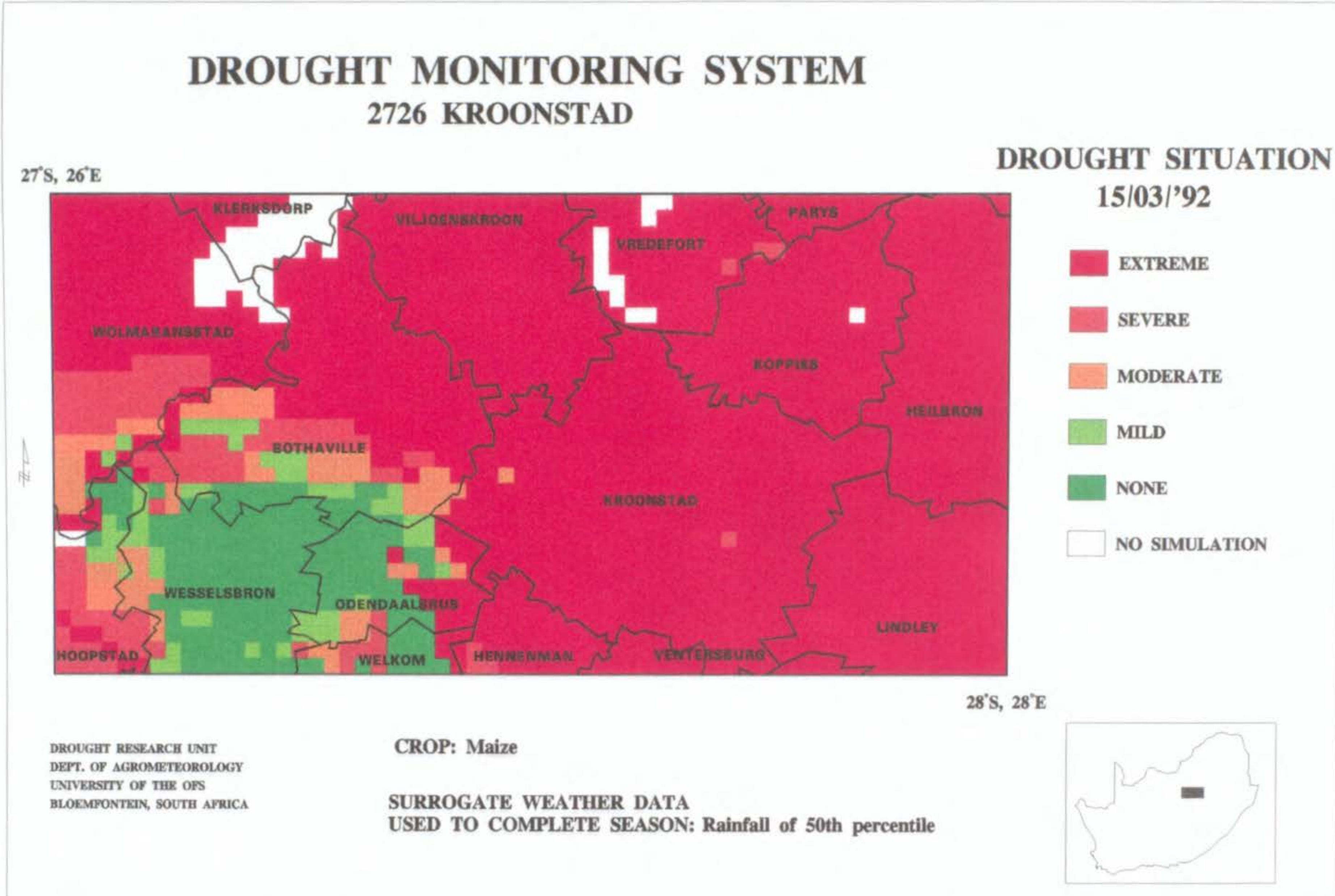

Figure 5.13b Drought map for 2726 KROONSTAD on 15/03/1992. Season completed with average rainfall year.

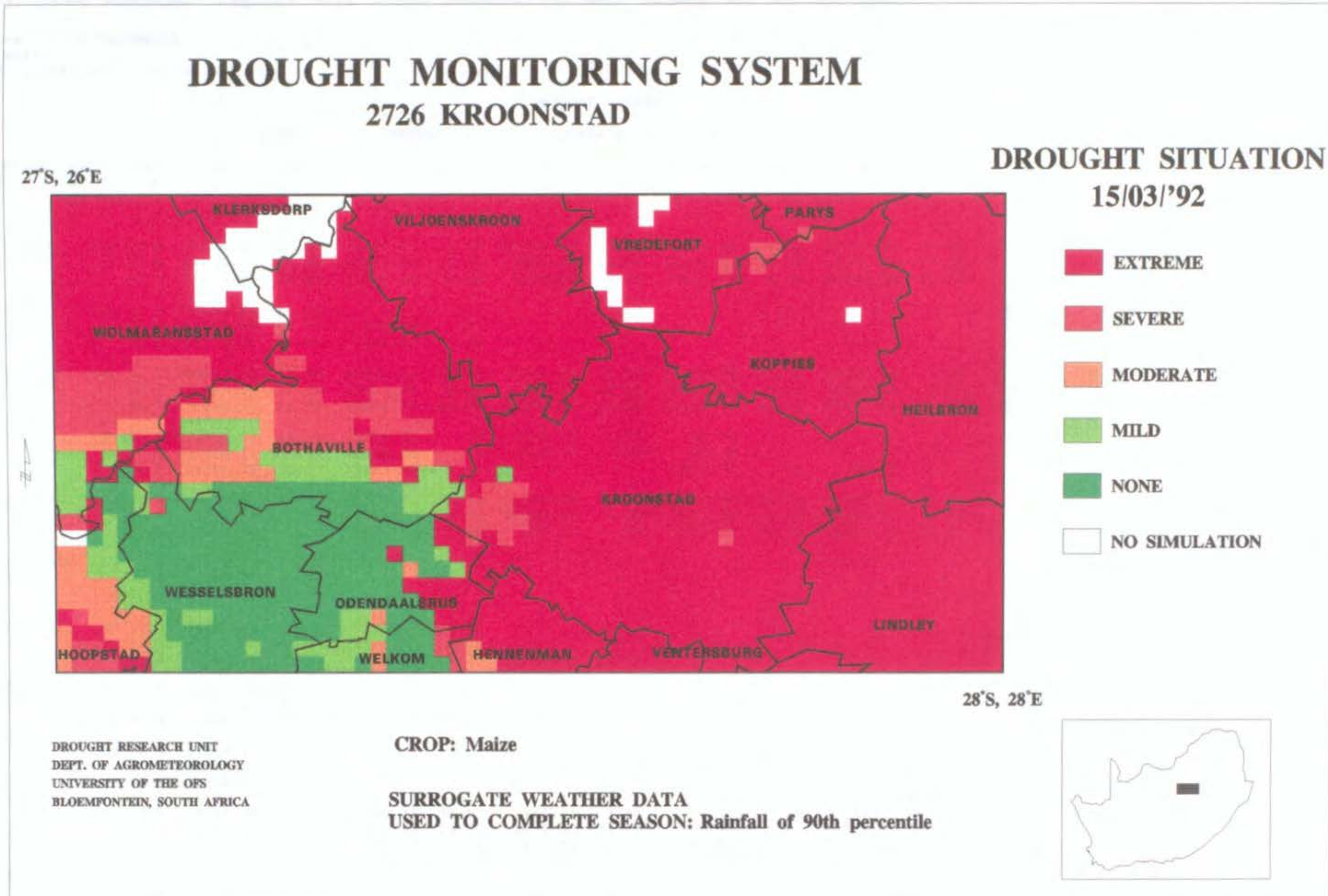

Figure 5.13c Drought map for 2726 KROONSTAD on 15/03/1992. Season completed with above average rainfall year.

Table 5.18 Drought report for 2726 KROONSTAD map sheet on 15/03/1992

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/03/'92

MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	DROUGHT CLASS: EXTREME ha	%	SEVERE ha	%	MODERATE ha	%	MILD ha	%	NONE ha	%	NO SIMULATION ha	%
ODENDAALSRUS	100	10 %	22878.31	26.08	1806.57	2.06	15106.75	17.22	6657.95	7.59	41279.09	47.05	-	-
		50 %	22878.31	26.08	1532.09	1.75	9548.22	10.88	12431.16	14.17	41338.09	47.12	-	-
		90 %	21839.42	24.89	1038.89	1.18	2425.44	2.76	7441.39	8.48	54983.59	62.67	-	-
KOPPIES	100	10 %	153934.41	99.21	-	-	-	-	-	-	-	-	1219.45	.79
		50 %	153533.59	98.96	400.86	.26	-	-	-	-	-	-	1219.45	.79
		90 %	151785.20	97.83	2149.29	1.39	-	-	-	-	-	-	1219.45	.79
BOTHAVILLE	100	10 %	160442.09	57.38	45464.03	16.26	35097.62	12.55	11350.50	4.06	20578.68	7.36	6667.97	2.38
		50 %	156499.30	55.97	37017.78	13.24	35322.59	12.63	23514.85	8.41	20578.68	7.36	6667.97	2.38
		90 %	130658.12	46.73	44614.20	15.96	34278.50	12.26	34349.08	12.29	29029.98	10.38	6670.01	2.39
KROONSTAD	99	10 %	413921.59	99.01	1214.24	.29	2915.79	.70	12.06	-	-	-	-	-
		50 %	413921.59	99.01	1214.24	.29	2915.79	.70	12.06	-	-	-	-	-
		90 %	399952.31	95.67	15183.56	3.63	-	-	2915.79	.70	12.06	-	-	-
WESSELSBRON	89	10 %	3207.24	2.07	18201.01	11.72	21188.48	13.64	18201.62	11.72	94497.61	60.85	-	-
		50 %	2344.44	1.51	8541.94	5.50	13084.43	8.43	17162.73	11.05	114163.37	73.51	-	-
		90 %	2345.05	1.51	5834.88	3.76	862.19	.56	17492.43	11.26	128761.38	82.91	-	-
VILJOENSKROON	87	10 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
		50 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
		90 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
HENNENMAN	80	10 %	42743.43	92.16	3634.27	7.84	-	-	-	-	-	-	-	-
		50 %	42743.43	92.16	3634.27	7.84	-	-	-	-	-	-	-	-
		90 %	41203.72	88.84	1539.78	3.32	3634.27	7.84	-	-	-	-	-	-
VREDEFORT	77	10 %	92353.99	87.33	-	-	-	-	-	-	-	-	13395.68	12.67
		50 %	89095.42	84.25	3258.59	3.08	-	-	-	-	-	-	13395.68	12.67
		90 %	89056.52	84.21	3297.50	3.12	-	-	-	-	-	-	13395.68	12.67
LINDLEY	59	10 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
WELKOM	54	10 %	4245.55	13.90	10550.34	34.55	447.37	1.46	-	-	15295.71	50.09	-	-
		50 %	4245.55	13.90	7436.35	24.35	3552.95	11.63	8.48	.03	15296.30	50.09	-	-
		90 %	1393.27	4.56	2852.19	9.34	2421.69	7.93	8567.53	28.05	15304.19	50.11	-	-
HEILBRON	47	10 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-

Table 5.18 ctd

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/03/'92

MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	DROUGHT CLASS: EXTREME ha	EXTREME %	SEVERE ha	SEVERE %	MODERATE ha	MODERATE %	MILD ha	MILD %	NONE ha	NONE %	NO SIMULATION ha	NO SIMULATION %
WOLMARANSSTAD	47	10 %	195798.23	90.48	17850.68	8.25	2748.12	1.27	-	-	-	-	-	-
		50 %	154681.03	71.48	41126.89	19.01	17758.73	8.21	2375.11	1.10	454.97	.21	-	-
		90 %	151778.36	70.14	44029.57	20.35	8289.64	3.83	11844.20	5.47	454.97	.21	-	-
PARYS	22	10 %	20966.80	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	20964.78	99.99	1.98	.01	-	-	-	-	-	-	-	-
		90 %	20310.60	96.87	656.15	3.13	-	-	-	-	-	-	-	-
HOOPSTAD	19	10 %	39270.66	58.55	16654.38	24.83	5105.72	7.61	3826.01	5.70	640.97	.96	1574.00	2.35
		50 %	9812.17	14.63	30740.77	45.83	8929.05	13.31	7652.20	11.41	8363.67	12.47	1574.00	2.35
		90 %	9344.57	13.93	7736.44	11.53	28244.19	42.11	10885.28	16.23	9287.31	13.85	1574.00	2.35
VENTERSBURG	14	10 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
KLERKSDORP	12	10 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
		50 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
		90 %	15391.94	36.68	-	-	-	-	-	-	-	-	26572.51	63.32
SASOLBURG	2	10 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
SENEKAL	2	10 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-

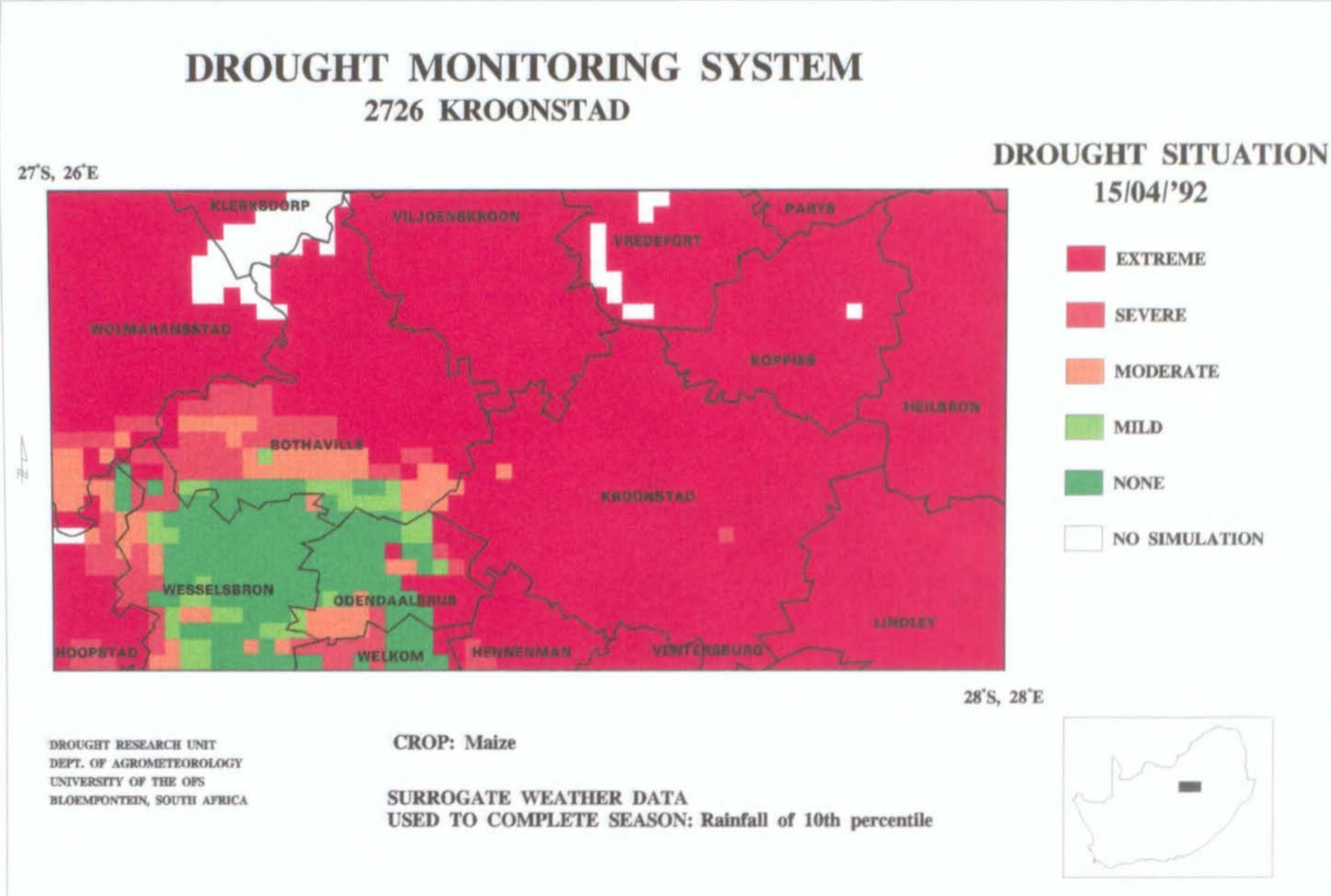

Figure 5.14a Drought map for 2726 KROONSTAD on 15/04/1992. Season completed with below average rainfall year.

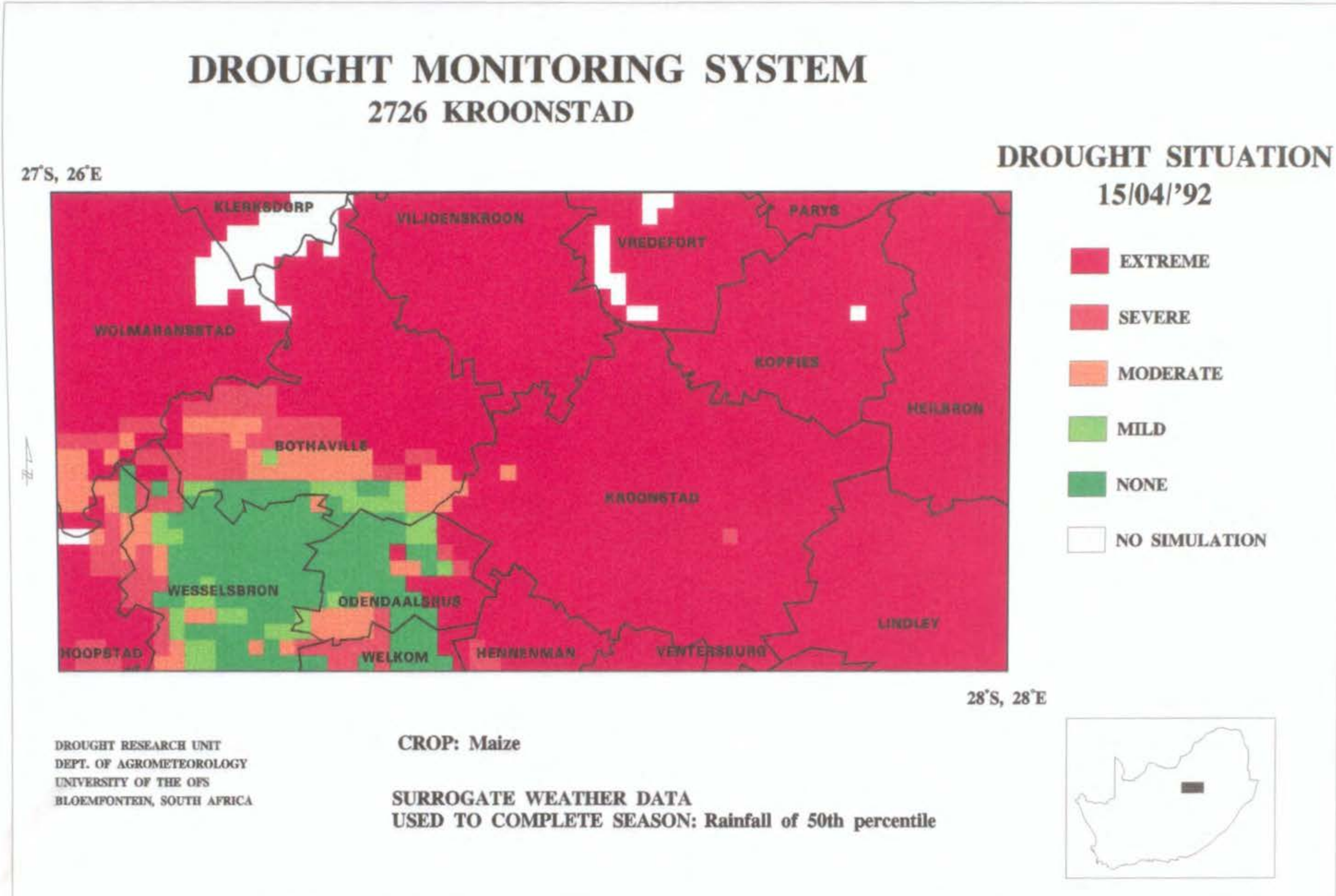

Figure 5.14b Drought map for 2726 KROONSTAD on 15/04/1992. Season completed with average rainfall year.

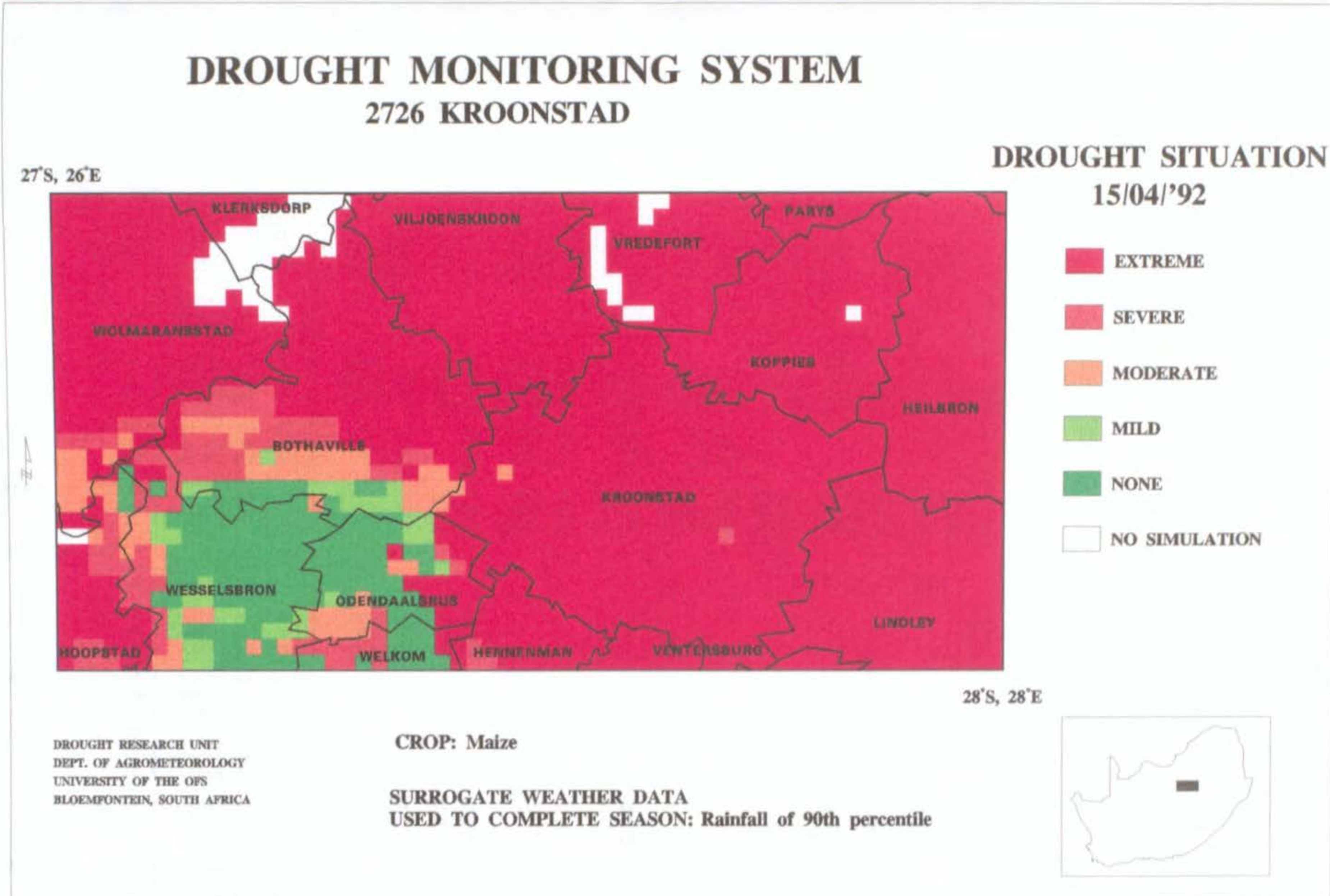

Figure 5.14c Drought map for 2726 KROONSTAD on 15/04/1992. Season completed with above average rainfall year.

Table 5.19 Drought report for 2726 KROONSTAD map sheet on 15/04/1992

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/04/'92

MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	DROUGHT CLASS: EXTREME ha	%	SEVERE ha	%	MODERATE ha	%	MILD ha	%	NONE ha	%	NO SIMULATION ha	%
ODENDAALSRUS	100	10 %	22878.31	26.08	4234.01	4.83	12679.32	14.45	7952.50	9.06	39984.54	45.58	-	-
		50 %	22878.31	26.08	4234.01	4.83	12679.32	14.45	7952.50	9.06	39984.54	45.58	-	-
		90 %	22878.31	26.08	4234.01	4.83	12679.32	14.45	7952.50	9.06	39984.54	45.58	-	-
KOPPIES	100	10 %	153934.41	99.21	-	-	-	-	-	-	-	-	1219.45	.79
		50 %	153934.41	99.21	-	-	-	-	-	-	-	-	1219.45	.79
		90 %	153934.41	99.21	-	-	-	-	-	-	-	-	1219.45	.79
BOTHAVILLE	100	10 %	160435.45	57.38	45794.04	16.38	34994.46	12.52	13698.60	4.90	18010.96	6.44	6667.97	2.38
		50 %	160435.45	57.38	45794.04	16.38	34994.46	12.52	13698.60	4.90	18010.96	6.44	6667.97	2.38
		90 %	160435.45	57.38	45794.04	16.38	34994.46	12.52	13698.60	4.90	18010.96	6.44	6667.97	2.38
KROONSTAD	99	10 %	413921.59	99.01	1214.24	.29	2915.79	.70	12.06	-	-	-	-	-
		50 %	413921.59	99.01	1214.24	.29	2915.79	.70	12.06	-	-	-	-	-
		90 %	413921.59	99.01	1214.24	.29	2915.79	.70	12.06	-	-	-	-	-
WESSELSBRON	89	10 %	4423.04	2.85	20128.35	12.96	16432.58	10.58	20809.80	13.40	93502.21	60.21	-	-
		50 %	4423.04	2.85	20128.35	12.96	16432.58	10.58	20809.80	13.40	93502.21	60.21	-	-
		90 %	4423.04	2.85	20128.35	12.96	16432.58	10.58	20809.80	13.40	93502.21	60.21	-	-
VILJOENSKROON	87	10 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
		50 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
		90 %	182333.59	99.81	-	-	-	-	-	-	-	-	340.77	.19
HENNENMAN	80	10 %	42743.43	92.16	3634.27	7.84	-	-	-	-	-	-	-	-
		50 %	42743.43	92.16	3634.27	7.84	-	-	-	-	-	-	-	-
		90 %	42743.43	92.16	3634.27	7.84	-	-	-	-	-	-	-	-
VREDEFORT	77	10 %	92353.99	87.33	-	-	-	-	-	-	-	-	13395.68	12.67
		50 %	92353.99	87.33	-	-	-	-	-	-	-	-	13395.68	12.67
		90 %	92353.99	87.33	-	-	-	-	-	-	-	-	13395.68	12.67
LINDLEY	59	10 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	168064.70	100.00	-	-	-	-	-	-	-	-	-	-
WELKOM	54	10 %	4245.55	13.90	10550.34	34.55	447.37	1.46	-	-	15295.71	50.09	-	-
		50 %	4245.55	13.90	10550.34	34.55	447.37	1.46	-	-	15295.71	50.09	-	-
		90 %	4245.55	13.90	10550.34	34.55	447.37	1.46	-	-	15295.71	50.09	-	-
HEILBRON	47	10 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	172196.70	100.00	-	-	-	-	-	-	-	-	-	-

Table 5.19 ctd

Map sheet: 2726 KROONSTAD
CROP: MAIZE
DROUGHT SITUATION 15/04/'92

MAGISTERIAL DISTRICT (MD)	AREA OF MD ON MAP	SURRG. SCENA.	DROUGHT CLASS: EXTREME ha	%	SEVERE ha	%	MODERATE ha	%	MILD ha	%	NONE ha	%	NO SIMULATION ha	%
WOLMARANSSTAD	47	10 %	195797.53	90.48	8299.62	3.84	12299.17	5.68	-	-	-	-	-	-
		50 %	195797.53	90.48	8299.62	3.84	12299.17	5.68	-	-	-	-	-	-
		90 %	195797.53	90.48	8299.62	3.84	12299.17	5.68	-	-	-	-	-	-
PARYS	22	10 %	20966.80	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	20966.80	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	20966.80	100.00	-	-	-	-	-	-	-	-	-	-
HOOPSTAD	19	10 %	39270.66	58.55	16660.10	24.84	6495.40	9.68	-	-	3071.58	4.58	1574.00	2.35
		50 %	39270.66	58.55	16660.10	24.84	6495.40	9.68	-	-	3071.58	4.58	1574.00	2.35
		90 %	39270.66	58.55	16660.10	24.84	6495.40	9.68	-	-	3071.58	4.58	1574.00	2.35
VENTERSBURG	14	10 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	17783.23	100.00	-	-	-	-	-	-	-	-	-	-
KLERKSDORP	12	10 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
		50 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
		90 %	15391.94	36.68	-	-	-	-	-	-	-	-	26571.23	63.32
SASOLBURG	2	10 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	2074.95	100.00	-	-	-	-	-	-	-	-	-	-
SENEKAL	2	10 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-
		50 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-
		90 %	7107.37	100.00	-	-	-	-	-	-	-	-	-	-

The following observations were made from Figures 5.10(a - c) to 5.14(a - c), respectively:

a) As the season progresses, the drought maps produced using the three different surrogate scenarios, converge in appearance. This is due to fact that the observed record is used to a greater extent as each monitoring round is completed. The maps produced for the 15th of April are identical for all three scenarios. The maps of the 15th of February and 15th of March differ as these cover the flowering period of the crop.

b) The critical flowering period, when the grain sink size is determined biologically and which is highly sensitive to water stress; commenced between the 28th of January and 8th of February, respectively, depending on the planting date in the magisterial district. The flowering period was completed between the 8th of February and the 19th of February. The prognosis for the maps produced for the 15th of February is therefore better than for the 15th of March, as surrogate data is used to complete the flowering period for many of the simulations done on the 15th of February.

c) It can be seen from Figure 5.10b that certain areas in the KROONSTAD, KOPPIES and HEILBRON magisterial districts were already at risk of severe drought losses at the outset of the season, if the season were to continue as normal.

d) Widespread general rainfall occurred over much of the summer rainfall areas in December 1991. The response to this rainfall is evident in a generally better prognosis on the 15th of January (Figures 5.11a - 5.11c), although certain areas are worse off. Rainfall was however well below normal (<= 30% of the long-term average) for the remainder of the season and critical flowering period, resulting in large scale drought losses.

e) Isolated rainfall did however occur in areas covered by the south-western corner of the map sheet. From all the figures it can be seen that much of the WESSELSBRON magisterial district and ODENDAALSRUS district had normal yields. This trend is reflected in the average maize yield of the WESSELSBRON magisterial district being considerably higher than those of surrounding districts. Average maize yields of magisterial districts are discussed in Section 5.6 below. Furthermore, this trend was also found in on-farm maize yield data obtained from farmers in the WESSELSBRON magisterial district (Singels, De Jager and Neethling, 1994). High yields (eg 3.75 tons ha^{-1}) were recorded for the 91/92 production season, when surrounding districts were experiencing severe drought. This phenomenon was accurately reflected by the drought monitoring system.

f) One cell on the western edge of the KROONSTAD magisterial district close to the boundary of the BOTHAVILLE district stands out as a separate class from its neighbours in all the maps. A possible explanation of this is that the soil form representing the cell is a deep (1.5 m) soil with a high water holding capacity. The plants may have had sufficient soil water to survive the stress during flowering and consequently given a higher yield than those planted within areas covered by neighbouring cells, not having the same soil form.

5.6 ACCURACY OF THE DROUGHT MONITORING SYSTEM

Two tests were used to determine the accuracy of the drought monitoring system. Firstly, the average maize yield simulated for each of the magisterial districts was compared with figures provided by the Department of Agriculture (Kruger pers. comm.[2]). Secondly, individual farm yields obtained from farmers in the Orange Free State for the 1992/93 season, were compared with those simulated by the model in the drought monitoring system.

5.6.1 Comparison of average maize yield per Magisterial District

The comparison of average maize yield as determined by the Department of Agriculture (DOA) and the drought monitoring system (DMS) is shown in Table 5.20 below. From Table 5.20 it can be seen that the same overall trend is apparent in both the DOA and DMS data sets. The average yield for the 1988/89 season is considerably higher than that of the 1991/92 season when severe drought occurred. Similarly the yields of the 1992/93 season are considerably higher than those of the 1991/92 season.

The method of determining average yield used by the DOA and that used in the DMS does however differ drastically. The DOA approach is to sum the yields of the farms used as the sample of the magisterial district and to divide this total by the sum of cultivated area on all these farms. The sample used per magisterial district varies from 5 to 120 farms depending on the size of the district. In the DMS on the other hand the yield of each cell within the district is summed and this total divided by the number of cells in the district. This difference in approach may account for some of the large absolute differences obtained between the DOA and DMS data.

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[2]J.P. Kruger, Assistant Director, Directorate of Agricultural Economic Tendencies, Department of Agriculture.

Table 5.20 Comparison of average maize yield per magisterial district determined by the Department of Agriculture and simulated by the PUTU maize model in the Drought Monitoring System

DOA = DEPARTMENT OF AGRICULTURE
DMS = DROUGHT MONITORING SYSTEM

MAGISTERIAL DISTRICT	Yield tons ha^{-1}					
	DOA AVG	DMS AVG	DOA AVG	DMS AVG	DOA AVG	DMS AVG
	1988/89		1991/92		1992/93	
BOTHAVILLE	3.19	3.96	1.31	0.67	2.55	3.58
BRANDFORT	1.75	2.56	0.12	0.08	0.89	2.42
BULTFONTEIN	3.15	1.74	1.20	1.01	3.05	2.39
COLIGNY	3.44	3.97	0.25	0.25	2.08	3.70
FICKSBURG	3.40	2.66	0.85	0.94	1.92	4.38
HEILBRON	2.60	1.38	0.31	0.01	1.91	3.72
HENNENMAN	3.30	3.44	0.16	0.43	2.54	3.38
KLERKSDORP	3.13	3.92	0.20	0.07	1.51	2.97
KOPPIES	2.92	2.93	0.53	0.03	2.66	3.07
KROONSTAD	2.94	3.81	0.33	0.20	2.72	2.01
LINDLEY	2.50	3.57	0.43	0.13	2.03	1.96
MARQUARD	3.10	2.88	0.47	0.36	2.19	3.51
OBERHOLZER	2.50	1.33	0.36	0.03	3.29	2.72
ODENDAALSRUS	3.50	3.79	0.69	2.35	2.51	3.49
PARYS	2.90	3.76	0.71	0.03	2.18	3.64
POTCHEFSTROOM	3.24	3.14	0.25	0.09	1.55	3.62
SENEKAL	2.20	2.94	0.10	0.40	2.37	2.03
THEUNISSEN	2.89	3.01	0.77	1.13	2.32	2.86
VANDERBIJLPARK	3.15	0.94	0.55	0.05	2.91	4.42
VENTERSBURG	3.40	3.11	0.13	0.26	2.95	2.60
VENTERSDORP	3.00	3.51	0.22	0.24	1.96	3.00
VILJOENSKROON	4.00	3.96	0.54	0.06	3.39	3.37
VIRGINIA	3.10	3.51	0.44	2.40	3.44	3.61
VREDEFORT	2.77	4.00	0.32	0.02	2.71	3.14
WELKOM	3.80	3.22	0.50	2.19	2.59	3.21
WESSELSBRON	3.41	3.21	1.56	2.04	2.98	3.19
WESTONARIA	3.50	1.23	0.53	0.09	3.29	3.56
WINBURG	2.10	3.03	0.44	0.16	2.44	2.87

5.6.2 Comparison of individual farm yields and simulated cell yields in the drought monitoring system

In the comparison of simulated cell yield with individual farm yields, the cell in which the farm occurred was identified and the final simulated yield was compared to the yield recorded by the farmer. The measured yields obtained were not from experimental plots but each of the 57 used were on-farm yields. The yields were those recorded by the farmer as delivered to the silo. Harvesting losses are therefore not known. It must be borne in mind that the yield of a cell which covers approximately 1300 hectares was compared to single farm yields (200 - 300 ha) within the cell.

In the DMS, the dominant soil type and depth of the land-type within which the cell lies is used as the soil input. This means that the precise depth and characteristics of the particular farm were unknown in the simulation. Furthermore the DMS uses a recommended planting date per magisterial district. The exact planting date for the measured yields was therefore not known.

Bearing these limitations in mind, it was decided beforehand that the DMS would be deemed to be producing acceptable results if the following criteria were met in the statistical analysis:

a) RMSE (kg ha^{-1}) <700

b) MAE (%) <20

c) r^2 >0.55

d) Willmott Index of Agreement >0.8

The statistical analysis of the comparison is shown in Table 5.21 below. From Table 5.21 it can be seen that the cell yields simulated in the DMS met each of the criteria. Furthermore as in the validation of the maize model (Section 5.1) the value of the unsystematic RMSE is considerably higher than that of the systematic RMSE, and relatively close to the RMSE. This indicates that there is no consistent bias in the model and that good agreement exists between measured and simulated values.

The results obtained from comparison of simulated cell yield with individual farm yields show that the DMS functions well. This is so as indexing of drought classes in the DMS is done purely on comparison of simulated yield for a given cell, with its particular CDF. The simulated yields compared well with the measured yield, bearing the limitations outlined above in mind. As the allocation of drought class depends on simulated yield it was concluded that the DMS was a good indicator of agricultural drought in a given area.

Table 5.21 Statistical analysis of measured farm yields and simulated cell yields

STATISTIC		
Number of pairs (n)	57	
Root Mean Square Error (RMSE)	567 kg ha^{-1}	
Systematic RMSE	339 kg ha^{-1}	35%
Unsystematic RMSE	458 kg ha^{-1}	65%
Mean absolute error	482 kg ha^{-1}	17%
Coefficient of determination (r^2)	0.592	
Willmott Index of Agreement	0.854	

The conclusions drawn from the study and recommendations made are documented in Chapter 6.

6. CONCLUSIONS AND RECOMMENDATIONS

In this chapter, recommendations for improving the system, aspects of operational implementation of the system, and the main conclusions drawn, are recorded.

6.1 RECOMMENDATIONS FOR IMPROVING THE WEATHER DATA BASE

The major disadvantage of the ordinary kriging interpolation process used for daily maximum and minimum temperatures, was that altitude was not taken into account during interpolation. This had a negative effect on minimum temperatures interpolated during the colder months of the season. Although the method applied yielded r^2 values of 0.5 and greater, when compared to measured values, its accuracy may be increased by using co-kriging as the interpolation technique.

Digital elevation data would serve as an additional variable to be combined with the temperature data. Gridded elevation data may be obtained from the Surveyor General at a 1′ x 1′ resolution. These data should be tested in co-kriging interpolation to determine whether interpolated values of greater accuracy could be attained.

Only the visible band of METEOSAT data was used to estimate total radiant flux density in this study. Research should be undertaken to evaluate the feasibility of using METEOSAT thermal infra-red data for estimating surface temperatures. Should this prove to be successful it will greatly aid in obtaining true spatially distributed temperature data, rather than interpolated values. These infra-red data may also be used to supplement existing surface observations. The greatest problem here is that the temperature of cloud tops are sensed when a pixel is obscured by cloud. Ideally the surface should be cloud free around the time of the daily maximum and minimum temperatures.

6.2 RECOMMENDATIONS FOR IMPROVING THE SOIL DATA BASE

The process of establishing the soil data base for the three map sheets used in the study was extremely time consuming and relied heavily on expert interpretation of land-type inventories. To use the system operationally would require the rapid creation of gridded soil data bases for several 1:250 000 map sheets. Obtaining the necessary soil data in a digital format would be best. The ISCW has captured much of the land-type data digitally at a scale of 1:50 000. The attribute data associated with the digitized polygons has also been computerized. Using these two sources, soil scientists at the ISCW could produce the necessary information. The cost of such data is at present prohibitive and will have to be borne in mind in operational application of the drought monitoring system.

6.3 GENERAL CONCLUSIONS

The main conclusions drawn from the study are:

a) The adapted method of estimating daily total radiant flux density from METEOSAT visible band imagery is extremely accurate. Spatially distributed irradiance maps (digital or hard copy) can easily be generated and may be used in spheres other than drought assessment and agriculture.

b) The PUTU maize crop growth model was successfully adapted to work on a spatially distributed grid of input weather and management data, in order to compute a numerical crop-specific drought index on a daily basis. The drought monitoring system is so designed that any other crop model using daily temperature, rainfall and irradiance data could easily be altered to be linked with the spatially distributed weather data bases.

c) Mechanisms to obtain, process and interpolate the weather, soil and crop data inputs required for running the models have been established and tested.

d) A crop-specific drought monitoring system, based upon simulation models, has been developed, implemented and tested with excellent results. The PUTU maize model was applied in this study. Similar monitoring can be undertaken with the PUTU wheat or PUTU rangeland model.

The crop modelling approach to drought assessment takes the interaction of the soil, plant and atmosphere into account and is crop specific. The important influence of both the amount and timing of rainfall in relation to crop growth stages is reflected in the drought index. A major requirement for an effective and reliable drought index is that it should be crop and region specific. The present system ensures this by using the cumulative probability distribution function; for each combination of soil, planting date and homogeneous climate zone within which the crop is cultivated, as an accurate norm against which current season performance is compared. This provides an assessment of drought severity which meets these requirements.

The use of a GIS makes for convenient display of the spatial extent and severity of a current drought together with other spatially significant information, such as magisterial district boundaries. Furthermore the GIS/modelling system permits both delimitation of drought stricken areas and indication of the intensity of the drought. The system is dynamic in the sense of providing regular updates of a drought situation during the current season. The use of different surrogate scenarios for completing the season provides valuable decision support for planners and policy makers.

The system described is suitable for use in any country where the necessary resource information exists for establishment of the data bases required.

7. SUMMARY

The objectives of this study were:

(i) to develop a near real-time crop-specific drought monitoring system that delimits drought stricken areas and assesses the severity of droughts in these areas,

(ii) to produce products from the system which can be used for decision support by decision makers, and,

(ii) to test the system for maize production using historical production seasons.

Objectives (i) and (ii)

An agricultural drought monitoring system was designed, which combined crop growth modelling and a Geographic Information System (GIS). The use of crop models made it possible to assess the drought damage suffered by crops, in relation to their growth stage. As drought is a spatially related phenomenon, a GIS was used to present the geographic distribution of a drought situation.

A grid based, spatially distributed, system was designed. The map units of the South African 1:250 000 map series were used as the base units on which to present information. Each base unit was divided into cells covering an area of 2′ by 2′ minutes of latitude and longitude. There were thus 1800 grid cells in one such unit. The models were run for each of these cells.

The data inputs required by the crop models therefore had to be spatially distributed. Methods of creating spatially distributed weather data bases, were implemented or developed. Existing interpolation techniques were used to create the rainfall and temperature data bases. A technique developed for determining daily irradiance, from the Japanese Geostationary Meteorological Satellite, was adapted for use on METEOSAT data obtained over South Africa. A spatially distributed soil data base was also created.

Maize was chosen as the crop to monitor in the initial evaluation of the system. Drought monitoring was undertaken at fortnightly intervals from the beginning of the crop production season. At each interval, observed weather data was used up to the present date, and the season completed with surrogate data. Three surrogate scenarios were used: a below normal rainfall year, a normal rainfall year, and, an above normal rainfall year.

Surrogate data were created for each homogeneous climate zone (HCZ) within the study area. The HCZ within which the cell lay was determined and its data used to complete the season. A rainfall data generator, the accuracy of which had been proved, was used in establishing the surrogate data.

The cumulative probability distribution function (CDF) of seasonal yield, was used as the norm against which to measure current season performance at the conclusion of each monitoring session. CDF's were established for all combinations of soil, climate, and planting dates used within the bounds of a particular 1:250 000 map unit.

The yield simulated for each cell was compared with the appropriate CDF, and the probability range within which it lay, determined. A drought index value was assigned based on this comparison. The indices were:

1 - Extreme Drought (CDF probability range 0 - 10%),
2 - Severe Drought (>10 - 20%),
3 - Moderate Drought (>20 - 30%),
4 - Mild Drought (>30 - 40%), and,
5 - No Drought (>40 - 100%).

Maps showing the distribution, and tables providing the extent of area classified, were produced.

<u>Objective (iii)</u>

The drought monitoring system was tested for three maize production seasons. The accuracy of the system was determined by comparing the average maize yield per magisterial district with measured yield data. Individual farm records were also evaluated. The system accurately portrayed the general maize production trends during a severe drought (91/92), while an r^2 of 0.59 was obtained for the individual yields.

The crop modelling approach to drought assessment takes the interaction of the soil, plant and atmosphere into account and is crop specific. The important influence of both the amount and timing of rainfall in relation to crop growth stages is therefore reflected in the drought index.

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APPENDIX A Median maize yields obtained from cumulative distribution functions determined for each homogeneous climate zone used in the study

HCZ = Homogeneous climate zone
PDATE = Planting Date (Day and Month)
EFFCT SOIL DEPTH = Effective soil depth
MAP = Mean Annual Precipitation
MEAS = Measured **GEN** = Generated

MAG DISTRICT = Magisterial District
PDENS = Planting density (ha^{-1})
TOT WAT = Plant available water in the effective soil depth

MAP SHEET **2626 WEST RAND**

HCZ	MAG DISTRICT	LAND TYPE	SOIL FORM	PDATE	PDENS	ROW WIDTH	EFFCT SOIL DEPTH (m)	TOT WAT (mm)	MEDIAN YIELD kg ha^{-1}
458	MEAS MAP 602.3		GEN MAP 596.64						
458	COLIGNY	Ba25	Hu26P202.a	25 11	18000	1.90	1.50	188.	3969.63
458	COLIGNY	Bb23	Av36P228.b	25 11	18000	1.90	.70	62.	3935.42
458	COLIGNY	Bc33	Hu36P201.a	25 11	18000	1.90	1.50	158.	3968.60
458	COLIGNY	Bd10	Av36P120.a	25 11	18000	1.90	.95	127.	3963.84
458	KLERKSDORP	Bd10	Av36P120.a	20 11	18000	1.20	.95	127.	3953.51
458	LICHTENBURG	Ba25	Hu26P202.a	28 11	18000	1.20	1.50	188.	3967.47
458	LICHTENBURG	Bc11	Hu26P113.a	28 11	18000	1.20	1.20	142.	3956.12
458	LICHTENBURG	Bc19	Hu36P203.a	28 11	18000	1.20	.75	68.	3845.18
458	LICHTENBURG	Bc31	Hu36P203.d	28 11	18000	1.20	.75	68.	3844.50
458	LICHTENBURG	Bd10	Av36P120.a	28 11	18000	1.20	.95	127.	3959.33
458	LICHTENBURG	Bd23	Av36P228.c	28 11	18000	1.20	.95	86.	3954.02
458	LICHTENBURG	Bd6	We12P112.a	28 11	18000	1.20	.40	52.	3248.34
458	LICHTENBURG	Ea14	Rg20P114.a	28 11	18000	1.20	.60	72.	3900.96
458	LICHTENBURG	Fa11	Hu26P225.a	28 11	18000	1.20	.60	61.	3453.43
459	MEAS MAP 550.4		GEN MAP 581.49						
459	KLERKSDORP	Bd10	Av36P120.a	20 11	18000	1.20	.95	127.	3920.69
459	LICHTENBURG	Bc19	Hu36P203.a	28 11	18000	1.20	.75	68.	3517.97
459	LICHTENBURG	Bd10	Av36P120.a	28 11	18000	1.20	.95	127.	3945.66
459	WOLMARANSSTAD	Bd10	Av36P120.a	24 11	14000	1.90	.95	127.	3214.13
467	MEAS MAP 548.7		GEN MAP 542.85						
467	KLERKSDORP	Bc18	Hu36P171.a	20 11	18000	1.20	.60	69.	2208.29
467	KLERKSDORP	Bc20	Hu36P203.b	20 11	18000	1.20	.50	51.	1859.57
467	KLERKSDORP	Bc23	Hu37P204.a	20 11	18000	1.20	.45	39.	1840.75
467	KLERKSDORP	Bd10	Av36P120.a	20 11	18000	1.20	.95	127.	3463.43
467	KLERKSDORP	Bd12	Cv36P172.a	20 11	18000	1.20	.50	50.	1971.99
467	WOLMARANSSTAD	Bc18	Hu36P171.a	24 11	14000	1.90	.60	69.	2378.69
467	WOLMARANSSTAD	Bd10	Av36P120.a	24 11	14000	1.90	.95	127.	3196.91
468	MEAS MAP 578.1		GEN MAP 592.31						
468	KLERKSDORP	Ba26	Hu26P194.a	20 11	18000	1.20	1.00	91.	3907.86
468	KLERKSDORP	Ba40	Hu26P224.d	20 11	18000	1.20	1.50	166.	3963.00
468	KLERKSDORP	Bc18	Hu36P171.a	20 11	18000	1.20	.60	69.	3228.34
468	KLERKSDORP	Bc20	Hu36P203.b	20 11	18000	1.20	.50	51.	2901.19
468	KLERKSDORP	Bc31	Hu36P203.d	20 11	18000	1.20	.75	68.	3443.90
468	KLERKSDORP	Bc32	Hu36P203.e	20 11	18000	1.20	.50	52.	2817.79
468	KLERKSDORP	Bc34	Hu36P203.f	20 11	18000	1.20	.75	68.	3472.73
468	KLERKSDORP	Bd10	Av36P120.a	20 11	18000	1.20	.95	127.	3922.00
468	KLERKSDORP	Bd23	Av36P228.c	20 11	18000	1.20	.95	86.	3929.62
468	LICHTENBURG	Bd10	Av36P120.a	28 11	18000	1.20	.95	127.	3933.60
468	WOLMARANSSTAD	Bc31	Hu36P203.d	24 11	14000	1.90	.75	68.	3189.45
468	WOLMARANSSTAD	Bd10	Av36P120.a	24 11	14000	1.90	.95	127.	3214.60
469	MEAS MAP 589.0		GEN MAP 589.68						
469	KLERKSDORP	Ba26	Hu26P194.a	20 11	18000	1.20	1.00	91.	3768.32
469	KLERKSDORP	Ba41	Hu26P211.b	20 11	18000	1.20	1.50	166.	3949.61
469	KLERKSDORP	Ba42	Hu26P211.c	20 11	18000	1.20	1.10	114.	3793.93
469	KLERKSDORP	Bc20	Hu36P203.b	20 11	18000	1.20	.50	51.	2583.83
469	KLERKSDORP	Bc23	Hu37P204.a	20 11	18000	1.20	.45	39.	2340.64
469	KLERKSDORP	Bc24	Hu36P171.b	20 11	18000	1.20	1.50	159.	3950.83
469	KLERKSDORP	Bc25	Hu36P171.c	20 11	18000	1.20	1.50	159.	3950.83

469 KLERKSDORP	Bc31	Hu36P203.d	20	11	18000	1.20	.75	68.	3052.39
469 KLERKSDORP	Bc34	Hu36P203.f	20	11	18000	1.20	.75	68.	3122.11
469 KLERKSDORP	Bd12	Cv36P172.a	20	11	18000	1.20	.50	50.	2534.92
469 KLERKSDORP	Fa14	Hu26P217.a	20	11	18000	1.20	.60	62.	2697.04
469 POTCHEFSTROOM	Ae41	Hu26P208.a	15	11	18000	1.20	1.50	159.	3892.30
469 POTCHEFSTROOM	Ba42	Hu26P211.c	15	11	18000	1.20	1.10	114.	3707.52
469 POTCHEFSTROOM	Bc33	Hu36P201.a	15	11	18000	1.20	1.50	158.	3701.60
469 POTCHEFSTROOM	Fa14	Hu26P217.a	15	11	18000	1.20	.60	62.	2566.88
469 VENTERSDORP	Ba41	Hu26P211.b	18	11	18000	1.90	1.50	166.	3962.65
469 VENTERSDORP	Ba42	Hu26P211.c	18	11	18000	1.90	1.10	114.	3804.39
469 VENTERSDORP	Bc33	Hu36P201.a	18	11	18000	1.90	1.50	158.	3891.24
469 VENTERSDORP	Bc34	Hu36P203.f	18	11	18000	1.90	.75	68.	3263.88
470 MEAS MAP 558.7		GEN MAP 564.96							
470 COLIGNY	Ba25	Hu26P202.a	25	11	18000	1.90	1.50	188.	3967.75
470 COLIGNY	Bb23	Av36P228.b	25	11	18000	1.90	.70	62.	3416.50
470 COLIGNY	Bc31	Hu36P203.d	25	11	18000	1.90	.75	68.	3140.12
470 COLIGNY	Bc33	Hu36P201.a	25	11	18000	1.90	1.50	158.	3960.08
470 COLIGNY	Bd10	Av36P120.a	25	11	18000	1.90	.95	127.	3895.01
470 COLIGNY	Bd23	Av36P228.c	25	11	18000	1.90	.95	86.	3767.29
470 COLIGNY	Fa15	Hu26P210.a	25	11	18000	1.90	.70	70.	2877.64
470 KLERKSDORP	Ba41	Hu26P211.b	20	11	18000	1.20	1.50	166.	3960.24
470 KLERKSDORP	Bb23	Av36P228.b	20	11	18000	1.20	.70	62.	3077.45
470 KLERKSDORP	Bc31	Hu36P203.d	20	11	18000	1.20	.75	68.	2904.12
470 KLERKSDORP	Bc32	Hu36P203.e	20	11	18000	1.20	.50	52.	2217.00
470 KLERKSDORP	Bc33	Hu36P201.a	20	11	18000	1.20	1.50	158.	3954.98
470 KLERKSDORP	Bc34	Hu36P203.f	20	11	18000	1.20	.75	68.	2963.46
470 KLERKSDORP	Bd23	Av36P228.c	20	11	18000	1.20	.95	86.	3654.41
470 VENTERSDORP	Ba41	Hu26P211.b	18	11	18000	1.90	1.50	166.	3963.97
470 VENTERSDORP	Ba42	Hu26P211.c	18	11	18000	1.90	1.10	114.	3637.67
470 VENTERSDORP	Bc33	Hu36P201.a	18	11	18000	1.90	1.50	158.	3955.00
471 MEAS MAP 483.0		GEN MAP 461.15							
471 COLIGNY	Ba25	Hu26P202.a	25	11	18000	1.90	1.50	188.	3947.92
471 COLIGNY	Bd10	Av36P120.a	25	11	18000	1.90	.95	127.	3528.27
471 COLIGNY	Fa15	Hu26P210.a	25	11	18000	1.90	.70	70.	2331.57
471 KOSTER	Ba43	Hu26P748.a	20	11	18000	1.20	1.50	158.	3270.35
471 KOSTER	Fa15	Hu26P210.a	20	11	18000	1.20	.70	70.	2001.93
471 LICHTENBURG	Ae42	Hu26P208.b	28	11	18000	1.20	1.50	163.	2827.25
471 LICHTENBURG	Ba25	Hu26P202.a	28	11	18000	1.20	1.50	188.	3647.42
471 LICHTENBURG	Bd10	Av36P120.a	28	11	18000	1.20	.95	127.	3213.70
471 LICHTENBURG	Fa11	Hu26P225.a	28	11	18000	1.20	.60	61.	2122.52
471 LICHTENBURG	Fa15	Hu26P210.a	28	11	18000	1.20	.70	70.	2257.44
471 VENTERSDORP	Ba43	Hu26P748.a	18	11	18000	1.90	1.50	158.	3706.06
471 VENTERSDORP	Bc33	Hu36P201.a	18	11	18000	1.90	1.50	158.	3183.42
471 VENTERSDORP	Fa15	Hu26P210.a	18	11	18000	1.90	.70	70.	2152.15
472 MEAS MAP 639.2		GEN MAP 636.31							
472 VENTERSDORP	Ae43	Hu26P208.c	18	11	18000	1.90	.75	69.	3103.55
472 VENTERSDORP	Ba42	Hu26P211.c	18	11	18000	1.90	1.10	114.	3811.87
472 VENTERSDORP	Bc33	Hu36P201.a	18	11	18000	1.90	1.50	158.	3951.11
472 VENTERSDORP	Fa15	Hu26P210.a	18	11	18000	1.90	.70	70.	2665.69
473 MEAS MAP 483.6		GEN MAP 473.76							
473 VENTERSDORP	Ba41	Hu26P211.b	18	11	18000	1.90	1.50	166.	2352.21
473 VENTERSDORP	Ba42	Hu26P211.c	18	11	18000	1.90	1.10	114.	2239.49
473 VENTERSDORP	Bc33	Hu36P201.a	18	11	18000	1.90	1.50	158.	2121.78
474 MEAS MAP 575.9		GEN MAP 582.70							
474 KOSTER	Ba43	Hu26P748.a	20	11	18000	1.20	1.50	158.	3965.49
474 OBERHOLZER	Ab7	Hu26P224.b	08	11	25000	1.20	.70	67.	2679.41
474 OBERHOLZER	Fa14	Hu26P217.a	08	11	25000	1.20	.60	62.	2382.22
474 POTCHEFSTROOM	Bc37	Hu36P203.h	15	11	18000	1.20	1.50	157.	3963.97
474 POTCHEFSTROOM	Fa14	Hu26P217.a	15	11	18000	1.20	.60	62.	2325.94
474 RANDFONTEIN	Ab7	Hu26P224.b	08	11	25000	1.20	.70	67.	2679.41
474 RANDFONTEIN	Ba36	Gc24P226.a	08	11	25000	1.20	1.20	121.	4441.49
474 RANDFONTEIN	Fa17	Hu26P225.a	08	11	25000	1.20	.60	61.	2350.13
474 VENTERSDORP	Ab7	Hu26P224.b	18	11	18000	1.90	.70	67.	2795.71
474 VENTERSDORP	Ae41	Hu26P208.a	18	11	18000	1.90	1.50	159.	3934.75
474 VENTERSDORP	Ba43	Hu26P748.a	18	11	18000	1.90	1.50	158.	3950.83

474	VENTERSDORP	Bc33	Hu36P201.a	18	11	18000	1.90	1.50	158.	3844.35
474	VENTERSDORP	Fa14	Hu26P217.a	18	11	18000	1.90	.60	62.	2398.64
474	VENTERSDORP	Fa15	Hu26P210.a	18	11	18000	1.90	.70	70.	2732.03
474	WESTONARIA	Ab7	Hu26P224.b	07	11	25000	1.20	.70	67.	2680.15
474	WESTONARIA	Ba36	Gc24P226.a	07	11	25000	1.20	1.20	121.	4406.69
475	MEAS MAP 656.3		GEN MAP 619.91							
475	KOSTER	Ba43	Hu26P748.a	20	11	18000	1.20	1.50	158.	3969.36
475	KOSTER	Ba44	Hu26P211.d	20	11	18000	1.20	1.50	156.	3965.99
475	KOSTER	Fa17	Hu26P225.a	20	11	18000	1.20	.60	61.	3083.06
475	KRUGERSDORP	Fa17	Hu26P225.a	10	11	25000	0.91	.60	61.	3205.41
475	OBERHOLZER	Ab7	Hu26P224.b	08	11	25000	1.20	.70	67.	3334.69
475	OBERHOLZER	Fa14	Hu26P217.a	08	11	25000	1.20	.60	62.	3185.97
475	POTCHEFSTROOM	Ba1	Hu27P150.a	15	11	18000	1.20	.90	73.	3797.69
475	POTCHEFSTROOM	Bc36	Hu36P203.h	15	11	18000	1.20	1.50	157.	3968.60
475	POTCHEFSTROOM	Fb5	Hu16P227.a	15	11	18000	1.20	.60	72.	3757.92
475	RANDFONTEIN	Ab4	Hu26P224.a	08	11	25000	1.20	1.50	163.	4857.83
475	RANDFONTEIN	Ab7	Hu26P224.b	08	11	25000	1.20	.70	67.	3334.69
475	RANDFONTEIN	Ba36	Gc24P226.a	08	11	25000	1.20	1.20	121.	4866.72
475	RANDFONTEIN	Bc36	Hu36P203.h	08	11	25000	1.20	1.50	157.	4940.54
475	RANDFONTEIN	Fa17	Hu26P225.a	08	11	25000	1.20	.60	61.	3114.91
475	VANDERBIJLPARK	Ba1	Hu27P150.a	08	11	23000	1.20	.90	73.	3983.17
475	VENTERSDORP	Ab7	Hu26P224.b	18	11	18000	1.90	.70	67.	3576.14
475	VENTERSDORP	Ae41	Hu26P208.a	18	11	18000	1.90	1.50	159.	3971.00
475	VENTERSDORP	Ba43	Hu26P748.a	18	11	18000	1.90	1.50	158.	3971.34
475	VENTERSDORP	Fa14	Hu26P217.a	18	11	18000	1.90	.60	62.	3236.73
475	VENTERSDORP	Fa17	Hu26P225.a	18	11	18000	1.90	.60	61.	3250.66
475	WESTONARIA	Ab7	Hu26P224.b	07	11	25000	1.20	.70	67.	3206.70
475	WESTONARIA	Ba1	Hu27P150.a	07	11	25000	1.20	.90	73.	3952.23
475	WESTONARIA	Ba36	Gc24P226.a	07	11	25000	1.20	1.20	121.	4857.34
475	WESTONARIA	Fb5	Hu16P227.a	07	11	25000	1.20	.60	72.	3787.46
476	MEAS MAP 608.2		GEN MAP 627.82							
476	PARYS	Bc36	Hu36P203.h	10	11	20000	1.20	1.50	157.	4271.10
476	POTCHEFSTROOM	Bb23	Av36P228.b	15	11	18000	1.20	.70	62.	3314.09
476	POTCHEFSTROOM	Bc25	Hu36P171.c	15	11	18000	1.20	1.50	159.	3966.17
476	POTCHEFSTROOM	Bc36	Hu36P203.h	15	11	18000	1.20	1.50	157.	3965.09
476	POTCHEFSTROOM	Bc37	Hu36P203.h	15	11	18000	1.20	1.50	157.	3965.09
476	POTCHEFSTROOM	Bd23	Av36P228.c	15	11	18000	1.20	.95	86.	3871.31
476	POTCHEFSTROOM	Fa19	Hu26P210.a	15	11	18000	1.20	.70	70.	2933.91
476	VANDERBIJLPARK	Ba1	Hu27P150.a	08	11	23000	1.20	.90	73.	3306.56
476	VANDERBIJLPARK	Ba29	Hu36P146.a	08	11	23000	1.20	1.20	108.	4267.82
476	VANDERBIJLPARK	Bb23	Av36P228.b	08	11	23000	1.20	.70	62.	3119.12
476	VANDERBIJLPARK	Bc36	Hu36P203.h	08	11	23000	1.20	1.50	157.	4634.21
476	VANDERBIJLPARK	Bd23	Av36P228.c	08	11	23000	1.20	.95	86.	3666.05
476	VEREENIGING	Ba1	Hu27P150.a	01	11	23000	1.20	.90	73.	3217.74
476	VEREENIGING	Ba29	Hu36P146.a	01	11	23000	1.20	1.20	108.	4152.15
476	WESTONARIA	Ba1	Hu27P150.a	07	11	25000	1.20	.90	73.	3272.45
476	WESTONARIA	Fb5	Hu16P227.a	07	11	25000	1.20	.60	72.	3043.32
477	MEAS MAP 620.2		GEN MAP 615.67							
477	KLERKSDORP	Fa14	Hu26P217.a	20	11	18000	1.20	.60	62.	2602.77
477	POTCHEFSTROOM	Bc25	Hu36P171.c	15	11	18000	1.20	1.50	159.	3959.34
477	POTCHEFSTROOM	Bc36	Hu36P203.h	15	11	18000	1.20	1.50	157.	3953.22
477	POTCHEFSTROOM	Bc37	Hu36P203.h	15	11	18000	1.20	1.50	157.	3953.22
477	POTCHEFSTROOM	Fa14	Hu26P217.a	15	11	18000	1.20	.60	62.	2553.65
477	POTCHEFSTROOM	Fa19	Hu26P210.a	15	11	18000	1.20	.70	70.	2654.49
478	MEAS MAP 645.0		GEN MAP 657.34							
478	POTCHEFSTROOM	Bc25	Hu36P171.c	15	11	18000	1.20	1.50	159.	3959.14
478	VILJOENSKROON	Bc25	Hu36P171.c	15	11	18000	1.90	1.50	159.	3965.62
478	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.90	1.05	92.	3925.97
478	VREDEFORT	Bc25	Hu36P171.c	13	11	20000	1.20	1.50	159.	4249.70
479	MEAS MAP 597.2		GEN MAP 595.42							
479	KLERKSDORP	Bc25	Hu36P171.c	20	11	18000	1.20	1.50	159.	3940.84
479	POTCHEFSTROOM	Bc25	Hu36P171.c	15	11	18000	1.20	1.50	159.	3903.00
479	VILJOENSKROON	Bc25	Hu36P171.c	15	11	18000	1.90	1.50	159.	3881.90
479	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.90	1.05	92.	3867.75
479	VREDEFORT	Bc25	Hu36P171.c	13	11	20000	1.20	1.50	159.	3883.63

480	MEAS MAP 527.9	GEN MAP	533.59							
480	VILJOENSKROON	Bc25	Hu36P171.c	15	11	18000	1.90	1.50	159.	3702.59
480	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.90	1.05	92.	3693.16
489	MEAS MAP 663.0	GEN MAP	684.17							
489	PARYS	Ba38	Hu26P194.d	10	11	20000	1.20	.80	82.	3163.98
489	PARYS	Bd17	We13P758.a	10	11	20000	1.20	.40	31.	1884.50
489	PARYS	Dc7	Ar20P195.a	10	11	20000	1.20	.60	54.	2598.81
489	VREDEFORT	Ba38	Hu26P194.d	13	11	20000	1.20	.80	82.	3166.21
490	MEAS MAP 643.7	GEN MAP	640.11							
490	HEILBRON	Dc7	Ar20P195.a	01	11	20000	1.20	.60	54.	2962.91
490	PARYS	Bb23	Av36P228.b	10	11	20000	1.20	.70	62.	3321.65
490	PARYS	Dc7	Ar20P195.a	10	11	20000	1.20	.60	54.	2676.99
490	SASOLBURG	Bb23	Av36P228.b	05	11	22000	1.20	.70	62.	3204.87
490	SASOLBURG	Bd23	Av36P228.c	05	11	22000	1.20	.95	86.	3919.07
490	SASOLBURG	Ca1	Gc20P153.a	05	11	22000	1.20	.80	54.	2942.24
490	SASOLBURG	Dc7	Ar20P195.a	05	11	22000	1.20	.60	54.	2792.77
490	SASOLBURG	Ea16	Rg20P114.b	05	11	22000	1.20	.40	37.	2076.26
490	SASOLBURG	Ea27	Ar20P213.a	05	11	22000	1.20	.70	57.	3006.96
491	MEAS MAP 583.4	GEN MAP	576.41							
491	PARYS	Ba38	Hu26P194.d	10	11	20000	1.20	.80	82.	2345.34
491	PARYS	Ba39	Hu26P211.a	10	11	20000	1.20	1.00	109.	2946.25
491	PARYS	Bb23	Av36P228.b	10	11	20000	1.20	.70	62.	2344.73
491	PARYS	Dc7	Ar20P195.a	10	11	20000	1.20	.60	54.	1981.89
491	POTCHEFSTROOM	Ba38	Hu26P194.d	15	11	18000	1.20	.80	82.	2544.37
491	SASOLBURG	Bb23	Av36P228.b	05	11	22000	1.20	.70	62.	2171.21
491	VREDEFORT	Ba38	Hu26P194.d	13	11	20000	1.20	.80	82.	2364.62
492	MEAS MAP 694.2	GEN MAP	689.43							
492	PARYS	Ba38	Hu26P194.d	10	11	20000	1.20	.80	82.	3917.78
492	PARYS	Ba39	Hu26P211.a	10	11	20000	1.20	1.00	109.	4211.48
492	PARYS	Bb23	Av36P228.b	10	11	20000	1.20	.70	62.	3790.71
492	POTCHEFSTROOM	Ba38	Hu26P194.d	15	11	18000	1.20	.80	82.	3849.98
492	POTCHEFSTROOM	Ba39	Hu26P211.a	15	11	18000	1.20	1.00	109.	3912.34
492	SASOLBURG	Bb23	Av36P228.b	05	11	22000	1.20	.70	62.	3906.35
492	SASOLBURG	Ca1	Gc20P153.a	05	11	22000	1.20	.80	54.	3571.45
492	VANDERBIJLPARK	Ba31	Hu26P194.c	08	11	23000	1.20	1.20	137.	4380.17
492	VANDERBIJLPARK	Bb23	Av36P228.b	08	11	23000	1.20	.70	62.	3974.35
492	VEREENIGING	Ba29	Hu36P146.a	01	11	23000	1.20	1.20	108.	4622.70
492	VEREENIGING	Bb23	Av36P228.b	01	11	23000	1.20	.70	62.	3895.10
493	MEAS MAP 685.5	GEN MAP	685.26							
493	SASOLBURG	Bb23	Av36P228.b	05	11	22000	1.20	.70	62.	4143.05
493	SASOLBURG	Ca1	Gc20P153.a	05	11	22000	1.20	.80	54.	3660.17
493	VEREENIGING	Ba1	Hu27P150.a	01	11	23000	1.20	.90	73.	4274.43
493	VEREENIGING	Ba29	Hu36P146.a	01	11	23000	1.20	1.20	108.	4683.53
494	MEAS MAP 630.2	GEN MAP	613.36							
494	VEREENIGING	Ba1	Hu27P150.a	01	11	23000	1.20	.90	73.	3745.00
495	MEAS MAP 688.1	GEN MAP	702.48							
495	JOHANNESBURG	Ab7	Hu26P224.b	05	11	25000	1.20	.70	67.	4655.03
495	JOHANNESBURG	Ba27	Hu26P194.b	05	11	25000	1.20	.90	100.	4931.37
495	JOHANNESBURG	Ba35	Gc24P226.a	05	11	25000	1.20	1.20	121.	4951.05
495	JOHANNESBURG	Ba36	Gc24P226.a	05	11	25000	1.20	1.20	121.	4951.05
495	KOSTER	Ba44	Hu26P211.d	20	11	18000	1.20	1.50	156.	3969.60
495	KRUGERSDORP	Ab4	Hu26P224.a	10	11	25000	0.91	1.50	163.	4954.48
495	KRUGERSDORP	Ba36	Gc24P226.a	10	11	25000	0.91	1.20	121.	4948.54
495	KRUGERSDORP	Ba44	Hu26P211.d	10	11	25000	0.91	1.50	156.	4953.15
495	KRUGERSDORP	Fa17	Hu26P225.a	10	11	25000	0.91	.60	61.	4337.84
495	RANDFONTEIN	Ab4	Hu26P224.a	08	11	25000	1.20	1.50	163.	4955.58
495	RANDFONTEIN	Ab7	Hu26P224.b	08	11	25000	1.20	.70	67.	4558.83
495	RANDFONTEIN	Ba35	Gc24P226.a	08	11	25000	1.20	1.20	121.	4949.71
495	RANDFONTEIN	Ba36	Gc24P226.a	08	11	25000	1.20	1.20	121.	4949.71
495	RANDFONTEIN	Fa17	Hu26P225.a	08	11	25000	1.20	.60	61.	4177.77
495	ROODEPOORT	Ab7	Hu26P224.b	05	11	25000	1.20	.70	67.	4655.03
495	VEREENIGING	Ab7	Hu26P224.b	01	11	23000	1.20	.70	67.	4472.91

495	VEREENIGING	Fb5	Hu16P227.a	01 11	23000	1.20	.60	72.	4620.48
495	WESTONARIA	Ab7	Hu26P224.b	07 11	25000	1.20	.70	67.	4616.76
495	WESTONARIA	Ba1	Hu27P150.a	07 11	25000	1.20	.90	73.	4912.99
496	MEAS MAP 699.6		GEN MAP 691.45						
496	JOHANNESBURG	Ba36	Gc24P226.a	05 11	25000	1.20	1.20	121.	4951.04
496	KRUGERSDORP	Ab12	Hu26P224.c	10 11	25000	0.91	1.00	93.	4903.84
496	KRUGERSDORP	Ba35	Gc24P226.a	10 11	25000	0.91	1.20	121.	4945.83
496	KRUGERSDORP	Ba36	Gc24P226.a	10 11	25000	0.91	1.20	121.	4945.83
496	KRUGERSDORP	Bb1	Av36P228.a	10 11	25000	0.91	.60	75.	4018.34
496	RANDBURG	Bb1	Av36P228.a	05 11	25000	1.20	.60	75.	4168.61
496	RANDFONTEIN	Ba35	Gc24P226.a	08 11	25000	1.20	1.20	121.	4951.52
496	RANDFONTEIN	Ba36	Gc24P226.a	08 11	25000	1.20	1.20	121.	4951.52
496	ROODEPOORT	Ba36	Gc24P226.a	05 11	25000	1.20	1.20	121.	4951.04
496	ROODEPOORT	Bb1	Av36P228.a	05 11	25000	1.20	.60	75.	4168.61
496	VEREENIGING	Ab7	Hu26P224.b	01 11	23000	1.20	.70	67.	4092.82
496	VEREENIGING	Ba1	Hu27P150.a	01 11	23000	1.20	.90	73.	4578.45
496	VEREENIGING	Fb5	Hu16P227.a	01 11	23000	1.20	.60	72.	4447.09
497	MEAS MAP 799.4		GEN MAP 781.43						
497	JOHANNESBURG	Ba36	Gc24P226.a	05 11	25000	1.20	1.20	121.	4955.84
497	KRUGERSDORP	Ab12	Hu26P224.c	10 11	25000	0.91	1.00	93.	4953.99
497	KRUGERSDORP	Ba35	Gc24P226.a	10 11	25000	0.91	1.20	121.	4954.68
497	ROODEPOORT	Ba35	Gc24P226.a	05 11	25000	1.20	1.20	121.	4955.84
497	ROODEPOORT	Ba36	Gc24P226.a	05 11	25000	1.20	1.20	121.	4955.84
498	MEAS MAP 817.2		GEN MAP 837.69						
498	JOHANNESBURG	Ba35	Gc24P226.a	05 11	25000	1.20	1.20	121.	4955.92
498	JOHANNESBURG	Bb1	Av36P228.a	05 11	25000	1.20	.60	75.	4932.98
499	MEAS MAP 680.5		GEN MAP 687.07						
499	KRUGERSDORP	Ab12	Hu26P224.c	10 11	25000	0.91	1.00	93.	4743.61
499	KRUGERSDORP	Bb1	Av36P228.a	10 11	25000	0.91	.60	75.	3808.51
499	KRUGERSDORP	Bb2	Av36P228.a	10 11	25000	0.91	.60	75.	3808.51
499	RANDBURG	Bb1	Av36P228.a	05 11	25000	1.20	.60	75.	3919.58
499	RANDBURG	Bb2	Av36P228.a	05 11	25000	1.20	.60	75.	3919.58
554	MEAS MAP 601.9		GEN MAP 604.86						
554	LICHTENBURG	Bc11	Hu26P113.a	28 11	18000	1.20	1.20	142.	3960.94
554	LICHTENBURG	Fa10	Hu33P745.a	28 11	18000	1.20	.60	66.	3105.79
554	LICHTENBURG	Fa11	Hu26P225.a	28 11	18000	1.20	.60	61.	2955.02
571	MEAS MAP 668.9		GEN MAP 643.63						
571	KOSTER	Fa15	Hu26P210.a	20 11	18000	1.20	.70	70.	3409.74
571	LICHTENBURG	Ae42	Hu26P208.b	28 11	18000	1.20	1.50	163.	3966.45
571	LICHTENBURG	Fa15	Hu26P210.a	28 11	18000	1.20	.70	70.	3456.84
574	MEAS MAP 603.4		GEN MAP 580.00						
574	KOSTER	Ba43	Hu26P748.a	20 11	18000	1.20	1.50	158.	3957.15
574	KOSTER	Fa15	Hu26P210.a	20 11	18000	1.20	.70	70.	2392.47
574	VENTERSDORP	Fa15	Hu26P210.a	18 11	18000	1.90	.70	70.	2399.16

MAP SHEET 2726 KROONSTAD

HCZ	MAG DISTRICT	LAND TYPE	SOIL FORM	PDATE	PDENS	ROW WIDTH	EFFCT SOIL DEPTH (m)	TOT WAT (mm)	MEDIAN YIELD kg ha^{-1}
331	MEAS MAP 491.7		GEN MAP 503.16						
331	HOOPSTAD	Ae38	Hu36P162.b	28 11	12000	1.90	1.50	122.	2757.84
331	HOOPSTAD	Ah20	Hu36P456.a	28 11	12000	1.90	1.50	166.	2758.31
331	HOOPSTAD	Ai5	Cv34P170.a	28 11	12000	1.90	1.50	124.	2757.57
331	HOOPSTAD	Ai6	Cv33P175.a	28 11	12000	1.90	1.50	120.	2755.75
331	HOOPSTAD	Dc4	Va41P486.a	28 11	12000	1.90	.60	61.	1644.09
331	HOOPSTAD	Dc8	Va41P486.b	28 11	12000	1.90	.60	57.	1650.82
331	WESSELSBRON	Ae38	Hu36P162.b	25 11	14000	1.20	1.50	122.	3208.79
331	WESSELSBRON	Ae40	Hu33P176.a	25 11	14000	1.20	1.50	161.	3206.67
331	WESSELSBRON	Ai6	Cv33P175.a	25 11	14000	1.20	1.50	120.	3197.43

331	WESSELSBRON	Dc9	Hu36P162.c	25	11	14000	1.20	1.20	140.	3138.35
331	WOLMARANSSTAD	Bd11	Av31P168.a	24	11	14000	1.20	1.50	97.	3148.84
343	MEAS MAP 499.8	GEN MAP 493.92								
343	BOTHAVILLE	Bc28	Bv36P183.a	16	11	18000	1.90	1.50	172.	2664.97
343	BOTHAVILLE	Bd18	Av34P174.a	16	11	18000	1.90	1.50	128.	2972.43
343	BOTHAVILLE	Bd19	Av34P174.b	16	11	18000	1.90	1.00	124.	2401.68
343	BOTHAVILLE	Db1	Va41P486.a	16	11	18000	1.90	.60	61.	1441.86
343	BOTHAVILLE	Dc6	Bo40P184.a	16	11	18000	1.90	.60	66.	1858.44
343	HENNENMAN	Bc30	Bv36P181.a	17	11	15000	1.90	.75	104.	2622.15
343	KROONSTAD	Bc28	Bv36P183.a	15	11	18000	1.52	1.50	172.	2539.13
343	KROONSTAD	Bd18	Av34P174.a	15	11	18000	1.52	1.50	128.	2889.30
343	KROONSTAD	Bd19	Av34P174.b	15	11	18000	1.52	1.00	124.	2279.94
343	KROONSTAD	Bd21	Av36P190.a	15	11	18000	1.52	1.00	105.	2624.94
343	KROONSTAD	Db1	Va41P486.a	15	11	18000	1.52	.60	61.	1387.34
343	KROONSTAD	Dc6	Bo40P184.a	15	11	18000	1.52	.60	66.	1711.63
343	ODENDAALSRUS	Ae39	Hu36P162.b	18	11	17000	1.52	1.50	122.	3742.35
343	ODENDAALSRUS	Ae40	Hu33P176.a	18	11	17000	1.52	1.50	161.	3628.68
343	ODENDAALSRUS	Bd18	Av34P174.a	18	11	17000	1.52	1.50	128.	2977.48
343	ODENDAALSRUS	Bd19	Av34P174.b	18	11	17000	1.52	1.00	124.	2502.45
343	ODENDAALSRUS	Bd20	Cv36P485.a	18	11	17000	1.52	1.50	178.	3723.20
343	ODENDAALSRUS	Db1	Va41P486.a	18	11	17000	1.52	.60	61.	1526.34
343	ODENDAALSRUS	Dc9	Hu36P162.c	18	11	17000	1.52	1.20	140.	3365.70
343	WELKOM	Ae40	Hu33P176.a	20	11	14000	1.20	1.50	161.	3204.20
343	WELKOM	Bc30	Bv36P181.a	20	11	14000	1.20	.75	104.	2798.28
343	WELKOM	Bd20	Cv36P485.a	20	11	14000	1.20	1.50	178.	3211.95
343	WELKOM	Db1	Va41P486.a	20	11	14000	1.20	.60	61.	1700.64
343	WELKOM	Dc9	Hu36P162.c	20	11	14000	1.20	1.20	140.	3163.81
343	WESSELSBRON	Ae40	Hu33P176.a	25	11	14000	1.20	1.50	161.	3209.36
343	WESSELSBRON	Dc9	Hu36P162.c	25	11	14000	1.20	1.20	140.	3164.64
345	MEAS MAP 626.6	GEN MAP 598.59								
345	HENNENMAN	Bd21	Av36P190.a	17	11	15000	1.90	1.00	105.	3432.60
345	KROONSTAD	Bd21	Av36P190.a	15	11	18000	1.52	1.00	105.	3905.44
345	KROONSTAD	Dc10	Sw41P189.a	15	11	18000	1.52	.60	69.	3194.23
345	KROONSTAD	Dc12	Sw41P491.a	15	11	18000	1.52	.60	51.	2908.10
345	LINDLEY	Dc10	Sw41P189.a	01	11	22000	1.20	.60	69.	2795.45
345	SENEKAL	Bd22	We13P492.a	08	11	22000	0.91	.50	40.	2429.13
345	SENEKAL	Dc10	Sw41P189.a	08	11	22000	0.91	.60	69.	2852.05
345	VENTERSBURG	Bd21	Av36P190.a	16	11	14000	1.20	1.00	105.	3202.04
345	VENTERSBURG	Dc10	Sw41P189.a	16	11	14000	1.20	.60	69.	3049.14
345	VENTERSBURG	Dc12	Sw41P491.a	16	11	14000	1.20	.60	51.	2935.63
347	MEAS MAP 477.2	GEN MAP 482.15								
347	KROONSTAD	Bd21	Av36P190.a	15	11	18000	1.52	1.00	105.	2472.60
347	KROONSTAD	Dc10	Sw41P189.a	15	11	18000	1.52	.60	69.	1713.51
347	KROONSTAD	Dc6	Bo40P184.a	15	11	18000	1.52	.60	66.	1436.68
347	LINDLEY	Bd22	We13P492.a	01	11	22000	1.20	.50	40.	1406.65
347	LINDLEY	Ca5	We13P494.a	01	11	22000	1.20	.50	57.	1309.88
347	LINDLEY	Dc10	Sw41P189.a	01	11	22000	1.20	.60	69.	1627.90
347	SENEKAL	Bd22	We13P492.a	08	11	22000	0.91	.50	40.	1322.50
355	MEAS MAP 689.0	GEN MAP 651.97								
355	LINDLEY	Ca5	We13P494.a	01	11	22000	1.20	.50	57.	2862.60
355	LINDLEY	Ca6	Av36P173.b	01	11	22000	1.20	.80	91.	3438.34
355	LINDLEY	Dc10	Sw41P189.a	01	11	22000	1.20	.60	69.	3384.27
448	MEAS MAP 441.3	GEN MAP 435.42								
448	HOOPSTAD	Ai6	Cv33P175.a	28	11	12000	1.90	1.50	120.	2749.75
448	HOOPSTAD	Bd18	Av34P174.a	28	11	12000	1.90	1.50	128.	2660.12
448	HOOPSTAD	Dc4	Va41P486.a	28	11	12000	1.90	.60	61.	1333.49
448	WOLMARANSSTAD	Bc22	Av36P173.a	24	11	14000	1.20	1.00	129.	2520.76
448	WOLMARANSSTAD	Dc4	Va41P486.a	24	11	14000	1.20	.60	61.	1164.87
460	MEAS MAP 515.6	GEN MAP 521.26								
460	WOLMARANSSTAD	Bc19	Hu36P203.a	24	11	14000	1.20	.75	68.	2880.22
460	WOLMARANSSTAD	Bc21	Hu36P171.b	24	11	14000	1.20	.60	66.	2601.57
461	MEAS MAP 514.1	GEN MAP 519.58								
461	BOTHAVILLE	Bc23	Hu37P204.a	16	11	18000	1.90	.45	39.	1715.78

461	BOTHAVILLE	Bd13	Av34P178.a	16	11	18000	1.90		1.05	92.	3775.16
461	KLERKSDORP	Bd12	Cv36P172.a	20	11	18000	1.90		.50	50.	1999.01
461	WOLMARANSSTAD	Ae37	Hu36P162.a	24	11	14000	1.20		.40	35.	1785.45
461	WOLMARANSSTAD	Bc18	Hu36P171.a	24	11	14000	1.20		.60	69.	2227.87
461	WOLMARANSSTAD	Bc19	Hu36P203.a	24	11	14000	1.20		.75	68.	2440.47
461	WOLMARANSSTAD	Bc21	Hu36P171.b	24	11	14000	1.20		.60	66.	2461.39
461	WOLMARANSSTAD	Bc22	Av36P173.a	24	11	14000	1.20		1.00	129.	3190.51
461	WOLMARANSSTAD	Bc23	Hu37P204.a	24	11	14000	1.20		.45	39.	1706.55
461	WOLMARANSSTAD	Bd12	Cv36P172.a	24	11	14000	1.20		.50	50.	2092.58
461	WOLMARANSSTAD	Bd13	Av34P178.a	24	11	14000	1.20		1.05	92.	3185.00
462	MEAS MAP	484.3	GEN MAP	494.95							
462	BOTHAVILLE	Bd18	Av34P174.a	16	11	18000	1.90		1.50	128.	2781.69
462	BOTHAVILLE	Dc4	Va41P486.a	16	11	18000	1.90		.60	61.	1687.08
462	WOLMARANSSTAD	Bc22	Av36P173.a	24	11	14000	1.20		1.00	129.	3074.36
462	WOLMARANSSTAD	Bd13	Av34P178.a	24	11	14000	1.20		1.05	92.	3154.78
462	WOLMARANSSTAD	Dc4	Va41P486.a	24	11	14000	1.20		.60	61.	1792.22
463	MEAS MAP	463.5	GEN MAP	455.61							
463	WESSELSBRON	Ae40	Hu33P176.a	25	11	14000	1.20		1.50	161.	3128.34
463	WESSELSBRON	Dc9	Hu36P162.c	25	11	14000	1.20		1.20	140.	2925.11
464	MEAS MAP	545.1	GEN MAP	562.54							
464	BOTHAVILLE	Bd18	Av34P174.a	16	11	18000	1.90		1.50	128.	3857.39
464	HOOPSTAD	Ai6	Cv33P175.a	28	11	12000	1.90		1.50	120.	2758.80
464	ODENDAALSRUS	Bd18	Av34P174.a	18	11	17000	1.52		1.50	128.	3761.02
464	WESSELSBRON	Ae38	Hu36P162.b	25	11	14000	1.20		1.50	122.	3214.73
464	WESSELSBRON	Ae40	Hu33P176.a	25	11	14000	1.20		1.50	161.	3217.12
464	WESSELSBRON	Ai6	Cv33P175.a	25	11	14000	1.20		1.50	120.	3212.99
464	WESSELSBRON	Bd18	Av34P174.a	25	11	14000	1.20		1.50	128.	3216.46
464	WESSELSBRON	Dc4	Va41P486.a	25	11	14000	1.20		.60	61.	2459.21
464	WESSELSBRON	Dc9	Hu36P162.c	25	11	14000	1.20		1.20	140.	3192.64
464	WOLMARANSSTAD	Bc22	Av36P173.a	24	11	14000	1.20		1.00	129.	3168.40
464	WOLMARANSSTAD	Dc4	Va41P486.a	24	11	14000	1.20		.60	61.	2399.57
465	MEAS MAP	524.3	GEN MAP	518.79							
465	BOTHAVILLE	Bc24	Hu36P171.c	16	11	18000	1.90		1.50	159.	3453.50
465	BOTHAVILLE	Bc28	Bv36P183.a	16	11	18000	1.90		1.50	172.	3583.01
465	BOTHAVILLE	Bd13	Av34P178.a	16	11	18000	1.90		1.05	92.	3727.12
465	BOTHAVILLE	Bd14	Av36P120.b	16	11	18000	1.90		1.50	138.	3929.10
465	BOTHAVILLE	Bd15	Av36P120.c	16	11	18000	1.90		1.00	122.	3166.13
465	BOTHAVILLE	Bd18	Av34P174.a	16	11	18000	1.90		1.50	128.	3645.87
465	BOTHAVILLE	Dc4	Va41P486.a	16	11	18000	1.90		.60	61.	1791.57
465	BOTHAVILLE	Dc6	Bo40P184.a	16	11	18000	1.90		.60	66.	2220.49
465	WOLMARANSSTAD	Bc22	Av36P173.a	24	11	14000	1.20		1.00	129.	3166.31
465	WOLMARANSSTAD	Bc24	Hu36P171.c	24	11	14000	1.20		1.50	159.	3209.72
465	WOLMARANSSTAD	Bd12	Cv36P172.a	24	11	14000	1.20		.50	50.	1974.02
465	WOLMARANSSTAD	Bd13	Av34P178.a	24	11	14000	1.20		1.05	92.	3181.32
465	WOLMARANSSTAD	Dc4	Va41P486.a	24	11	14000	1.20		.60	61.	1838.09
466	MEAS MAP	598.2	GEN MAP	578.75							
466	BOTHAVILLE	Bc24	Hu36P171.c	16	11	18000	1.90		1.50	159.	3445.32
466	BOTHAVILLE	Bd14	Av36P120.b	16	11	18000	1.90		1.50	138.	3890.78
466	BOTHAVILLE	Bd15	Av36P120.c	16	11	18000	1.90		1.00	122.	3086.79
466	VILJOENSKROON	Bc24	Hu36P171.c	15	11	18000	1.20		1.50	159.	3315.86
466	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.20		1.05	92.	3262.75
466	VILJOENSKROON	Bd14	Av36P120.b	15	11	18000	1.20		1.50	138.	3771.77
466	VILJOENSKROON	Bd15	Av36P120.c	15	11	18000	1.20		1.00	122.	2947.91
467	MEAS MAP	548.7	GEN MAP	542.85							
467	BOTHAVILLE	Bc24	Hu36P171.c	16	11	18000	1.90		1.50	159.	3724.27
467	BOTHAVILLE	Bd13	Av34P178.a	16	11	18000	1.90		1.05	92.	3787.66
467	BOTHAVILLE	Bd14	Av36P120.b	16	11	18000	1.90		1.50	138.	3959.88
467	KLERKSDORP	Bc23	Hu37P204.a	20	11	18000	1.90		.45	39.	1843.76
467	KLERKSDORP	Bd12	Cv36P172.a	20	11	18000	1.90		.50	50.	1958.19
467	VILJOENSKROON	Bc23	Hu37P204.a	15	11	18000	1.20		.45	39.	1711.92
467	VILJOENSKROON	Bc24	Hu36P171.c	15	11	18000	1.20		1.50	159.	3691.50
467	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.20		1.05	92.	3690.22
467	VILJOENSKROON	Bd14	Av36P120.b	15	11	18000	1.20		1.50	138.	3951.16
467	WOLMARANSSTAD	Bc18	Hu36P171.a	24	11	14000	1.20		.60	69.	2341.45

467	WOLMARANSSTAD	Bc20	Hu36P203.b	24	11	14000	1.20	.50	51.	2029.87
468	MEAS MAP 578.1	GEN MAP 592.31								
468	WOLMARANSSTAD	Bc19	Hu36P203.a	24	11	14000	1.20	.75	68.	3178.98
479	MEAS MAP 597.2	GEN MAP 595.42								
479	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.20	1.05	92.	3804.41
479	VREDEFORT	Bc26	Hu36P203.c	13	11	20000	1.20	1.50	157.	3828.78
479	VREDEFORT	Bd13	Av34P178.a	13	11	20000	1.20	1.05	92.	3969.32
480	MEAS MAP 527.9	GEN MAP 533.59								
480	BOTHAVILLE	Bc24	Hu36P171.c	16	11	18000	1.90	1.50	159.	3767.00
480	BOTHAVILLE	Bd15	Av36P120.c	16	11	18000	1.90	1.00	122.	3225.43
480	BOTHAVILLE	Dc6	Bo40P184.a	16	11	18000	1.90	.60	66.	2211.38
480	KOPPIES	Bd21	Av36P190.a	08	11	20000	1.50	1.00	105.	2885.48
480	KOPPIES	Dc11	Bo41P187.a	08	11	20000	1.50	.60	63.	1962.17
480	KOPPIES	Dc7	Ar20P195.a	08	11	20000	1.50	.60	54.	1848.15
480	KROONSTAD	Bd16	We13P188.a	15	11	18000	1.52	.50	59.	1731.44
480	KROONSTAD	Bd19	Av34P174.b	15	11	18000	1.52	1.00	124.	2955.24
480	KROONSTAD	Bd21	Av36P190.a	15	11	18000	1.52	1.00	105.	3199.14
480	KROONSTAD	Dc11	Bo41P187.a	15	11	18000	1.52	.60	63.	2025.54
480	KROONSTAD	Dc6	Bo40P184.a	15	11	18000	1.52	.60	66.	2198.97
480	VILJOENSKROON	Bc25	Hu36P171.c	15	11	18000	1.20	1.50	159.	3305.32
480	VILJOENSKROON	Bd13	Av34P178.a	15	11	18000	1.20	1.05	92.	3564.56
480	VILJOENSKROON	Bd14	Av36P120.b	15	11	18000	1.20	1.50	138.	3806.13
480	VILJOENSKROON	Bd15	Av36P120.c	15	11	18000	1.20	1.00	122.	3206.34
480	VILJOENSKROON	Bd16	We13P188.a	15	11	18000	1.20	.50	59.	1727.14
480	VILJOENSKROON	Dc11	Bo41P187.a	15	11	18000	1.20	.60	63.	2080.67
480	VILJOENSKROON	Dc6	Bo40P184.a	15	11	18000	1.20	.60	66.	2202.85
480	VREDEFORT	Ba38	Hu26P194.a	13	11	20000	1.20	.80	82.	2360.85
480	VREDEFORT	Bc25	Hu36P171.c	13	11	20000	1.20	1.50	159.	2933.72
480	VREDEFORT	Bc26	Hu36P203.c	13	11	20000	1.20	1.50	157.	2823.99
480	VREDEFORT	Bd21	Av36P190.a	13	11	20000	1.20	1.00	105.	3117.70
480	VREDEFORT	Dc11	Bo41P187.a	13	11	20000	1.20	.60	63.	2056.86
480	VREDEFORT	Dc7	Ar20P195.a	13	11	20000	1.20	.60	54.	1926.81
481	MEAS MAP 593.0	GEN MAP 566.95								
481	HENNENMAN	Bc30	Bv36P181.a	17	11	15000	1.90	.75	104.	3389.52
481	HENNENMAN	Bd21	Av36P190.a	17	11	15000	1.90	1.00	105.	3383.17
481	HENNENMAN	Db1	Va41P486.a	17	11	15000	1.90	.60	61.	1991.23
481	HENNENMAN	Dc8	Va41P486.b	17	11	15000	1.90	.60	57.	2111.38
481	KROONSTAD	Bc28	Bv36P183.a	15	11	18000	1.52	1.50	172.	3937.85
481	KROONSTAD	Bd18	Av34P174.a	15	11	18000	1.52	1.50	128.	3938.02
481	KROONSTAD	Bd19	Av34P174.b	15	11	18000	1.52	1.00	124.	3339.16
481	KROONSTAD	Bd21	Av36P190.a	15	11	18000	1.52	1.00	105.	3497.59
481	KROONSTAD	Db1	Va41P486.a	15	11	18000	1.52	.60	61.	1720.23
481	KROONSTAD	Dc10	Sw41P189.a	15	11	18000	1.52	.60	69.	2442.62
481	KROONSTAD	Dc6	Bo40P184.a	15	11	18000	1.52	.60	66.	2284.46
481	ODENDAALSRUS	Bd18	Av34P174.a	18	11	17000	1.52	1.50	128.	3793.15
481	ODENDAALSRUS	Bd19	Av34P174.b	18	11	17000	1.52	1.00	124.	3465.33
481	ODENDAALSRUS	Db1	Va41P486.a	18	11	17000	1.52	.60	61.	1840.93
481	VENTERSBURG	Bd21	Av36P190.a	16	11	14000	1.20	1.00	105.	3165.86
481	VENTERSBURG	Dc10	Sw41P189.a	16	11	14000	1.20	.60	69.	2600.29
482	MEAS MAP 656.4	GEN MAP 654.77								
482	LINDLEY	Ca6	Av36P173.b	01	11	22000	1.20	.80	91.	3181.17
482	LINDLEY	Dc10	Sw41P189.a	01	11	22000	1.20	.60	69.	2853.93
483	MEAS MAP 553.1	GEN MAP 554.00								
483	KROONSTAD	Bd21	Av36P190.a	15	11	18000	1.52	1.00	105.	3576.44
483	KROONSTAD	Dc10	Sw41P189.a	15	11	18000	1.52	.60	69.	2539.11
483	LINDLEY	Bd21	Av36P190.a	01	11	22000	1.20	1.00	105.	3037.80
483	LINDLEY	Dc10	Sw41P189.a	01	11	22000	1.20	.60	69.	2024.16
484	MEAS MAP 597.6	GEN MAP 595.03								
484	HEILBRON	Bd21	Av36P190.a	01	11	20000	1.90	1.00	105.	3780.47
484	HEILBRON	Ca6	Av36P173.b	01	11	20000	1.90	.80	91.	3473.69
484	HEILBRON	Dc10	Sw41P189.a	01	11	20000	1.90	.60	69.	2893.92
484	KOPPIES	Bd21	Av36P190.a	08	11	20000	1.50	1.00	105.	3835.54
484	KOPPIES	Dc11	Bo41P187.a	08	11	20000	1.50	.60	63.	2580.76

484	KROONSTAD	Bd21	Av36P190.a	15 11	18000	1.52	1.00	105.	3791.96
484	KROONSTAD	Dc10	Sw41P189.a	15 11	18000	1.52	.60	69.	2911.15
484	KROONSTAD	Dc11	Bo41P187.a	15 11	18000	1.52	.60	63.	2555.24
484	KROONSTAD	Dc6	Bo40P184.a	15 11	18000	1.52	.60	66.	2761.55
484	LINDLEY	Ca6	Av36P173.b	01 11	22000	1.20	.80	91.	2943.78
484	LINDLEY	Dc10	Sw41P189.a	01 11	22000	1.20	.60	69.	2684.52
484	LINDLEY	Dc11	Bo41P187.a	01 11	22000	1.20	.60	63.	2515.48
485	MEAS MAP 687.4		GEN MAP 685.14						
485	HEILBRON	Ca6	Av36P173.b	01 11	20000	1.90	.80	91.	4155.28
485	HEILBRON	Dc10	Sw41P189.a	01 11	20000	1.90	.60	69.	3743.63
485	HEILBRON	Ea28	Ar20P195.b	01 11	20000	1.90	.70	45.	3391.25
486	MEAS MAP 587.4		GEN MAP 585.21						
486	HEILBRON	Dc10	Sw41P189.a	01 11	20000	1.90	.60	69.	2326.48
486	HEILBRON	Dc7	Ar20P195.a	01 11	20000	1.90	.60	54.	1972.50
486	HEILBRON	Ea28	Ar20P195.b	01 11	20000	1.90	.70	45.	1972.50
486	KOPPIES	Bd21	Av36P190.a	08 11	20000	1.50	1.00	105.	3280.16
486	KOPPIES	Dc10	Sw41P189.a	08 11	20000	1.50	.60	69.	2448.01
486	KOPPIES	Dc11	Bo41P187.a	08 11	20000	1.50	.60	63.	2082.24
486	KOPPIES	Dc7	Ar20P195.a	08 11	20000	1.50	.60	54.	2126.68
487	MEAS MAP 612.6		GEN MAP 627.34						
487	HEILBRON	Dc7	Ar20P195.a	01 11	20000	1.90	.60	54.	2748.43
487	HEILBRON	Ea28	Ar20P195.b	01 11	20000	1.90	.70	45.	2748.43
487	HEILBRON	Ea29	Ar20P195.b	01 11	20000	1.90	.70	45.	2748.43
487	KOPPIES	Dc7	Ar20P195.a	08 11	20000	1.50	.60	54.	2752.59
488	MEAS MAP 562.2		GEN MAP 542.16						
488	HEILBRON	Dc7	Ar20P195.a	01 11	20000	1.90	.60	54.	1929.61
488	KOPPIES	Bd17	We13P758.a	08 11	20000	1.50	.40	31.	1416.53
488	KOPPIES	Dc7	Ar20P195.a	08 11	20000	1.50	.60	54.	1688.22
488	PARYS	Dc7	Ar20P195.a	10 11	20000	1.20	.60	54.	1753.57
488	SASOLBURG	Dc7	Ar20P195.a	05 11	22000	1.20	.60	54.	1643.27
488	VREDEFORT	Dc7	Ar20P195.a	13 11	20000	1.20	.60	54.	1703.81
489	MEAS MAP 663.0		GEN MAP 684.17						
489	PARYS	Bd17	We13P758.a	10 11	20000	1.20	.40	31.	1884.50
489	PARYS	Dc7	Ar20P195.a	10 11	20000	1.20	.60	54.	2598.81
489	VREDEFORT	Ba38	Hu26P194.a	13 11	20000	1.20	.80	82.	3166.21
489	VREDEFORT	Bd17	We13P758.a	13 11	20000	1.20	.40	31.	1932.37
489	VREDEFORT	Dc7	Ar20P195.a	13 11	20000	1.20	.60	54.	2681.20
490	MEAS MAP 643.7		GEN MAP 640.11						
490	HEILBRON	Dc7	Ar20P195.a	01 11	20000	1.90	.60	54.	2948.90

MAP SHEET 2826 WINBURG

HCZ	MAG DISTRICT	LAND TYPE	SOIL FORM	PDATE	PDENS	ROW WIDTH	EFFCT SOIL DEPTH (m)	TOT WAT (mm)	MEDIAN YIELD kg ha^{-1}
327	MEAS MAP 473.6		GEN MAP 465.88						
327	BLOEMFONTEIN	Ae46	Hu26P208.a	01 12	12000	2.25	1.20	127.	2672.61
327	BLOEMFONTEIN	Ca8	Bv36P465.a	01 12	12000	2.25	.80	90.	2653.87
327	BLOEMFONTEIN	Dc13	Va41P464.a	01 12	12000	2.25	.60	54.	2158.91
327	BOSHOF	Da1	Va41P461.a	05 12	12000	2.25	.60	58.	2460.07
327	BRANDFORT	Ae46	Hu26P208.a	28 11	13000	2.25	1.20	127.	2831.47
327	BRANDFORT	Ca8	Bv36P465.a	28 11	13000	2.25	.80	90.	2700.30
327	BRANDFORT	Da1	Va41P461.a	28 11	13000	2.25	.60	58.	2404.38
327	BRANDFORT	Dc13	Va41P464.a	28 11	13000	2.25	.60	54.	2030.65
331	MEAS MAP 491.7		GEN MAP 503.16						
331	BOSHOF	Da1	Va41P461.a	05 12	12000	2.25	.60	58.	2434.80
331	BRANDFORT	Da1	Va41P461.a	28 11	13000	2.25	.60	58.	2087.83
331	BRANDFORT	Dc8	Va41P486.b	28 11	13000	2.25	.60	57.	1689.19
331	BULTFONTEIN	Ah20	Hu36P456.a	01 12	12000	2.25	1.50	166.	2759.80
331	BULTFONTEIN	Da1	Va41P461.a	01 12	12000	2.25	.60	58.	2196.01
331	BULTFONTEIN	Dc8	Va41P486.b	01 12	12000	2.25	.60	57.	1899.59

331	HOOPSTAD	Ah20	Hu36P456.a	28	11	12000	2.25	1.50	166.	2759.48
331	THEUNISSEN	Ae40	Hu33P176.a	25	11	14000	2.25	1.50	161.	3215.11
331	THEUNISSEN	Ah20	Hu36P456.a	25	11	14000	2.25	1.50	166.	3216.52
331	THEUNISSEN	Bd20	Cv36P485.a	25	11	14000	2.25	1.50	178.	3217.69
331	THEUNISSEN	Ca22	Va41P460.a	25	11	14000	2.25	.60	64.	1945.50
331	THEUNISSEN	Da1	Va41P461.a	25	11	14000	2.25	.60	58.	2069.39
331	THEUNISSEN	Dc8	Va41P486.b	25	11	14000	2.25	.60	57.	1757.58
331	WELKOM	Ae40	Hu33P176.a	20	11	14000	1.52	1.50	161.	3202.54
331	WESSELSBRON	Ae40	Hu33P176.a	25	11	14000	1.52	1.50	161.	3206.73
331	WESSELSBRON	Dc8	Va41P486.b	25	11	14000	1.52	.60	57.	1615.75
332	MEAS MAP 546.7	GEN MAP 532.77								
332	BLOEMFONTEIN	Ea39	Bo21P470.a	01	12	12000	2.25	.60	53.	2273.82
332	BRANDFORT	Ca22	Va41P460.a	28	11	13000	2.25	.60	64.	2430.86
332	BRANDFORT	Ca8	Bv36P465.a	28	11	13000	2.25	.80	90.	2932.77
332	BRANDFORT	Da1	Va41P461.a	28	11	13000	2.25	.60	58.	2570.56
332	BRANDFORT	Dc13	Va41P464.a	28	11	13000	2.25	.60	54.	2311.77
332	BRANDFORT	Dc16	We12P479.a	28	11	13000	2.25	.40	39.	1935.44
332	BRANDFORT	Ea39	Bo21P470.a	28	11	13000	2.25	.60	53.	2159.31
332	THEUNISSEN	Ca22	Va41P460.a	25	11	14000	2.25	.60	64.	2307.26
332	THEUNISSEN	Dc16	We12P479.a	25	11	14000	2.25	.40	39.	1691.89
332	THEUNISSEN	Dc8	Va41P486.b	25	11	14000	2.25	.60	57.	2043.46
332	THEUNISSEN	Ea41	Bo41P484.a	25	11	14000	2.25	.40	44.	1576.17
333	MEAS MAP 475.4	GEN MAP 495.48								
333	BRANDFORT	Ca22	Va41P460.a	28	11	13000	2.25	.60	64.	2467.45
333	BRANDFORT	Ca8	Bv36P465.a	28	11	13000	2.25	.80	90.	2945.96
333	BRANDFORT	Dc16	We12P479.a	28	11	13000	2.25	.40	39.	2032.87
333	BRANDFORT	Dc8	Va41P486.b	28	11	13000	2.25	.60	57.	2293.59
333	BRANDFORT	Ea39	Bo21P470.a	28	11	13000	2.25	.60	53.	2396.85
333	THEUNISSEN	Ca22	Va41P460.a	25	11	14000	2.25	.60	64.	2371.09
333	THEUNISSEN	Dc16	We12P479.a	25	11	14000	2.25	.40	39.	1971.50
333	THEUNISSEN	Dc8	Va41P486.b	25	11	14000	2.25	.60	57.	2263.08
333	WINBURG	Ca22	Va41P460.a	18	11	18000	1.52	.60	64.	1850.11
333	WINBURG	Dc16	We12P479.a	18	11	18000	1.52	.40	39.	1806.79
334	MEAS MAP 539.7	GEN MAP 531.03								
334	BLOEMFONTEIN	Dc13	Va41P464.a	01	12	12000	2.25	.60	54.	2395.77
334	BLOEMFONTEIN	Ea39	Bo21P470.a	01	12	12000	2.25	.60	53.	2224.00
334	BRANDFORT	Db37	Va41P475.a	28	11	13000	2.25	.60	65.	2145.43
334	BRANDFORT	Dc16	We12P479.a	28	11	13000	2.25	.40	39.	1984.26
334	BRANDFORT	Dc17	We12P479.a	28	11	13000	2.25	.40	39.	1984.26
334	BRANDFORT	Ea39	Bo21P470.a	28	11	13000	2.25	.60	53.	2206.82
334	EXCELSIOR	Ca24	We13P494.a	18	11	20000	0.91	.50	57.	1822.46
334	EXCELSIOR	Db37	Va41P475.a	18	11	20000	0.91	.60	65.	1847.00
334	WINBURG	Db37	Va41P475.a	18	11	18000	1.52	.60	65.	1957.68
334	WINBURG	Dc16	We12P479.a	18	11	18000	1.52	.40	39.	1844.56
334	BOPHUTHATSWANA	Db37	Va41P475.a	01	12	12000	2.25	.60	65.	1847.00
334	BOPHUTHATSWANA	Dc17	We12P479.a	01	12	12000	2.25	.40	39.	1984.26
340	MEAS MAP 615.4	GEN MAP 612.99								
340	CLOCOLAN	Db35	Va41P475.a	08	11	22000	0.91	.60	65.	2405.86
340	EXCELSIOR	Ca24	We13P494.a	18	11	20000	0.91	.50	57.	2168.74
340	EXCELSIOR	Db36	Va41P475.a	18	11	20000	0.91	.60	65.	2287.65
340	MARQUARD	Ca24	We13P494.a	10	11	22000	0.91	.50	57.	2177.60
340	MARQUARD	Ca5	We13P494.a	10	11	22000	0.91	.50	57.	2177.60
340	MARQUARD	Ea42	Bo41P484.a	10	11	22000	0.91	.40	44.	2013.21
340	WINBURG	Ca24	We13P494.a	18	11	18000	1.52	.50	57.	2229.53
341	MEAS MAP 506.9	GEN MAP 533.27								
341	BRANDFORT	Db37	Va41P475.a	28	11	13000	2.25	.60	65.	1855.32
341	EXCELSIOR	Ca24	We13P494.a	18	11	20000	0.91	.50	57.	1290.70
341	EXCELSIOR	Db37	Va41P475.a	18	11	20000	0.91	.60	65.	1388.74
341	EXCELSIOR	Dc16	We12P479.a	18	11	20000	0.91	.40	39.	1312.26
341	WINBURG	Ca24	We13P494.a	18	11	18000	1.52	.50	57.	1315.81
341	WINBURG	Db37	Va41P475.a	18	11	18000	1.52	.60	65.	1392.12
341	WINBURG	Dc16	We12P479.a	18	11	18000	1.52	.40	39.	1322.99
341	WINBURG	Ea41	Bo41P484.a	18	11	18000	1.52	.40	44.	1165.06
342	MEAS MAP 506.9	GEN MAP 583.67								

342	EXCELSIOR	Ca24	We13P494.a	18	11	20000	0.91	.50	57.	1979.55
342	MARQUARD	Ca5	We13P494.a	10	11	22000	0.91	.50	57.	1771.32
342	MARQUARD	Dc12	Sw41P491.a	10	11	22000	0.91	.60	51.	1837.28
342	SENEKAL	Ca5	We13P494.a	12	11	22000	0.91	.50	57.	1841.84
342	SENEKAL	Dc12	Sw41P491.a	12	11	22000	0.91	.60	51.	2018.86
342	SENEKAL	Ea40	Bo41P484.a	12	11	22000	0.91	.40	44.	1596.96
342	THEUNISSEN	Ca22	Va41P460.a	25	11	14000	2.25	.60	64.	3047.53
342	THEUNISSEN	Dc8	Va41P486.b	25	11	14000	2.25	.60	57.	2641.61
342	THEUNISSEN	Ea41	Bo41P484.a	25	11	14000	2.25	.40	44.	2253.56
342	WINBURG	Ca24	We13P494.a	18	11	18000	1.52	.50	57.	1956.92
342	WINBURG	Ca5	We13P494.a	18	11	18000	1.52	.50	57.	1956.92
342	WINBURG	Dc12	Sw41P491.a	18	11	18000	1.52	.60	51.	2301.38
342	WINBURG	Dc16	We12P479.a	18	11	18000	1.52	.40	39.	1963.24
342	WINBURG	Ea40	Bo41P484.a	18	11	18000	1.52	.40	44.	1786.34
342	WINBURG	Ea41	Bo41P484.a	18	11	18000	1.52	.40	44.	1786.34
343	MEAS MAP	499.8	GEN MAP	493.92						
343	HENNENMAN	Bc30	Bv36P181.a	17	11	15000	1.52	.75	104.	2612.94
343	HENNENMAN	Dc8	Va41P486.b	17	11	15000	1.52	.60	57.	1614.32
343	THEUNISSEN	Bd20	Cv36P485.a	25	11	14000	2.25	1.50	178.	3219.23
343	THEUNISSEN	Dc12	Sw41P491.a	25	11	14000	2.25	.60	51.	2234.44
343	THEUNISSEN	Dc8	Va41P486.b	25	11	14000	2.25	.60	57.	2029.33
343	THEUNISSEN	Ea41	Bo41P484.a	25	11	14000	2.25	.40	44.	1681.32
343	VIRGINIA	Bc30	Bv36P181.a	20	11	16000	2.25	.75	104.	2855.09
343	VIRGINIA	Bd20	Cv36P485.a	20	11	16000	2.25	1.50	178.	3623.59
343	VIRGINIA	Dc12	Sw41P491.a	20	11	16000	2.25	.60	51.	2088.48
343	VIRGINIA	Dc8	Va41P486.b	20	11	16000	2.25	.60	57.	1823.16
343	WELKOM	Ae40	Hu33P176.a	20	11	14000	1.52	1.50	161.	3204.63
343	WELKOM	Bd20	Cv36P485.a	20	11	14000	1.52	1.50	178.	3212.02
343	WELKOM	Dc9	Hu36P162.c	20	11	14000	1.52	1.20	140.	3163.81
343	WINBURG	Dc12	Sw41P491.a	18	11	18000	1.52	.60	51.	1783.77
343	WINBURG	Ea41	Bo41P484.a	18	11	18000	1.52	.40	44.	1175.82
344	MEAS MAP	547.3	GEN MAP	541.56						
344	VENTERSBURG	Bd20	Cv36P485.a	16	11	14000	1.52	1.50	178.	3218.52
344	VENTERSBURG	Dc12	Sw41P491.a	16	11	14000	1.52	.60	51.	2207.35
344	VENTERSBURG	Dc8	Va41P486.b	16	11	14000	1.52	.60	57.	2014.25
344	VENTERSBURG	Ea40	Bo41P484.a	16	11	14000	1.52	.40	44.	1773.09
344	VIRGINIA	Bd20	Cv36P485.a	20	11	16000	2.25	1.50	178.	3628.82
344	VIRGINIA	Dc12	Sw41P491.a	20	11	16000	2.25	.60	51.	2525.52
344	VIRGINIA	Dc8	Va41P486.b	20	11	16000	2.25	.60	57.	2496.05
344	WINBURG	Dc12	Sw41P491.a	18	11	18000	1.52	.60	51.	2452.49
344	WINBURG	Ea40	Bo41P484.a	18	11	18000	1.52	.40	44.	1908.60
345	MEAS MAP	626.6	GEN MAP	598.59						
345	HENNENMAN	Bc30	Bv36P181.a	17	11	15000	1.52	.75	104.	3433.44
345	HENNENMAN	Dc12	Sw41P491.a	17	11	15000	1.52	.60	51.	3018.62
345	KROONSTAD	Dc12	Sw41P491.a	15	11	18000	1.52	.60	51.	2908.10
345	SENEKAL	Bd22	We13P492.a	12	11	22000	0.91	.50	40.	2444.24
345	SENEKAL	Dc12	Sw41P491.a	12	11	22000	0.91	.60	51.	2763.93
345	SENEKAL	Ea40	Bo41P484.a	12	11	22000	0.91	.40	44.	2241.21
345	VENTERSBURG	Ae40	Hu33P176.a	16	11	14000	1.52	1.50	161.	3220.44
345	VENTERSBURG	Bd21	Av36P190.a	16	11	14000	1.52	1.00	105.	3202.58
345	VENTERSBURG	Bd28	We13P496.a	16	11	14000	1.52	.50	50.	2626.97
345	VENTERSBURG	Dc12	Sw41P491.a	16	11	14000	1.52	.60	51.	2935.63
345	VENTERSBURG	Ea40	Bo41P484.a	16	11	14000	1.52	.40	44.	2247.79
346	MEAS MAP	529.3	GEN MAP	503.19						
346	SENEKAL	Bd22	We13P492.a	12	11	22000	0.91	.50	40.	1417.15
346	SENEKAL	Ca5	We13P494.a	12	11	22000	0.91	.50	57.	1350.10
346	SENEKAL	Dc12	Sw41P491.a	12	11	22000	0.91	.60	51.	1519.57
346	VENTERSBURG	Dc12	Sw41P491.a	16	11	14000	1.52	.60	51.	1927.20
347	MEAS MAP	477.2	GEN MAP	482.15						
347	LINDLEY	Bd22	We13P492.a	01	11	22000	1.52	.50	40.	1424.38
347	LINDLEY	Ca5	We13P494.a	01	11	22000	1.52	.50	57.	1284.48
347	SENEKAL	Bd22	We13P492.a	12	11	22000	0.91	.50	40.	1179.35
347	SENEKAL	Ca5	We13P494.a	12	11	22000	0.91	.50	57.	1060.99
348	MEAS MAP	617.5	GEN MAP	619.77						

348	FICKSBURG		Bd29	Av26P502.a	26	10	22000	0.91	1.10	122.	3792.58
348	SENEKAL		Ad4	Cv26P000.a	12	11	22000	0.91	.70	62.	2679.47
348	SENEKAL		Bd29	Av26P502.a	12	11	22000	0.91	1.10	122.	3991.80
348	SENEKAL		Ca23	We13P494.a	12	11	22000	0.91	.50	57.	2118.35
348	SENEKAL		Ca5	We13P494.a	12	11	22000	0.91	.50	57.	2118.35
349	MEAS MAP	669.5		GEN MAP	654.96						
349	CLOCOLAN		Ai7	Cv26P000.a	08	11	22000	0.91	.70	62.	3301.87
349	CLOCOLAN		Bd29	Av26P502.a	08	11	22000	0.91	1.10	122.	4288.88
349	CLOCOLAN		Bd30	Av26P502.a	08	11	22000	0.91	1.10	122.	4288.88
349	CLOCOLAN		Bd31	Av26P502.a	08	11	22000	0.91	1.10	122.	4288.88
349	CLOCOLAN		Db35	Va41P475.a	08	11	22000	0.91	.60	65.	2588.28
349	CLOCOLAN		Db36	Va41P475.a	08	11	22000	0.91	.60	65.	2588.28
349	EXCELSIOR		Ai7	Cv26P000.a	18	11	20000	0.91	.70	62.	3400.55
349	EXCELSIOR		Db36	Va41P475.a	18	11	20000	0.91	.60	65.	2935.41
349	FICKSBURG		Bd29	Av26P502.a	26	10	22000	0.91	1.10	122.	4100.08
349	FICKSBURG		Bd30	Av26P502.a	26	10	22000	0.91	1.10	122.	4100.08
349	FICKSBURG		Bd31	Av26P502.a	26	10	22000	0.91	1.10	122.	4100.08
349	LADYBRAND		Bd31	Av26P502.a	08	11	22000	0.91	1.10	122.	4288.88
349	MARQUARD		Bd29	Av26P502.a	10	11	22000	0.91	1.10	122.	4305.43
349	MARQUARD		Bd31	Av26P502.a	10	11	22000	0.91	1.10	122.	4305.43
349	MARQUARD		Ca24	We13P494.a	10	11	22000	0.91	.50	57.	2394.84
349	MARQUARD		Ca5	We13P494.a	10	11	22000	0.91	.50	57.	2394.84
349	MARQUARD		Db35	Va41P475.a	10	11	22000	0.91	.60	65.	2523.18
349	MARQUARD		Db36	Va41P475.a	10	11	22000	0.91	.60	65.	2523.18
349	SENEKAL		Bd29	Av26P502.a	12	11	22000	0.91	1.10	122.	4309.84
349	SENEKAL		Ca5	We13P494.a	12	11	22000	0.91	.50	57.	2451.38
353	MEAS MAP	739.9		GEN MAP	759.17						
353	CLOCOLAN		Bd29	Av26P502.a	08	11	22000	0.91	1.10	122.	4564.29
353	FICKSBURG		Ad4	Cv26P000.a	26	10	22000	0.91	.70	62.	4404.50
353	FICKSBURG		Bd29	Av26P502.a	26	10	22000	0.91	1.10	122.	4565.62
353	FICKSBURG		Bd31	Av26P502.a	26	10	22000	0.91	1.10	122.	4565.62
353	MARQUARD		Bd29	Av26P502.a	10	11	22000	0.91	1.10	122.	4564.03
353	MARQUARD		Ca5	We13P494.a	10	11	22000	0.91	.50	57.	3772.65
353	SENEKAL		Bd29	Av26P502.a	12	11	22000	0.91	1.10	122.	4563.62
353	SENEKAL		Ca5	We13P494.a	12	11	22000	0.91	.50	57.	3767.65
354	MEAS MAP	790.1		GEN MAP	790.98						
354	FICKSBURG		Bd29	Av26P502.a	26	10	22000	0.91	1.10	122.	4559.98
354	SENEKAL		Ad4	Cv26P000.a	12	11	22000	0.91	.70	62.	3912.20
355	MEAS MAP	689.0		GEN MAP	651.97						
355	BETHLEHEM		Ad4	Cv26P000.a	22	10	25000	0.91	.70	62.	3016.36
355	BETHLEHEM		Bd29	Av26P502.a	22	10	25000	0.91	1.10	122.	4080.70
355	BETHLEHEM		Ca23	We13P494.a	22	10	25000	0.91	.50	57.	2856.65
355	LINDLEY		Ca23	We13P494.a	01	11	22000	1.52	.50	57.	2803.80
355	LINDLEY		Ca5	We13P494.a	01	11	22000	1.52	.50	57.	2803.80
355	LINDLEY		Dc10	Sw41P189.a	01	11	22000	1.52	.60	69.	3542.11
355	SENEKAL		Bd29	Av26P502.a	12	11	22000	0.91	1.10	122.	4093.93
355	SENEKAL		Ca23	We13P494.a	12	11	22000	0.91	.50	57.	2576.61
355	SENEKAL		Ca5	We13P494.a	12	11	22000	0.91	.50	57.	2576.61

APPENDIX B Comparative statistics for measured and generated rainfall data sets determined for each homogeneous climate zone used in the study

HCZ = Homogenous climate zones MEAS = Measured data
GEN = Generated data MEDN = Median STD = Standard deviation
C.V. = Coefficient of variation SKEW = Skewness

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
319	JAN	54.4	57.8	47.4	54.8	45	40.7	82.6	70.4	0.9	0.9
319	FEB	61.1	57.4	47.8	52.6	86.4	38.8	141.4	67.6	6.2	0.7
319	MAR	59.8	65.4	50.5	60.6	45.4	45	75.9	68.7	0.7	1.2
319	APR	32.5	34.4	23.5	30.9	29.5	29.5	90.8	86	1	1.4
319	MAY	15.1	15.7	5.9	9.4	20	20.4	132.4	130.2	1.4	1.7
319	JUN	5.4	5.1	0	0	10.9	9.2	199.9	179.9	2.5	1.9
319	JUL	3.4	4.3	0	0	7.5	11.6	220.6	269.3	2.5	4.6
319	AUG	7.6	6.4	0	0	15.3	13.7	200.8	214.7	2.5	2.8
319	SEP	11.8	18.2	0	9.4	21.7	22.7	184.4	124.6	2.2	1.3
319	OCT	33.1	32.3	25.5	29.3	31.9	28.2	96.3	87.2	1.5	1.1
319	NOV	39	40.4	33.5	44	27.3	29.3	69.9	72.4	0.6	0.9
319	DEC	46.1	45.7	40.3	38	35.3	35	76.5	76.6	0.7	1.2
327	JAN	73.5	70.1	63.2	62	54.8	45.8	74.6	65.3	0.8	0.7
327	FEB	73.4	71.4	72.2	60.9	40.6	40.2	55.4	56.4	0.5	0.6
327	MAR	74.2	74.2	65.8	72.6	43.9	46.6	59.2	62.8	0.7	1
327	APR	48	43.2	45	36.6	43.5	35.7	90.7	82.6	1.4	0.9
327	MAY	14.7	18.4	8	15.9	19.3	16.7	131.7	91	1.7	0.8
327	JUN	7.7	6.7	2.5	0	11.1	10.6	145.1	158.5	1.9	2.4
327	JUL	6.7	4.2	2	0	10.5	8.6	156.9	205.5	1.9	2.7
327	AUG	10.1	10.4	3	3.6	16.2	14.1	160.7	135.5	2.4	1.6
327	SEP	18.7	17	3.8	15.6	29.1	17	155.5	99.7	2	0.9
327	OCT	40.6	39.8	35.6	34.7	35.9	34.9	88.3	87.8	1.2	1.4
327	NOV	53.6	48.1	50.7	42	37	34.1	69	70.9	0.7	0.7
327	DEC	54.2	62.5	46.8	53.8	33.5	39.9	61.9	63.9	0.8	0.7
331	JAN	86.3	77.6	77.9	71.9	67	48.5	77.6	62.5	1.1	0.7
331	FEB	76.7	79.8	63.5	67.6	50.7	52.5	66.1	65.8	0.5	0.9
331	MAR	67.2	74.3	65.8	68.5	48.4	41.9	72	56.4	0.5	0.5
331	APR	41.5	42.8	31.3	35.7	42	33.1	101.3	77.4	1.6	1.7
331	MAY	17.3	17.3	8.5	10	22.4	19.4	129.4	112	2.1	1.5
331	JUN	5.9	7.8	0.6	1	10.1	13.3	170.2	169.8	2.6	2.1
331	JUL	7.6	6.7	0	0.2	13.9	11	182.1	165.3	2.3	1.9
331	AUG	9.6	7.8	0.6	2.7	16.5	12.1	172.1	154.2	2.1	2.3
331	SEP	15.5	16.6	3.5	11.4	25.4	20.3	163.4	122	2.2	3
331	OCT	42.5	39.9	36	32.4	33.4	34.8	78.7	87.3	0.8	2.2
331	NOV	60.7	60.4	48.7	47	53.8	49.2	88.6	81.5	1.4	1.9
331	DEC	64.2	72.2	66.3	59.8	46.4	43.2	72.4	59.8	0.4	0.9
332	JAN	86	83.7	72.9	76.3	56.4	48	65.6	57.3	0.8	0.8
332	FEB	80.7	75.5	78.2	70.2	49.1	41.1	60.9	54.4	0.8	0.7
332	MAR	76.9	82.2	71.2	80.6	43.7	40.1	56.8	48.9	0.9	0.3
332	APR	47.9	42	37.5	38.3	41.5	30.8	86.6	73.3	1.1	1
332	MAY	20.2	22.9	12.7	16.6	23.4	22.9	116.1	100.2	1.8	1.4
332	JUN	8.4	11.6	2.8	6.3	12.4	14.9	147.3	128.5	2	1.8
332	JUL	8.6	5.7	2.5	0	13.5	9.1	156	160.2	2	1.8
332	AUG	11.4	9.2	3.8	3.8	17.2	13.4	151.1	145.9	2	2.3
332	SEP	18.5	23.2	7.1	19.5	27.5	20	148.8	86.2	2.7	0.8
332	OCT	45.8	43.6	38.8	43.6	32.6	30.5	71.2	69.8	0.9	0.9
332	NOV	69	61.7	60.8	57.2	45.2	35.3	65.5	57.2	0.8	0.7
332	DEC	66.4	71.5	61.5	63.5	44.1	43.8	66.4	61.2	1.3	0.9
333	JAN	80	74.4	68.6	70	55.9	41.5	70	55.8	0.6	0.6
333	FEB	72.2	81.4	69.4	78	43.1	47.1	59.6	57.9	0.5	0.9
333	MAR	71.9	71.6	71	64.9	44.6	42.2	62	58.9	0.9	0.9
333	APR	42.6	44.8	42.2	32.2	36.2	40.8	85	91.1	1	1.2
333	MAY	19	19	9.7	13.1	24.3	22	128.2	115.6	1.7	1.8
333	JUN	6.2	6.1	0	0	11.6	12.3	185.9	200.2	2.6	3.4
333	JUL	7	7.1	0	0	11.8	12.5	168.3	175.8	2.1	2.4
333	AUG	8	8.8	0	2.3	14.4	12.3	178.9	140.7	2.2	1.8
333	SEP	12.6	23.8	3.9	16.9	22.9	23.2	182.3	97.7	3	0.9
333	OCT	40.8	39.2	34.9	36.9	31.5	31	77.3	79.1	1.1	0.6
333	NOV	59.5	55.9	46.2	53.4	46.4	36.8	78	65.7	1.1	0.7
333	DEC	58.1	63.2	55.5	54.6	41.9	43.1	72.1	68.2	1	0.5
334	JAN	84	83.5	74.6	78.7	56.4	43.6	67.2	52.2	1.2	0.8
334	FEB	86.5	76.7	77.1	70.6	61.7	45.3	71.3	59.1	2.3	0.8
334	MAR	79.1	74.8	73.5	69.5	44.8	41.9	56.7	56	0.5	1.2
334	APR	49.6	46.3	40.7	43.2	39.7	31.3	80	67.7	1.4	0.6
334	MAY	20	23.1	15	15.6	20.8	22.1	104	95.8	1.5	2.1
334	JUN	8.7	10.1	4.1	6.1	13.3	13.3	153.1	132.4	3	2.4
334	JUL	8.7	6.6	3.1	2.6	12.7	9	145.7	136.6	1.9	1.5
334	AUG	12.5	10.3	4.6	5.2	20.6	15.4	165	148.7	2.5	2.4
334	SEP	19	20.1	8.1	14.6	24.3	19.1	128.1	95	1.8	1
334	OCT	45.9	45.3	37.2	38.8	38	35.1	82.8	77.4	1.2	1.2
334	NOV	62.9	61.1	54.6	54	42.8	35.4	68	57.9	1.1	0.4
334	DEC	61.9	73	53.4	67.4	41.4	40.1	66.9	55	0.7	0.7
340	JAN	93.6	88.5	85.4	79.8	57.3	44.7	61.2	50.5	0.9	0.9
340	FEB	90.4	85.9	82.9	80.2	53	48.7	58.6	56.7	1.1	0.5
340	MAR	86.2	85.9	77.1	87	51.9	47	60.2	54.7	1.6	0.6
340	APR	57.8	58.5	48.7	51.3	46	37.4	79.6	63.9	1	1.1
340	MAY	23.2	28.8	14.2	19.1	24.9	30.4	107.2	105.5	1.2	1.8
340	JUN	12	10.6	6.5	4.1	14.4	15.8	120.2	149.5	1.4	2.8

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HCZ = Homogenous climate zones **MEAS** = Measured data
GEN = Generated data **MEDN** = Median **STD** = Standard deviation
C.V. = Coefficient of variation **SKEW** = Skewness

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
319	JAN	54.4	57.8	47.4	54.8	45	40.7	82.6	70.4	0.9	0.9
319	FEB	61.1	57.4	47.8	52.6	86.4	38.8	141.4	67.6	6.2	0.7
319	MAR	59.8	65.4	50.5	60.6	45.4	45	75.9	68.7	0.7	1.2
319	APR	32.5	34.4	23.5	30.9	29.5	29.5	90.8	86	1	1.4
319	MAY	15.1	15.7	5.9	9.4	20	20.4	132.4	130.2	1.4	1.7
319	JUN	5.4	5.1	0	0	10.9	9.2	199.9	179.9	2.5	1.9
319	JUL	3.4	4.3	0	0	7.5	11.6	220.6	269.3	2.5	4.6
319	AUG	7.6	6.4	0	0	15.3	13.7	200.8	214.7	2.5	2.8
319	SEP	11.8	18.2	0	9.4	21.7	22.7	184.4	124.6	2.2	1.3
319	OCT	33.1	32.3	25.5	29.3	31.9	28.2	96.3	87.2	1.5	1.1
319	NOV	39	40.4	33.5	44	27.3	29.3	69.9	72.4	0.6	0.9
319	DEC	46.1	45.7	40.3	38	35.3	35	76.5	76.6	0.7	1.2
327	JAN	73.5	70.1	63.2	62	54.8	45.8	74.6	65.3	0.8	0.7
327	FEB	73.4	71.4	72.2	60.9	40.6	40.2	55.4	56.4	0.5	0.6
327	MAR	74.2	74.2	65.8	72.6	43.9	46.6	59.2	62.8	0.7	1
327	APR	48	43.2	45	36.6	43.5	35.7	90.7	82.6	1.4	0.9
327	MAY	14.7	18.4	8	15.9	19.3	16.7	131.7	91	1.7	0.8
327	JUN	7.7	6.7	2.5	0	11.1	10.6	145.1	158.5	1.9	2.4
327	JUL	6.7	4.2	2	0	10.5	8.6	156.9	205.5	1.9	2.7
327	AUG	10.1	10.4	3	3.6	16.2	14.1	160.7	135.5	2.4	1.6
327	SEP	18.7	17	3.8	15.6	29.1	17	155.5	99.7	2	0.9
327	OCT	40.6	39.8	35.6	34.7	35.9	34.9	88.3	87.8	1.2	1.4
327	NOV	53.6	48.1	50.7	42	37	34.1	69	70.9	0.7	0.7
327	DEC	54.2	62.5	46.8	53.8	33.5	39.9	61.9	63.9	0.8	0.7
331	JAN	86.3	77.6	77.9	71.9	67	48.5	77.6	62.5	1.1	0.7
331	FEB	76.7	79.8	63.5	67.6	50.7	52.5	66.1	65.8	0.5	0.9
331	MAR	67.2	74.3	65.8	68.5	48.4	41.9	72	56.4	0.5	0.5
331	APR	41.5	42.8	31.3	35.7	42	33.1	101.3	77.4	1.6	1.7
331	MAY	17.3	17.3	8.5	10	22.4	19.4	129.4	112	2.1	1.5
331	JUN	5.9	7.8	0.6	1	10.1	13.3	170.2	169.8	2.6	2.1
331	JUL	7.6	6.7	0	0.2	13.9	11	182.1	165.3	2.3	1.9
331	AUG	9.6	7.8	0.6	2.7	16.5	12.1	172.1	154.2	2.1	2.3
331	SEP	15.5	16.6	3.5	11.4	25.4	20.3	163.4	122	2.2	3
331	OCT	42.5	39.9	36	32.4	33.4	34.8	78.7	87.3	0.8	2.2
331	NOV	60.7	60.4	48.7	47	53.8	49.2	88.6	81.5	1.4	1.9
331	DEC	64.2	72.2	66.3	59.8	46.4	43.2	72.4	59.8	0.4	0.9
332	JAN	86	83.7	72.9	76.3	56.4	48	65.6	57.3	0.8	0.8
332	FEB	80.7	75.5	78.2	70.2	49.1	41.1	60.9	54.4	0.8	0.7
332	MAR	76.9	82.2	71.2	80.6	43.7	40.1	56.8	48.9	0.9	0.3
332	APR	47.9	42	37.5	38.3	41.5	30.8	86.6	73.3	1.1	1
332	MAY	20.2	22.9	12.7	16.6	23.4	22.9	116.1	100.2	1.8	1.4
332	JUN	8.4	11.6	2.8	6.3	12.4	14.9	147.3	128.5	2	1.8
332	JUL	8.6	5.7	2.5	0	13.5	9.1	156	160.2	2	1.8
332	AUG	11.4	9.2	3.8	3.8	17.2	13.4	151.1	145.9	2	2.3
332	SEP	18.5	23.2	7.1	19.5	27.5	20	148.8	86.2	2.7	0.8
332	OCT	45.8	43.6	38.8	43.6	32.6	30.5	71.2	69.8	0.9	0.9
332	NOV	69	61.7	60.8	57.2	45.2	35.3	65.5	57.2	0.8	0.7
332	DEC	66.4	71.5	61.5	63.5	44.1	43.8	66.4	61.2	1.3	0.9
333	JAN	80	74.4	68.6	70	55.9	41.5	70	55.8	0.6	0.6
333	FEB	72.2	81.4	69.4	78	43.1	47.1	59.6	57.9	0.5	0.9
333	MAR	71.9	71.6	71	64.9	44.6	42.2	62	58.9	0.9	0.9
333	APR	42.6	44.8	42.2	32.2	36.2	40.8	85	91.1	1	1.2
333	MAY	19	19	9.7	13.1	24.3	22	128.2	115.6	1.7	1.8
333	JUN	6.2	6.1	0	0	11.6	12.3	185.9	200.2	2.6	3.4
333	JUL	7	7.1	0	0	11.8	12.5	168.3	175.8	2.1	2.4
333	AUG	8	8.8	0	2.3	14.4	12.3	178.9	140.7	2.2	1.8
333	SEP	12.6	23.8	3.9	16.9	22.9	23.2	182.3	97.7	3	0.9
333	OCT	40.8	39.2	34.9	36.9	31.5	31	77.3	79.1	1.1	0.6
333	NOV	59.5	55.9	46.2	53.4	46.4	36.8	78	65.7	1.1	0.7
333	DEC	58.1	63.2	55.5	54.6	41.9	43.1	72.1	68.2	1	0.5
334	JAN	84	83.5	74.6	78.7	56.4	43.6	67.2	52.2	1.2	0.8
334	FEB	86.5	76.7	77.1	70.6	61.7	45.3	71.3	59.1	2.3	0.8
334	MAR	79.1	74.8	73.5	69.5	44.8	41.9	56.7	56	0.5	1.2
334	APR	49.6	46.3	40.7	43.2	39.7	31.3	80	67.7	1.4	0.6
334	MAY	20	23.1	15	15.6	20.8	22.1	104	95.8	1.5	2.1
334	JUN	8.7	10.1	4.1	6.1	13.3	13.3	153.1	132.4	3	2.4
334	JUL	8.7	6.6	3.1	2.6	12.7	9	145.7	136.6	1.9	1.5
334	AUG	12.5	10.3	4.6	5.2	20.6	15.4	165	148.7	2.5	2.4
334	SEP	19	20.1	8.1	14.6	24.3	19.1	128.1	95	1.8	1
334	OCT	45.9	45.3	37.2	38.8	38	35.1	82.8	77.4	1.2	1.2
334	NOV	62.9	61.1	54.6	54	42.8	35.4	68	57.9	1.1	0.4
334	DEC	61.9	73	53.4	67.4	41.4	40.1	66.9	55	0.7	0.7
340	JAN	93.6	88.5	85.4	79.8	57.3	44.7	61.2	50.5	0.9	0.9
340	FEB	90.4	85.9	82.9	80.2	53	48.7	58.6	56.7	1.1	0.5
340	MAR	86.2	85.9	77.1	87	51.9	47	60.2	54.7	1.6	0.6
340	APR	57.8	58.5	48.7	51.3	46	37.4	79.6	63.9	1	1.1
340	MAY	23.2	28.8	14.2	19.1	24.9	30.4	107.2	105.5	1.2	1.8
340	JUN	12	10.6	6.5	4.1	14.4	15.8	120.2	149.5	1.4	2.8

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
340	JUL	10.6	9.8	4.1	0.6	15.7	17.1	148.8	173.4	2.4	2.3
340	AUG	19.4	15.5	7.6	9.5	37.4	17	192.7	110.2	4.8	1.3
340	SEP	24.8	26.9	12.4	17.8	32.7	29.9	131.7	111.1	2.7	1.8
340	OCT	55.1	54.3	50.3	48	40.2	33.1	73	60.9	0.9	0.7
340	NOV	77.4	65.1	71.6	60.5	49	39.6	63.3	60.9	1	0.5
340	DEC	74.3	83.2	68.2	76.7	42.5	43.2	57.2	51.9	0.4	0.6
341	JAN	83.1	76.6	70.2	71.2	57.4	41.2	69.1	53.8	1.4	0.6
341	FEB	71.8	68.8	65.1	68	53.3	40.2	74.2	58.5	0.8	0.6
341	MAR	71.7	71.9	63.4	63.5	51.9	46.2	72.3	64.3	0.9	1.1
341	APR	46.8	47.2	41.9	42.5	34.8	31.9	74.3	67.6	1.4	0.7
341	MAY	20.6	23.1	11.9	17.4	25.4	24.1	123.2	104.3	1.5	1.7
341	JUN	6.7	6.6	0	0	13.4	10.8	199.2	162.9	2.7	2
341	JUL	8	6.5	0.6	0.2	13	12.6	161.6	192.8	2.4	2.8
341	AUG	9.8	9.6	0	1.9	14.9	15.6	152.9	163.4	1.6	2.3
341	SEP	17.8	21.3	7.3	15.6	31.8	24.8	178.9	116.3	2.9	2.1
341	OCT	48.9	51.9	45.1	45.5	35.1	40.5	71.7	78	1	0.8
341	NOV	68.5	72.2	61.5	63.9	50.4	46.5	73.5	64.3	1.2	0.9
341	DEC	65.7	77.5	60.6	64.7	41.9	54.7	63.8	70.7	0.3	1.1
342	JAN	83.1	80.2	70.2	76.7	57.4	41.3	69.1	51.5	1.4	0.3
342	FEB	71.8	95.4	65.1	88	53.3	54.2	74.2	56.8	0.8	1.2
342	MAR	71.7	83.4	63.4	72.7	51.9	51.3	72.3	61.6	0.9	1
342	APR	46.8	48	41.9	36.9	34.8	38.2	74.3	79.7	1.4	1.3
342	MAY	20.6	22	11.9	14.8	25.4	21.9	123.2	99.7	1.5	1.1
342	JUN	6.7	7.8	0	3.3	13.4	11.2	199.2	143.7	2.7	2
342	JUL	8	6.9	0.6	0.5	13	12	161.6	173.6	2.4	2.7
342	AUG	9.8	13.2	0	5.8	14.9	22	152.9	167.4	1.6	3.4
342	SEP	17.8	27.6	7.3	24.3	31.8	24	178.9	86.8	2.9	1.5
342	OCT	48.9	46.1	45.1	36.5	35.1	35.5	71.7	77	1	1.5
342	NOV	68.5	72.4	61.5	63.4	50.4	48.3	73.5	66.8	1.2	1
342	DEC	65.7	80.9	60.6	84.5	41.9	40.2	63.8	49.8	0.3	0.6
343	JAN	79.7	70.8	73.1	71.8	51	41	64	57.8	0.8	0.2
343	FEB	71.6	74.5	65.7	71.8	49.6	44.6	69.3	59.9	0.6	1
343	MAR	69.9	68.4	62.8	67.4	48.2	36.8	68.9	53.8	1.5	0.4
343	APR	41.5	37.2	29.5	31.1	36.6	31.2	88.2	84	0.9	1
343	MAY	16.7	21.6	8.6	13.6	22.4	23	134.4	106.5	2	1.3
343	JUN	7.1	8.1	0.5	0.5	12.3	13.4	173.5	164.5	2.6	2
343	JUL	6.6	6.8	0	0	11.9	11	180.2	162.6	2.4	1.8
343	AUG	8.8	8	0.2	1.3	16.9	12.6	192	157.7	2.8	2.2
343	SEP	16.5	16.9	6.2	13.2	25.8	15.8	156.1	93.3	2.7	1.3
343	OCT	51.3	44.1	40.5	41.7	40.5	29.8	78.8	67.7	1.1	0.6
343	NOV	69.4	63.3	51.5	56.9	51.7	41.9	74.4	66.3	1.3	0.8
343	DEC	60.7	74.3	55	71.8	40.6	38.1	66.8	51.3	0.6	0.8
344	JAN	91.1	84.8	92.1	79.5	50.4	51.7	55.3	60.9	0.3	0.8
344	FEB	76.5	88.6	65.8	79.8	45.1	47.3	59	53.4	0.8	0.7
344	MAR	76.7	70	68.9	65.9	47.5	41.3	61.9	59	0.9	0.7
344	APR	43	43.5	40.8	30.5	33.4	35.8	77.8	82.2	0.7	1.2
344	MAY	19.3	20.1	12.4	13.9	23.5	21.2	121.6	105.3	2	1.2
344	JUN	7.2	6.8	0	0	11.3	11.5	156.7	169.4	2.1	2.2
344	JUL	8.3	6.3	1.2	0.1	12.5	10	151.1	160.1	1.7	2.7
344	AUG	10	9.9	1	2.3	17.2	14	171.1	141	2.7	1.8
344	SEP	17.5	16.8	8.5	13.4	28.5	16.9	163	100.6	2.8	1
344	OCT	52	44.1	42.8	40.1	33.4	28.7	64.3	65.1	0.7	1.1
344	NOV	70	69.3	60	68	48.9	38.6	69.9	55.6	1	0.5
344	DEC	72.6	81.3	70.1	71.2	44.4	43.3	61.1	53.2	0.7	0.5
345	JAN	105.7	96.1	87.5	87.1	70.6	56.2	66.8	58.5	1	0.6
345	FEB	83.6	87	79.6	79.9	46.3	52.3	55.4	60.2	0.6	1.8
345	MAR	83.4	76.4	80.3	69.2	51.7	44.1	62	57.8	0.5	0.7
345	APR	49.9	47.4	39.5	41.1	40.9	36.6	82	77.3	0.8	1
345	MAY	22.8	26.4	10.4	20.1	28.7	27.2	126	103.2	1.6	1.8
345	JUN	9.9	12.3	2.5	0	15.6	18.2	158.4	147.8	2.5	1.4
345	JUL	8	8	0	0	15	14.5	187.9	180.2	2.1	2.3
345	AUG	12.2	9.6	0	0	20.6	13.7	168.5	143.2	2.2	1.5
345	SEP	21.3	22.4	11	11.7	32.2	27.8	150.9	123.9	3.1	1.6
345	OCT	59	54.4	49.7	48.5	43.2	38.3	73.1	70.4	0.7	0.9
345	NOV	77.1	73.4	67.1	66.7	50.2	43.6	65.1	59.4	1.2	0.6
345	DEC	84.9	85.2	75.4	87.4	44.2	47.2	52	55.3	0.5	0.5
346	JAN	88.3	75	79	66.6	51.8	54.7	58.7	73	0.5	1.4
346	FEB	66.2	67.5	67	58.5	43.7	39.7	66	58.8	0.5	1.2
346	MAR	66.8	58.1	58.8	51.5	43	43.2	64.4	74.4	0.6	1.1
346	APR	38.9	37.8	33.5	31.2	35	33.7	89.8	89.2	1	1
346	MAY	19.2	20.3	10.8	12.9	24	23.8	125	117.2	1.4	2.2
346	JUN	6.9	6.9	0	0	12.7	13.2	184.1	192.4	2	2.2
346	JUL	7.6	5.2	0	0	13.6	12	179.6	230.8	1.7	2.8
346	AUG	7.8	13.6	0	0	13.7	21.8	175.6	159.7	1.8	1.8
346	SEP	18.2	23.2	9	14.6	29.2	27.5	159.9	118.5	3	1.5
346	OCT	47.8	47	46.7	35.5	37.8	41.9	79	89.1	0.5	1.4
346	NOV	66	69.2	59.5	64.4	44.4	46.7	67.3	67.5	0.8	0.7
346	DEC	72	79.4	64	67.6	53.6	44	74.4	55.5	0.5	0.6
347	JAN	74.3	76.4	65.8	70.5	52	48.1	70	63	0.9	0.5
347	FEB	65.4	62.3	61.3	54.6	41.1	39.6	62.9	63.5	0.5	0.9
347	MAR	60.9	62.8	56.3	55.1	42.3	43.6	69.5	69.5	0.7	1.1
347	APR	38.2	34.2	27.9	27.9	33.2	27.8	86.8	81.3	0.7	1.1
347	MAY	19.4	17.6	8.7	10.1	24.9	21	128.4	119	1.7	1.2
347	JUN	5.4	7	0	0	10.4	12.2	193	174.3	3.1	2.6
347	JUL	7	4.3	0	0	13.8	9.4	196.9	222.2	2.2	2.9
347	AUG	7.8	9.8	0	0	12.7	16	163.3	163.3	1.7	1.8
347	SEP	17.6	20.8	8	16.3	30.3	22.1	171.5	106.1	3.6	1.1
347	OCT	45.9	42.3	37.8	34.6	40.2	35	87.7	82.9	1.6	1.2
347	NOV	59.6	63.8	52.3	59.8	41.8	36.4	70.2	57	1.1	0.5
347	DEC	69	80.8	55.2	78.2	52.5	44.6	76.1	55.2	0.7	0.6
348	JAN	102.1	99.4	91.1	99	53.5	49.7	52.4	50	0.7	0.3

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
348	FEB	85.6	87.8	82.8	77.3	47.1	46.9	55.1	53.4	0.4	0.9
348	MAR	84.5	79.3	75.7	69.1	49	49.7	58	62.7	1	1.1
348	APR	44.5	49.7	42.7	40.9	34.6	33.1	77.7	66.7	0.7	0.9
348	MAY	22.8	20.1	14	16.5	25.1	22	110.2	109.2	1.5	1.6
348	JUN	8.5	9.5	2.6	4.5	12.8	13.9	150.1	146.8	1.8	2.2
348	JUL	7.8	5.4	0	0	12.8	9.5	164.5	177.4	2.5	2.6
348	AUG	12.9	13.5	2.8	5.4	19.2	18.1	149.2	133.9	1.9	1.4
348	SEP	26.4	28.5	15	20.5	32.6	28.7	123.7	100.6	2.4	1.8
348	OCT	58.2	49.8	55	43.1	34.6	32.8	59.5	65.8	0.6	0.7
348	NOV	83.3	80.2	74.2	71	47.2	51.8	56.6	64.6	1.1	3
348	DEC	86.8	96.5	86.5	91.6	48.3	50.2	55.7	52	0.4	1
349	JAN	100.7	107.6	91	98.4	54.7	55.6	54.3	51.6	1.2	1.4
349	FEB	96.2	94.6	89	89.2	59	43.3	61.4	45.8	1.1	0.8
349	MAR	93.5	85.6	82.8	80.5	52.1	43.6	55.7	51	0.9	0.5
349	APR	57.9	51.6	53.2	47.2	40.1	36	69.3	69.7	0.7	1
349	MAY	24	25	18	22.4	22.5	22	93.7	88.1	1.3	1
349	JUN	9.1	7.8	3.4	3.6	12.7	10.2	139.4	130.8	2	1.7
349	JUL	10.6	7.1	3.8	1.9	14.5	11.6	136.9	162.7	1.7	2.3
349	AUG	13.5	11	4.6	4.8	19	16.6	141.2	151.1	1.7	3.1
349	SEP	23.2	30.5	11.7	24.2	29.1	29.2	125.3	95.9	2.1	1.7
349	OCT	63.2	61.6	56.1	55.8	39.3	38.7	62.3	62.7	0.7	1.2
349	NOV	82.6	80.2	73.8	74.3	49.5	41.5	59.9	51.8	0.8	1.1
349	DEC	92.2	92.4	90.6	87.4	47.7	42.1	51.8	45.5	0.1	0.8
351	JAN	123.2	124.9	106.7	120.4	69.8	51	56.7	40.8	0.6	0.5
351	FEB	113.8	120.5	103.1	117.7	60.9	58.9	53.5	48.9	0.4	0.6
351	MAR	98.5	110.2	93.4	102.9	62.1	56.3	63.1	51.1	0.8	0.7
351	APR	73.9	73.4	71.3	65.3	52.6	40.9	71.2	55.7	1.3	0.8
351	MAY	35.4	32.2	30	25	32.1	30.4	90.5	94.4	1.5	2.1
351	JUN	11.3	18.1	6.1	12.1	15.1	17.9	133.6	98.5	2.8	0.9
351	JUL	15.5	12.6	8.5	6.6	21	15.1	135.7	119.8	2	1.5
351	AUG	20.5	16.9	6.8	10.9	30.2	18.1	147	107.1	1.9	1.2
351	SEP	29.6	37.6	18.2	31	31.1	30.3	105	80.5	1.7	0.7
351	OCT	73.5	67.4	63	61.3	52.9	45.7	72	67.9	0.7	0.9
351	NOV	97.4	96	87.3	89.5	56.4	49.9	57.9	51.9	1	1.4
351	DEC	102.8	109.9	93.5	101.4	57.2	50.5	55.6	46	0.6	0.5
353	JAN	122.5	120.7	112.8	117.6	67.3	47.5	55	39.4	0.8	0.2
353	FEB	107.2	108.3	104.4	100	53.4	51.5	49.8	47.5	0.6	1.2
353	MAR	100.4	102	93.8	97.3	53.6	46.7	53.4	45.7	0.6	0.7
353	APR	56.1	63.9	50	56.9	42.1	37.8	75	59.1	1.3	1.2
353	MAY	25.8	23.7	19.7	16.9	23.5	20.5	91	86.2	1	1.3
353	JUN	10.5	11.5	5.1	6.5	13.9	14.1	132	123.4	1.8	2
353	JUL	11.1	11.3	4.1	2.6	16.7	16.9	150.4	150.1	2.4	2
353	AUG	16.8	15.3	8.2	9.1	22.8	16.9	135.2	110.4	1.7	1.3
353	SEP	28.7	27.1	14.6	18.5	33	27.8	115	102.8	1.7	1.6
353	OCT	68.9	71.3	62.4	66.4	44.2	42.4	64.1	59.4	1	0.5
353	NOV	91.2	93.4	83.4	83.1	52.9	49.5	58	53	1.2	0.9
353	DEC	103.4	110.6	98.1	111.9	50.5	50.4	48.8	45.6	0.6	0.4
354	JAN	124	122.1	125.9	116.8	55.5	51.2	44.8	41.9	0.4	0.6
354	FEB	112.9	109.4	103.4	104.7	59.7	51.9	52.9	47.4	0.6	0.5
354	MAR	104.1	101	97.1	96.4	49.6	43.7	47.6	43.3	0.6	0.2
354	APR	59.8	61.1	67.1	63.5	41.6	33	69.5	54.1	0.4	0.4
354	MAY	32.8	29.3	25	26.6	29.1	24.5	88.6	83.4	1.2	0.9
354	JUN	11	12.5	3.8	8.8	16.7	14	151.3	112.3	1.8	1.5
354	JUL	12.2	9.5	3.3	3.5	18.2	14.3	149.7	150.1	1.9	2.5
354	AUG	13.1	13.5	5.1	6.7	17.9	18.5	136.2	136.7	1.7	2.1
354	SEP	30.1	36.1	16	30.7	39.7	29.2	131.9	80.9	3.3	0.7
354	OCT	77.1	72.7	70.3	63.2	46.8	44.4	60.7	61.1	0.6	0.7
354	NOV	102.2	93	93.6	87.4	54.3	47.7	53.1	51.3	0.8	0.6
354	DEC	108.9	130.8	107.7	130.3	55.4	44.3	50.9	33.9	0.3	0.2
355	JAN	109.7	95.5	100.7	87.5	53.9	48.9	49.1	51.2	0.4	0.8
355	FEB	84.5	90.1	79	85.6	42.4	46.2	50.1	51.3	0.3	0.4
355	MAR	84.9	81	72.4	75.9	46.1	39.9	54.3	49.3	0.7	0.5
355	APR	50.3	49.6	38.8	48.2	41.8	34.4	83.1	69.3	0.7	0.7
355	MAY	24.7	24.7	13.5	20.7	27	23.5	109.1	95.2	1.6	1.3
355	JUN	9.9	12.6	3.6	3	15.1	19.5	153.1	154.5	2.5	2.3
355	JUL	9.2	9.5	0.8	2.1	16.6	15.2	180.7	158.9	2.4	2.4
355	AUG	14.9	14.1	3	5.4	24	20.9	161.1	148.2	2.4	2
355	SEP	27	28.9	14.5	20.3	38.1	28.3	141.2	97.9	3	1.5
355	OCT	66.4	56.6	57.2	50.8	47.3	34.2	71.3	60.4	1.1	0.7
355	NOV	87.3	84.9	73.2	83.9	55.5	45.6	63.6	53.7	0.9	0.8
355	DEC	101.3	104.4	92.5	101.4	55.1	47.7	54.4	45.7	0.8	0.6
448	JAN	74.1	70.6	55.6	64	66.5	44.1	89.7	62.4	1.3	1.3
448	FEB	66	71.9	61.3	65.3	44.6	42.5	67.6	59.1	0.8	0.6
448	MAR	75.1	73.5	73.1	61.3	48.8	46.4	65	63.1	0.9	0.8
448	APR	45.3	42.9	34.8	35.2	37.1	35.6	82	83	0.9	1.2
448	MAY	14.4	15.7	7.3	8.6	21.7	19	150.3	120.8	2.2	1.4
448	JUN	6.6	4.7	0	0	9.7	9	148.1	191.9	1.7	2.8
448	JUL	3.2	4	0	0	6.3	8.2	198.2	207.2	2.2	2.9
448	AUG	7.1	8.6	0	0	15.2	13.3	213.6	154.9	2.5	1.8
448	SEP	12.1	12	2.3	5.7	21	15.1	174	125.6	2.2	1.6
448	OCT	34.7	28.5	22.8	23.3	33.9	27.6	97.8	96.8	1.4	1.4
448	NOV	49.6	44.7	40	42.5	37.7	28.2	76	63.2	1.2	0.4
448	DEC	55.8	58.3	45.8	54.8	44	35.4	78.9	60.7	1.2	0.6
458	JAN	115.2	110	110.5	109.7	62.2	54.7	54	49.8	1.2	0.4
458	FEB	93.5	94.5	81.2	83.7	61.6	53.3	65.9	56.4	1.5	0.4
458	MAR	92.2	82.2	82.3	75.5	52.1	46	56.5	56	0.8	0.7
458	APR	46.8	46.4	34.2	41.6	40.5	30.5	86.6	65.8	1.2	0.7
458	MAY	17.1	16.7	8.8	11.8	20.3	17.2	118.9	103.1	1.4	1.3
458	JUN	6.3	5.8	0	0	15.3	10.8	244	186.2	4	2.4
458	JUL	4.9	1.8	0	0	12.2	5.1	248.2	278.4	3.4	3.7
458	AUG	4.8	7.5	0	0	12.6	13.1	260.5	175.2	4.4	2.4

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
458	SEP	14.4	13.7	5.5	5.3	23.7	21.6	164.9	158.3	2.6	2.8
458	OCT	42.8	46.8	37.6	41.3	29.4	34	68.7	72.6	0.9	1
458	NOV	73	75.2	73.5	69.3	38.9	46.7	53.4	62	0.4	0.9
458	DEC	93.1	96.1	89.3	93.2	50	41.5	53.7	43.2	1.4	0.4
459	JAN	100.4	114.1	95.8	103.6	58.7	69.1	58.4	60.5	0.9	1
459	FEB	90	96.2	84.9	92.8	49.7	51.9	55.2	54	0.8	1
459	MAR	83.3	85	71.1	69.7	53.8	61	64.6	71.8	0.9	0.9
459	APR	42.3	40.9	31.7	27	39.6	41.3	93.6	101	1.2	1.8
459	MAY	15	22.9	5.5	12.1	23.5	25.2	156.9	109.8	2.1	1.2
459	JUN	6.7	6.4	0	0	15.1	13.7	224.6	214.9	3.4	2.5
459	JUL	4.9	5.1	0	0	10.6	10.9	217.4	212.2	2.9	2.4
459	AUG	10.9	6.9	0	0	46.6	15.9	428.2	229.9	7.5	3.5
459	SEP	16	12.3	3	2.2	33.2	19.8	207.8	160.9	3.8	2.1
459	OCT	41.1	37.6	37	34.1	29.7	29.3	72.1	77.8	1	0.8
459	NOV	59.3	62.4	53	60.3	36.6	36.2	61.7	58	0.9	0.5
459	DEC	85.8	91.7	81.5	86.7	48.5	55.2	56.6	60.3	0.5	1.1
460	JAN	91.3	100.1	77.4	89.4	64.2	59.9	70.3	59.8	1.2	1
460	FEB	81.3	87.6	78	83	51.9	52.4	63.8	59.9	1.4	0.6
460	MAR	82.3	74.9	67	61.5	61.3	58	74.6	77.3	1	1
460	APR	43.5	42.6	34	34.2	39.3	32.5	90.4	76.3	0.8	1
460	MAY	13.7	15.9	0	5.2	24.2	24.2	177	151.8	3	2.3
460	JUN	5.4	3.4	0	0	11.9	9.7	221	287.9	2.8	4.5
460	JUL	4.1	2.4	0	0	11.9	6.7	293.4	279.9	4.2	3
460	AUG	5.5	4.6	0	0	13.6	13.1	246.3	283.1	4.1	3.3
460	SEP	14.2	16.1	2.5	2.4	26.6	24.1	187.3	149.4	2.7	2.2
460	OCT	37.4	31.7	36.4	25	31.9	25.2	85.2	79.4	1.5	0.6
460	NOV	62.9	70.8	50.5	65.2	45.6	49.3	72.4	69.6	1.5	0.8
460	DEC	66	71.2	55.3	65.4	47.4	43.6	71.9	61.3	1.6	0.7
461	JAN	87.5	89.6	73	82.3	58.7	47.8	67.2	53.4	0.9	0.6
461	FEB	87.1	78.9	79.2	72.5	49.8	37.8	57.1	47.9	1	0.6
461	MAR	79.5	74.5	69.7	69.4	51.9	47.8	65.3	64.2	1.4	0.9
461	APR	41	42.5	30.8	36.5	37.9	33.4	92.4	78.4	1.4	1.4
461	MAY	17.6	19.9	8.4	14.8	23.1	19.2	131.3	96.4	1.8	1.3
461	JUN	6.3	8.2	0.6	3.1	12.1	11.2	193.2	137.5	3.1	1.7
461	JUL	5.6	4.6	0	0	12.2	8.2	218.5	178.4	3.6	2.1
461	AUG	6.9	5.7	1	1	15	9.3	216.6	163.2	3.8	2.2
461	SEP	13.1	16.3	3	9.5	22.8	20.1	173.8	123.7	2.9	2.1
461	OCT	37.8	39.5	31	37.7	30.6	27.8	80.9	70.4	0.9	1
461	NOV	60.9	56.2	51.5	44.4	41.7	42.7	68.5	76	1.2	1.8
461	DEC	65.9	83.8	57.3	80.1	46.2	44.2	70.1	52.7	0.9	0.9
462	JAN	85.2	85.4	76.9	72.8	56.9	44.5	66.8	52.1	1	0.9
462	FEB	77.4	75.2	69.6	70.1	47.6	52.6	61.5	70	0.7	0.8
462	MAR	69.7	82.7	60.2	77.7	46.8	50.4	67.2	60.9	0.6	0.4
462	APR	42.5	34.7	30.8	29.2	39.6	27.5	93.3	79.2	2.2	1.1
462	MAY	14.4	20.4	5.8	11.7	22.5	24.7	155.8	121.6	2.1	1.9
462	JUN	6	5.9	0	0	12.5	9.9	209.2	167.5	3.1	2.4
462	JUL	5.4	3.4	0	0	12	7.7	220	229.2	2.8	2.5
462	AUG	7.6	7.1	0	0	17.5	14	228.9	196.9	3.6	3.2
462	SEP	12.2	15.4	0	7.9	24.5	20	201.4	129.6	2.4	1.7
462	OCT	40.1	41.6	34.2	35.3	33.5	34.1	83.4	81.9	1	1.3
462	NOV	63.1	55.5	55.2	45.9	46.2	37.2	73.2	67.1	1	1
462	DEC	59.1	67.5	56.7	59.6	38.2	44.1	64.7	65.3	0.3	0.8
463	JAN	74.2	70.1	64.5	64.2	51.3	37.7	69.2	53.7	1.2	0.7
463	FEB	65.9	64	52	59	46.7	36.4	70.9	56.9	1.1	0.9
463	MAR	67	67.3	57.9	63.5	50.2	37.5	74.9	55.7	2	0.6
463	APR	42.1	41.4	32.8	36.8	36.7	31.4	87.3	75.7	1.3	1.1
463	MAY	14.1	20.7	7.3	11.8	20.1	25.6	143	123.7	2.6	1.9
463	JUN	7.5	5.9	0.5	0	13.8	10.5	182.8	177.4	3.4	2.2
463	JUL	6.6	4.8	0	0	11.1	11.4	167.8	240	1.9	4.8
463	AUG	7	5.8	0	0	14.5	11	207.9	188.7	3.7	2.4
463	SEP	12.1	16.4	2.5	8.5	24.1	21.8	199.6	132.8	3	2.3
463	OCT	43.8	34.7	34.9	31	38.7	27.2	88.4	78.3	2.1	1.4
463	NOV	59.6	53	53.1	50.2	46.8	32.4	78.5	61.1	1.5	0.6
463	DEC	57.5	71.4	49.5	67.3	38.2	39.9	66.4	55.9	0.6	0.8
464	JAN	76.9	87.2	65	77.9	50	49.7	65.1	57.1	1.6	0.8
464	FEB	101.8	88.1	90.1	84.4	74.9	51.4	73.5	58.4	0.8	0.4
464	MAR	99.6	103.4	92	93.6	84.4	60.1	84.8	58.1	2.3	0.9
464	APR	46.7	56.3	28	51.3	57.6	42.2	123.2	75	2.8	0.8
464	MAY	23.8	19.1	6.3	10.7	37.4	21.7	157.6	113.6	2.4	1.2
464	JUN	7.5	6.4	0	0	18.3	12.9	245.7	201.1	3.8	2.6
464	JUL	9	5.2	0	0	18.5	10.1	205.9	193.5	2.4	2.4
464	AUG	8.1	11.8	0	0	14.6	23.7	180.7	201.5	2.4	2.6
464	SEP	12.1	16.8	1.8	7.8	19.6	22	161.8	130.9	1.9	2.3
464	OCT	35.1	38.3	26.4	29.3	35.8	33.4	102.2	87	1.9	0.9
464	NOV	62.8	55.6	50	46.8	51.9	38.1	82.7	68.5	1.7	1
464	DEC	63.4	74.3	50.3	66.1	54	46.1	85.3	62.1	0.7	0.9
465	JAN	85.7	77.4	70.5	75.8	54.8	41	64	53	1.2	0.8
465	FEB	83.4	80	68.2	75.5	59	44.6	70.7	55.7	1.5	0.7
465	MAR	78.2	75.1	67.6	63.8	47.9	48.1	61.2	64.1	1.1	1.1
465	APR	37.2	43.8	29.7	38.3	32.6	37.3	87.7	85.2	1.1	2.5
465	MAY	16.7	16.4	8.6	9.4	23.3	20.6	139.7	125.2	2.1	2.6
465	JUN	6.2	8.5	0.1	0.4	11.7	14.4	187.5	168.6	3.2	2.1
465	JUL	6.2	3.7	0	0	12.9	9	206.4	241.2	3.7	3.1
465	AUG	9.7	7.5	1	0	21	13.6	216.7	182	4.5	2.9
465	SEP	16.1	19.6	5.5	14.2	22.9	21.8	142.5	111.2	2	2.1
465	OCT	52.6	43.4	46.9	39.3	39.3	31.7	74.7	73.1	0.9	1
465	NOV	76.1	58.9	67	56.2	52.9	35.7	69.6	60.7	1	0.6
465	DEC	77.1	84.5	77.3	77.8	43.2	50.2	56.1	59.4	0.2	1
466	JAN	100.5	84.5	91.4	80	58	49.7	57.7	58.7	0.8	0.4
466	FEB	74.9	82.2	64	72.5	51.7	50	69	60.8	1	1.1
466	MAR	83.7	79.4	80.9	77.5	49.4	43.8	59	55.1	0.6	0.6

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
466	APR	56.8	52.3	44.9	46.6	47	40.9	82.6	78.2	1	1.3
466	MAY	19.2	19.8	9.8	11.2	27.7	24	144	121.7	2.1	1.3
466	JUN	7.6	6.9	0	0	15.5	13.6	204.9	196.5	2.9	2.4
466	JUL	6.3	4.6	0	0	12.5	10.3	199	223.5	2.9	2.5
466	AUG	8	7.3	0	0	14.5	16.1	181.2	220.4	2.7	3.7
466	SEP	18.2	22.5	6.8	12.4	26.2	30.8	143.4	137.3	1.7	2.2
466	OCT	57.7	57.4	54.5	51.8	42.3	44.1	73.3	76.8	0.9	1
466	NOV	79.6	76.4	70.3	67.4	50	45.2	62.8	59.2	0.9	0.6
466	DEC	78.4	85.5	69.9	74.5	44.1	44.4	56.2	51.9	0.5	0.5
467	JAN	93.9	94.8	85.2	92.6	51.4	48.3	54.7	51	0.9	0.5
467	FEB	94	88.3	76.7	73.6	64.2	62.2	68.4	70.4	1.1	1.3
467	MAR	79.1	72.5	71.4	67.9	54.8	40.8	69.3	56.3	0.9	0.4
467	APR	41.4	45.5	30.8	38.3	38.5	38.9	93	85.4	1.1	1
467	MAY	14.6	16	6.1	12.2	24.1	16.9	165.2	105.2	3.1	0.9
467	JUN	6.1	6.2	0	0	13.9	11.7	226.3	187.9	3.6	2.6
467	JUL	5.3	5.4	0	0	12.5	12	238.6	224.5	3.5	3.5
467	AUG	7	6.5	0	0	16.7	10.3	239.6	158.1	4.1	1.7
467	SEP	15.5	18	3.3	10.6	26.4	21.3	169.7	118.3	2.5	1.3
467	OCT	44.5	42.8	33.7	32.6	39.1	37.3	88	87.1	1.7	1.4
467	NOV	68.5	67.1	63	61.2	41.5	38.1	60.6	56.8	0.8	0.5
467	DEC	72.5	79.7	65.6	78.7	43.2	47.1	59.6	59.1	0.5	0.7
468	JAN	110.2	109.2	101.6	108.4	60.1	53.3	54.5	48.9	1.1	0.6
468	FEB	97.5	101.2	89.2	93.1	61.2	52.2	62.8	51.6	0.8	0.6
468	MAR	91	86.1	78.9	78.2	59	44.3	64.8	51.4	0.9	0.3
468	APR	47.9	50.3	32.8	44.1	44.1	38.7	92.1	76.9	1	1.4
468	MAY	15.6	17.7	5.2	10.6	24.5	19.8	156.8	111.5	2.5	1.3
468	JUN	7.3	7.5	0	1.1	16.3	13.5	223.1	179.9	3.4	3.7
468	JUL	4.7	3.3	0	0	10.3	6.7	219.6	206.3	2.4	2.4
468	AUG	7	5.5	0.3	0	14.4	10.7	205	196.1	3.7	2.3
468	SEP	14.2	13.7	4.1	7.7	22.1	21.8	155.4	159.2	1.9	3.4
468	OCT	40.8	41.2	35.7	35.6	28.1	28.2	68.8	68.4	0.9	0.9
468	NOV	70.3	59.7	61.6	56.5	42.2	32.7	60	54.8	1.2	0.9
468	DEC	84.2	97	77.1	92.1	47.9	50.2	56.9	51.8	0.7	0.8
469	JAN	104.4	95.9	105.7	90.7	52.1	49.8	49.9	51.9	0.7	0.4
469	FEB	84.1	101	86.2	95	46.8	51.5	55.7	51	0.6	0.5
469	MAR	79.8	84.1	73.9	80.4	45.8	42.8	57.4	50.9	0.8	0.7
469	APR	45.1	43.4	31.5	37.2	39.2	32.5	86.8	74.8	1.1	1
469	MAY	17.7	18.4	6.5	11.2	26.8	21.9	152	119	2	1.9
469	JUN	6.4	5.9	0	0	14.1	11.3	222.1	191.8	3.7	3
469	JUL	4.3	3.2	0	0	11.3	8.4	260.6	264.5	3	3.6
469	AUG	6.9	6	0	0	14.4	11.8	209.7	197.1	4.1	2.7
469	SEP	16.5	14.5	5.9	5.8	23.6	17.9	143.1	123.4	1.7	1.3
469	OCT	50.2	49.1	44.4	42.9	37	34.5	73.7	70.2	1.6	1.2
469	NOV	76.2	81.5	70.3	73.8	46.8	45	61.5	55.2	0.3	1.1
469	DEC	94.1	86.8	86.4	77.2	52.5	47.2	55.8	54.4	1	0.7
470	JAN	105.9	106.8	101.9	98.3	62.5	60.8	59	56.9	0.6	0.6
470	FEB	84.8	91.7	71.1	83.3	55.2	52.6	65.1	57.3	0.8	0.6
470	MAR	86.5	82	72.5	76.9	65	54.4	75.1	66.4	0.8	0.9
470	APR	45.2	46.1	32.8	34.3	43.3	41.5	95.9	90.1	1	1.4
470	MAY	13.8	9.7	0	0	20.1	15.7	145.2	161.3	1.6	1.9
470	JUN	3.2	4.3	0	0	9.3	12.3	286.7	288.4	4.2	4.2
470	JUL	4.3	3.1	0	0	11.6	8.4	272.3	272.1	3	3.8
470	AUG	5.4	6	0	0	14.1	11.8	263.4	196.6	4.1	2.1
470	SEP	14.5	13.4	1.9	6	22.6	18.4	156.1	136.8	1.9	2.4
470	OCT	36	42.5	32.2	31.7	24	39.7	66.6	93.5	0.4	1.1
470	NOV	70.3	69	61.2	61.3	54.2	41.5	77	60.2	1.1	0.8
470	DEC	83.7	90.3	84.2	87.6	55.3	49.2	66.1	54.5	0.7	2.1
471	JAN	86.2	83.7	72.4	81.9	59.9	48.4	69.5	57.8	0.5	0.5
471	FEB	71	79.4	65.6	77.5	48.6	47	68.4	59.2	0.5	0.8
471	MAR	75.6	62.7	65	52.3	63.2	44.3	83.7	70.7	1.2	1.1
471	APR	28.2	31.5	21.9	23.5	29.1	30.2	103.2	95.9	1.3	1
471	MAY	14	13.7	6.4	0.4	19.7	20.7	140.6	151.8	1.7	1.7
471	JUN	8.3	5	0	0	26	11.2	312.5	224	3.7	3.2
471	JUL	5.3	6	0	0	13.8	15.3	261.4	254	2.9	3.5
471	AUG	4.5	8.5	0	0	14	14.9	308.4	175.8	4.9	1.9
471	SEP	18.2	18.3	6.3	9.6	28.4	22.4	156.4	122.7	1.7	1.3
471	OCT	36.4	31.9	31.4	23.4	31.1	29.5	85.5	92.3	0.7	1.1
471	NOV	59.5	57.5	54.3	53.1	45.9	42.2	77.1	73.5	0.3	1.1
471	DEC	61.2	63	45.3	61.8	55.8	37.8	91.1	60.1	0.8	0.3
472	JAN	110.3	100.2	102.2	95.8	58.3	55.5	52.8	55.4	1.2	1.3
472	FEB	88.2	93.8	85.1	89.5	48.3	41.7	54.7	44.5	1.2	0.6
472	MAR	89	91.4	77.7	82.4	54.3	44.5	61.1	48.7	1.4	1
472	APR	48.6	45.7	41.4	36.4	39.4	35.1	81	76.8	0.8	0.9
472	MAY	17.4	18.8	10.5	14	21.6	19.8	124	105.3	2.3	1.6
472	JUN	8.6	6.2	0.5	0	20.7	11.3	241.4	183.2	4.3	2.9
472	JUL	6	4.1	0	0	13	8.8	216.2	213.8	2.9	2.8
472	AUG	7.8	6.5	0.5	0.9	16.4	11.1	210.7	170.2	3.4	3.1
472	SEP	20.2	20.3	12	14.8	24.7	22.6	122.1	111.2	1.7	1.9
472	OCT	54.1	60.1	51	52.5	33.5	40.7	62	67.6	0.6	1.1
472	NOV	85.3	84.3	81.3	78.7	49	43.7	57.4	51.9	0.6	0.6
472	DEC	100.6	105	102.7	96.2	46.1	50.1	45.8	47.8	0.2	0.8
473	JAN	80	79.1	74.2	67.7	41.1	53.1	51.4	67.2	0.9	1.3
473	FEB	77.1	66.9	61	57.9	55.1	42.7	71.4	63.9	1.6	0.7
473	MAR	73.6	69.9	65.6	62.9	51.3	39.9	69.7	57	0.8	0.9
473	APR	35.2	40.6	22.9	34.3	40.3	30.7	114.4	75.5	3	1.4
473	MAY	14.6	14.4	9.2	10.2	16.5	13.9	113.1	96.6	1.3	0.9
473	JUN	6.3	4.6	0	0	17.4	9.1	278.1	197.6	4.3	2.7
473	JUL	6.6	2.5	0	0	18.9	6.2	287.6	253.8	4.3	3.1
473	AUG	5.4	9.2	0	1	14.1	16.1	260.5	175.4	4.3	2.3
473	SEP	10.3	17.9	3.9	11.2	15.4	22.5	149.3	125.3	1.9	3
473	OCT	41	38.7	34.9	33.5	31.8	29.3	77.5	75.8	0.9	1.2

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
473	NOV	62.9	58.2	54.6	55.3	41.1	33.8	65.3	58.1	0.5	0.5
473	DEC	69.6	71.8	60	68.8	45.3	37.8	65	52.6	1.1	0.5
474	JAN	103.9	107.4	98.4	101.1	60.2	62.2	58	57.9	1.5	1.2
474	FEB	83.4	85.7	77	81.4	47.3	45.4	56.8	52.9	0.7	0.7
474	MAR	75.2	75.5	63.1	67.7	48.2	45.8	64.1	60.7	0.8	1.1
474	APR	42.8	36.9	34	31.8	43.9	31.1	102.4	84.3	1.7	1.4
474	MAY	15.4	11.9	9	4.6	20.5	18.5	133.2	155.4	2.2	2.5
474	JUN	6.7	8.3	0	0	17.1	14.9	257.7	180.3	4.2	2.2
474	JUL	4.5	3.1	0	0	11.5	8	254.6	260.5	3	4
474	AUG	6.4	6.1	0	0	15.2	12	235.9	196.1	3.4	2.4
474	SEP	15.5	18.9	8.9	13.3	19.2	22.9	123.4	120.8	1.8	2
474	OCT	47.7	56.1	43.7	52.7	32.7	39.2	68.4	69.9	1	1
474	NOV	81.5	75.4	76.2	65.5	49.3	41.3	60.6	54.7	0.8	0.6
474	DEC	93.4	97.3	93.7	89	40.5	48.9	43.4	50.3	0	0.5
475	JAN	118.7	99.6	110.7	94.2	70.5	52	59.4	52.2	1	0.5
475	FEB	88.5	92	80	84.7	48.3	54.9	54.6	59.6	1.1	0.8
475	MAR	85.9	82.7	79.2	80.1	54.4	42.6	63.3	51.6	1.1	0.6
475	APR	42.6	49.6	35.9	41.5	36.7	39	86.1	78.7	1	1.1
475	MAY	22.9	21.4	16.4	12.4	23.5	25.3	102.8	118.1	1.4	1.5
475	JUN	6.6	7.4	0	0	15.3	14.8	229.7	201.2	4.4	3.3
475	JUL	8.1	4.8	0	0	15	10.1	183.9	209.8	2.5	2.6
475	AUG	6.4	6.6	0	0	13.9	12.5	216.8	190.1	3.8	3.5
475	SEP	17.8	19.2	11	10.7	24.3	23.3	136.3	121.3	2.2	1.5
475	OCT	57.3	54.3	50.6	50.4	41.8	34.2	73	63	1.2	0.8
475	NOV	98.1	85.1	89.7	79.7	61.2	40.1	62.4	47.2	0.5	1
475	DEC	97.3	97.4	88.3	91.1	53.5	42.7	55	43.8	1.2	0.6
476	JAN	113.9	107.3	117.9	107.9	53.7	58.1	47.2	54.1	0.2	0.9
476	FEB	81.2	82.8	74.1	78.2	44.8	50.6	55.2	61.1	0.8	0.7
476	MAR	82.2	81.4	75.5	72.5	48.3	53	58.7	65.1	0.6	1.3
476	APR	47.9	50.1	33.9	42.3	36.3	35.7	75.9	71.3	0.5	0.6
476	MAY	14.6	20.5	4	10.9	22.1	23.2	151.6	113.1	1.9	1.2
476	JUN	6.4	9.5	0	0	15.5	15.7	240.4	164.4	3.4	2.7
476	JUL	6.7	3.4	0	0	15.1	7.8	224.8	228.4	2.8	2.9
476	AUG	6.6	5.2	0	0	14.2	11.1	213.4	215.6	3.4	4.4
476	SEP	18.3	20.8	8	15.7	27.5	22.4	150.5	107.4	2.2	1.7
476	OCT	53.4	57.5	48.5	54	35	37.1	65.5	64.4	1.1	1
476	NOV	86	80.2	80.5	74	50.9	42.6	59.2	53.2	0.6	0.9
476	DEC	95.3	109	90.8	103.7	45.8	55.4	48.1	50.8	0.2	0.9
477	JAN	109.7	104.5	107.1	99.9	54.7	49.7	49.9	47.6	0.4	0.4
477	FEB	89.6	91.7	87.2	81.7	47.8	52.9	53.3	57.7	1.3	0.6
477	MAR	85.5	85.4	74.9	82.1	54.7	52.6	63.9	61.6	1	0.7
477	APR	44.8	51.8	35	40.7	39.9	41.1	89	79.4	1.3	1.2
477	MAY	18	19	7.1	12.3	24.9	21.7	137.8	114.4	1.9	1.6
477	JUN	8	6.9	0	0	16.3	12.6	204.3	181.8	3	2.3
477	JUL	6.8	4.5	0	0	14.9	11.4	218.9	254.7	2.7	4.5
477	AUG	9.4	7.1	0	0	17.6	12.4	188.6	176.1	2.9	2.2
477	SEP	19.5	18.4	9.6	11.8	25.3	21.8	129.5	118.7	1.7	1.3
477	OCT	50.7	45.9	38.8	38	38.5	35.3	75.9	76.9	1.1	1.2
477	NOV	76	80	72.4	77.7	44.1	48.4	57.9	60.5	0.3	0.8
477	DEC	92.6	100.4	92.6	100.7	42.9	43.5	46.3	43.3	0.2	0.2
478	JAN	112.1	101.4	111.7	100.8	62.8	50	56	49.3	1.5	0.6
478	FEB	80.3	87.1	73.3	77	42.5	52.6	52.9	60.4	1.4	0.8
478	MAR	84.8	77.3	75	72.9	46.2	44.6	54.5	57.7	1.2	0.9
478	APR	57.2	56.5	44.3	50.8	48	36.3	83.9	64.3	1.3	0.3
478	MAY	20.6	27.4	8.3	21	25.7	26.4	124.6	96.6	1.4	1.1
478	JUN	8.5	8.8	1	2.5	19.1	14.8	223.9	168.9	3.4	2.8
478	JUL	6.8	4.8	0	0	14.5	9.9	213.7	207.8	2.7	2.5
478	AUG	7.7	5.9	0	0	15.8	8.8	204.7	148.7	4.2	1.5
478	SEP	17.1	23.3	9.1	15.2	23.5	26	137.2	111.7	1.9	1.6
478	OCT	53.2	57.7	51.9	50.9	32.5	38.3	61.1	66.4	0.6	0.8
478	NOV	94	95.1	85.6	88.3	52.4	45.3	55.7	47.7	0.6	0.6
478	DEC	102.4	112	94	108.8	54.6	48.8	53.4	43.6	1.5	0.5
479	JAN	104	103.1	93.8	102.2	68	52.7	65.4	51.1	2.2	0.5
479	FEB	83.1	92.8	79	88	44.8	49	53.9	52.8	0.8	0.8
479	MAR	84.1	80.2	85.2	73.5	45.4	46.8	54	58.3	0.4	1.1
479	APR	49.3	44.5	40.9	36	40	35.4	81.2	79.5	0.7	1
479	MAY	17.2	24.1	7.5	16.6	22.8	24.9	132.7	103.4	2.1	1.5
479	JUN	6.9	8.2	1.5	2.8	14.7	12.1	213	147.1	3.6	2
479	JUL	6.3	5.5	0	0	13.4	9.5	213.3	174.6	3.1	2.1
479	AUG	7.6	6.4	0.9	0.8	14.4	11.5	188.4	180.7	3	3.2
479	SEP	16.2	17.2	6.6	9.6	23.6	17.9	145.6	103.7	2	1
479	OCT	51.1	43.7	42.8	35.7	35.7	33.5	69.7	76.7	1	1.7
479	NOV	73.2	77.5	62.6	72.4	45.2	42.4	61.7	54.7	0.6	0.3
479	DEC	85.5	92.3	75.5	90.2	50.2	43.2	58.7	46.8	0.7	0.8
480	JAN	87.6	89.4	74	86.2	60.8	49.5	69.5	55.3	1.4	0.9
480	FEB	68.1	72	55.1	65.5	48.4	50.4	71.1	69.9	1.2	0.8
480	MAR	69.7	68.1	71.4	64.7	43	41.2	61.7	60.4	0.3	0.7
480	APR	44.7	38.9	44.2	34.3	36.1	31.3	80.7	80.5	0.5	1.1
480	MAY	15.4	17.2	4.2	10.7	25	20.1	162.5	116.5	2	1.2
480	JUN	5.5	6.6	0	0	12.3	12.1	223.4	183.9	3.3	2.1
480	JUL	6.1	4.9	0	0	12	12.9	196.9	261.5	2.4	3.6
480	AUG	7.6	8.6	0	0	15.7	16.2	206.9	186.9	3.3	2.6
480	SEP	17.1	19.9	8	13.9	23.8	20.5	139.2	102.9	2.1	1.3
480	OCT	54.5	53.7	40.3	47.9	44.8	38.3	82.3	71.3	1	1.4
480	NOV	68.3	68.1	53.2	60	49.4	39.3	72.3	57.8	1.3	0.6
480	DEC	73.6	86	70	76.3	43	53.1	58.4	61.7	0.7	0.6
481	JAN	94.9	81.5	83.8	76.6	50.6	35.8	53.3	44	0.9	0.7
481	FEB	78.5	76.8	79.7	75.2	38.5	39.3	49	51.2	0.3	0.7
481	MAR	80.6	73.3	66.6	68.4	44.9	39.7	55.8	54.1	0.6	0.8
481	APR	51.6	50.4	46	42.6	39	31.2	75.5	61.8	0.7	1.2
481	MAY	21.6	23.2	12.5	16.8	23.6	22.3	109.4	96.3	1.4	1.2

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
481	JUN	7.9	8.4	2.3	3.6	13	12.1	164.9	143.8	2.5	2.2
481	JUL	8.6	6.9	0.5	1.8	14.6	10	170.2	145.6	2.2	1.7
481	AUG	9.2	11.7	1.9	6.4	14.4	14.3	155.5	122	1.8	1.3
481	SEP	20.9	23.1	10.4	16.1	28.1	21.9	134.6	94.9	2.4	1.2
481	OCT	57.4	52.6	51.4	48.9	41.7	30.9	72.7	58.7	1.3	1
481	NOV	77.3	77.6	63.6	79.9	52.8	38.7	68.3	49.9	1.5	0.4
481	DEC	83.3	81.4	77.6	80.3	47.1	43.2	56.6	53	0.4	0.4
482	JAN	104.9	95.8	93.8	87.4	60.4	52.2	57.6	54.6	0.8	1.1
482	FEB	86.2	86.7	83.6	77.5	41	47.9	47.6	55.2	0.6	0.7
482	MAR	82.8	79.2	77.8	74.6	46.7	40.9	56.4	51.6	1	0.3
482	APR	55.3	53.8	54	46.1	37.3	37.7	67.4	70	0.4	1.3
482	MAY	26.8	24.6	11.7	21.1	31	24.1	115.6	97.9	1.3	1.4
482	JUN	7.8	12.6	1.8	2.9	12.5	18.5	160.4	146.3	2.3	1.6
482	JUL	10.1	7.1	0	0	18.3	14.8	180.3	207.9	1.9	2.9
482	AUG	10.1	11.6	0	2.5	21.5	17.7	213.5	152.6	4	1.9
482	SEP	22.9	27.5	10.7	23.4	36.9	25.5	161.1	92.8	3.3	1.4
482	OCT	59.6	59.4	52.2	52.9	41.2	39.2	69.1	66.1	0.8	1.3
482	NOV	90.4	90.4	80.4	88.3	53.2	43.3	58.9	47.9	1	1.1
482	DEC	95.8	105.9	82.9	98.7	60.6	53.1	63.2	50.2	0.8	0.4
483	JAN	84.2	82.2	78.1	78.1	55.1	48	65.4	58.5	0.5	0.9
483	FEB	74.8	85.4	59.6	78.2	49.9	49.4	66.7	57.8	0.6	0.6
483	MAR	72.5	69.3	65.3	63.3	48.5	41.1	67	59.3	0.7	0.9
483	APR	44.5	44.4	42.5	40.5	38.4	32	86.4	72.1	0.7	0.8
483	MAY	17.6	17.3	7.4	11.8	25.9	21.2	147.4	122.3	1.9	1.9
483	JUN	6.2	4.8	0	0	11.2	9.2	180.3	192.9	3.5	2
483	JUL	6	4	0	0	12.1	9.2	201.7	229.9	2.3	2.9
483	AUG	10.2	8.4	0	0	20.6	15.3	202.7	183.1	3.4	2.5
483	SEP	18.8	26.4	8.9	14.3	28.6	32.1	152.1	121.5	3.2	1.4
483	OCT	56.7	55.4	46	51.3	44.1	36.9	77.8	66.6	1.2	0.7
483	NOV	71	72.9	62.5	64.2	53.8	46.4	75.8	63.7	1.5	0.9
483	DEC	75.4	83.7	69.5	84.2	45.7	41.5	60.7	49.6	0.3	0.7
484	JAN	92	90.8	87.6	81.8	50.3	48.9	54.7	53.8	0	1.3
484	FEB	74.2	74.3	70.3	66.7	48.5	45.8	65.3	61.7	0.4	0.5
484	MAR	69.1	72.6	70.2	66.3	44.7	40.3	64.7	55.5	1	0.9
484	APR	40.3	43.1	32.3	36.2	30	32.9	74.4	76.3	0.5	1.4
484	MAY	20.5	25.7	11	18.5	25.8	23.5	126.3	91.5	1.6	1.3
484	JUN	9.9	10	5.1	4.9	14.3	14.3	145.1	142.8	2.7	1.8
484	JUL	8.9	8.2	0.1	3.2	19.4	11.6	219.4	141.9	2.9	1.9
484	AUG	12.2	12.5	2.4	4.2	19.8	18	163.2	143.3	1.8	1.7
484	SEP	26.9	25.7	14.8	21.2	34.1	22.8	126.5	88.5	2.6	0.9
484	OCT	62.6	50.7	57.7	46.8	43.9	37.5	70.1	74	0.9	0.9
484	NOV	83.6	85.3	71.7	79.3	64.3	38.4	77	45	1.3	0.5
484	DEC	85.2	96.1	90.8	89.7	46.5	51.1	54.6	53.2	0	0.8
485	JAN	112.3	107.6	113	99.9	56.4	46.2	50.3	42.9	0.2	0.4
485	FEB	86.7	90.5	74.9	84.2	49.1	51.8	56.6	57.2	0.5	1.8
485	MAR	81.5	82.2	75.8	73.3	45.1	45.3	55.4	55.1	0.8	1.1
485	APR	49.5	52.6	48.4	47.8	35.9	35.3	72.4	67.1	0.8	0.8
485	MAY	23.2	20.5	12.1	13.9	28.4	20.2	122.4	98.4	1.6	1.1
485	JUN	8.1	12.3	1.4	4.1	12.5	19.6	155.2	159.4	2.1	2.2
485	JUL	9.5	10	0	0	19.5	14.6	206.2	145.3	2.9	1.5
485	AUG	13.9	9.5	3.1	1.7	22.4	15.1	161.3	159.8	2.2	2.1
485	SEP	29.8	31.9	19.9	20.3	36.2	37.5	121.6	117.7	2.1	2.2
485	OCT	75.9	70.3	67.8	63	49.2	42.6	64.8	60.7	0.9	1
485	NOV	89.4	97.1	86.8	87.4	52	48.2	58.1	49.6	0.7	0.6
485	DEC	100.3	100.7	98	99.1	47	39.4	46.9	39.2	0.5	0.1
486	JAN	96.7	92.2	84.4	84.4	53.3	42.2	55.1	45.8	1.3	0.8
486	FEB	79.2	74.2	76.4	69.2	43.9	38	55.4	51.2	0.6	0.7
486	MAR	76.5	81.4	72.1	77.4	46.6	39.7	61	48.8	1	0.5
486	APR	42	42.8	35.6	33.8	32.6	32.1	77.6	74.9	0.7	1.5
486	MAY	19.1	18	9.1	11.7	24.3	19.3	127.4	107.6	1.7	1.2
486	JUN	7.1	6.9	2	1.7	10.8	12.1	151.2	176.3	2.4	3.1
486	JUL	6.7	6.1	1	0.1	12.3	11.1	182.6	182.6	2.5	3.1
486	AUG	9.9	9.5	0.9	2.6	17.5	15.1	176.7	159.7	2.3	2.1
486	SEP	20.5	24.9	12	16.1	24.8	27.9	120.8	112	1.8	2.3
486	OCT	61.1	55.5	58.5	51.1	42.4	28.9	69.4	52.1	0.7	0.4
486	NOV	84	76.8	80.1	70.6	54.7	44.5	65.2	57.9	1.4	1.8
486	DEC	79.9	97	73.4	97	43.2	43.5	54.1	44.9	0.5	0.3
487	JAN	107	99.2	97.2	95.4	57	53	53.3	53.4	0.7	0.9
487	FEB	77.8	84.2	65.5	79.3	41.6	46.7	53.4	55.4	0.9	0.8
487	MAR	73.2	69.4	64.9	62.2	42.8	39.1	58.4	56.2	0.8	0.6
487	APR	44	45.4	40.3	36.5	32.8	32.6	74.6	72	0.6	0.8
487	MAY	20.7	24.7	9.5	15.5	25.6	26.2	123.6	106.1	1.6	1.4
487	JUN	6.7	7.9	0.8	0	9.9	13.1	148.5	165.5	1.8	2
487	JUL	7.5	6.6	0	0	17.5	11.3	232.6	171.8	3.6	1.9
487	AUG	9.8	10.4	0.6	2.1	16.2	17.3	166	165.9	2.3	2.4
487	SEP	23.5	24.9	15.2	21.8	29.8	22.4	126.8	89.9	2.9	0.6
487	OCT	64.4	61	59.3	55.3	43.1	39.4	67	64.6	1.1	0.9
487	NOV	84.2	89.5	75.8	88.7	52.9	46.2	62.8	51.6	1.1	0.9
487	DEC	95.5	104	91	98.3	46.5	47.3	48.7	45.5	1.1	0.7
488	JAN	96.7	85.2	95.1	77.1	62.8	48.7	65	57.2	0.7	0.7
488	FEB	66.7	70.9	61.1	70	42.8	41.1	64.1	58	1.1	0.3
488	MAR	62.5	61.8	59	54	41.2	42.4	66	68.6	1	0.8
488	APR	40.6	40	35.6	32.9	36.4	33.4	89.6	83.4	1	1
488	MAY	18.2	20.9	12	9.1	23.7	24.9	130.4	119.2	1.7	1.4
488	JUN	7	6.9	0.3	0	11.8	15.2	169.8	219.8	2.6	3.5
488	JUL	7.7	4.4	0	0	17.7	9.2	228.3	212.2	3.1	2.3
488	AUG	10.4	11.3	0.7	3.6	18.7	17.1	178.8	151.3	2.7	2.5
488	SEP	20.8	20.1	12.5	11.2	28	22.8	134.6	113.8	2.9	1.2
488	OCT	59	52.3	52.5	48.2	42.9	32.2	72.6	61.6	0.6	0.4
488	NOV	89.1	77.7	84.5	70.4	52.5	43.7	58.9	56.2	0.5	0.5
488	DEC	84.8	90.6	82.8	83.1	52.1	48.6	61.4	53.7	0.2	0.6

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
489	JAN	113.5	116.6	104.1	106.9	68.1	53.3	60	45.7	1.5	0.6
489	FEB	86.5	93.3	73.6	87	50.7	48.3	58.6	51.7	1.1	0.8
489	MAR	86.4	86.1	80	79.5	52.1	47.2	60.3	54.8	0.7	0.7
489	APR	51	50.4	46.2	39.8	42	41.2	82.2	81.8	1	1
489	MAY	18.5	19.4	9.3	16.2	23.8	20.4	128.2	105	1.8	1.9
489	JUN	8.3	8.1	2	0.9	15.2	14.8	182.3	182	3.5	2.9
489	JUL	6.7	6.3	0	0	14.1	13.1	210.7	208.9	3.1	2.4
489	AUG	10	6.9	0.2	0	20.1	12.6	201.6	182	3.1	2.7
489	SEP	21.6	27.9	10.9	20.1	28.5	27.7	131.6	99	2	1.4
489	OCT	67.8	61.7	64.2	58.7	44.2	44.4	65.2	71.9	0.8	0.8
489	NOV	96.3	91.8	85.4	86.2	63.5	48.7	65.9	53.1	1	0.5
489	DEC	94.6	115.6	87.8	110.1	51.8	55	54.7	47.6	0.9	0.6
490	JAN	111.8	108.1	101.7	107.2	56.3	47.7	50.4	44.2	1.4	0.3
490	FEB	79.5	86.1	69.2	84.8	43.5	42.9	54.7	49.8	0.9	0.3
490	MAR	78	76.6	72	72.3	39.9	38.5	51.1	50.3	0.8	0.7
490	APR	42.7	50.5	36.1	45	35.1	37	82.3	73.3	1.1	1.3
490	MAY	18.5	18	10.7	11.8	21.6	21.7	117.1	121	1.5	2.9
490	JUN	9.3	9.5	1.5	1.3	18.3	15.1	196.3	159.2	3.5	2.1
490	JUL	6.8	5.2	0	0	13.9	11.4	203.7	216.7	2.8	2.7
490	AUG	10.3	7.6	0	1	20.5	16	198.6	210	3.7	4.8
490	SEP	21.7	21.7	14.8	17.5	28.2	20.3	129.7	93.9	2.9	1.2
490	OCT	67.3	59.5	58.8	50.7	40.6	36.1	60.3	60.7	0.7	0.9
490	NOV	98.7	86.9	87	76.3	68.2	49.7	69.1	57.2	1.5	0.9
490	DEC	99.6	110.7	93.5	106.2	46.3	43.6	46.5	39.4	0.8	0.3
491	JAN	96.7	93	90.9	87	54.3	45.9	56.1	49.3	0.6	0.5
491	FEB	74.6	75.7	68	69.7	44.8	42.5	60	56.2	0.3	0.8
491	MAR	72.4	68.1	67	65.3	51.9	38.4	71.7	56.3	1.2	0.8
491	APR	44.8	45.7	33.3	39.8	41.7	33	93	72.2	1.1	1
491	MAY	18.7	22.1	9.1	17.9	22.1	20	118.5	90.5	1.5	0.7
491	JUN	8.2	6	1.8	1.3	16	9.7	194.2	160.4	4	2.1
491	JUL	6.9	5	0	0	13.6	7.7	197.5	153.5	2.6	1.5
491	AUG	8.7	7.6	0.4	1.7	16.7	10.4	192	136.9	3	1.3
491	SEP	19.5	24.1	10	17.7	26.1	22.3	133.7	92.6	2.6	1.1
491	OCT	63.1	59.8	58.2	56.5	45.5	35.3	72	59	0.5	0.7
491	NOV	77.5	82.2	72.7	72.7	61.3	45.6	79.1	55.5	0.9	1.1
491	DEC	85.6	87.1	85.4	85.1	53.8	40.1	62.9	46.1	0.3	0.6
492	JAN	123.3	118.1	115.6	104	58.7	56.8	47.6	48.1	0.7	0.4
492	FEB	86.8	93.9	82.9	86.8	49	40.5	56.4	43.1	1.2	0.3
492	MAR	78.6	75.3	69.4	69.7	45.1	44.1	57.3	58.6	0.7	1.5
492	APR	48.5	47.5	33.9	42.2	39.9	31.1	82.3	65.4	1.1	0.8
492	MAY	20.3	22.2	10.7	16.3	24.2	20.4	119.2	91.8	1.7	1.2
492	JUN	8.7	7.2	2.5	2.5	17	10.6	196.1	147.5	4	1.9
492	JUL	8.1	5.5	0.5	0	16.1	14.1	199.3	254	2.7	5.2
492	AUG	11.4	8.7	1.8	1.8	21.2	13.5	185.9	154.4	3	1.9
492	SEP	24	24.6	15.5	14.8	26.7	28	111.1	114	2.2	2.1
492	OCT	68	63	59	55.5	39.8	35.2	58.5	55.8	0.7	1.6
492	NOV	99.5	99.4	93.8	91.8	52.5	47.6	52.7	47.9	1	0.6
492	DEC	107.2	123.9	100.5	116.9	47.4	49.5	44.3	39.9	0.9	0.7
493	JAN	122.1	115.9	116.3	112.7	59.4	56.6	48.7	48.8	0.6	0.7
493	FEB	94	100	77.3	93.8	59.4	50	63.2	50	1.6	0.6
493	MAR	79.5	79.2	75	75.9	42.1	43.2	53	54.5	0.8	0.6
493	APR	48.9	38.1	42.4	27.7	37.9	35.1	77.5	92.2	0.8	1.3
493	MAY	17.8	17.7	10.1	8	26.2	21.5	147	121.5	3.1	1.4
493	JUN	7.7	8.5	0	0	14.7	14.3	190.9	167.8	2.9	1.9
493	JUL	7.7	6.6	0	0	16.8	14.2	218.4	214.2	2.6	3.3
493	AUG	7	9.8	0	1.2	12.7	18	181.9	184	2.5	2.9
493	SEP	24.5	24.8	14.1	18.8	29.2	25.4	119.3	102.3	2.3	1.2
493	OCT	65.3	65.6	58	63.7	33.3	38.3	51	58.3	0.7	0.5
493	NOV	104	98.3	95.6	93.1	55.8	48.1	53.7	48.9	0.9	0.5
493	DEC	110.3	120.6	105	111.4	50	58.6	45.3	48.6	1.4	0.3
494	JAN	109	100.6	109.9	93.7	51.9	45.5	47.7	45.2	0.3	0.7
494	FEB	91.5	83.2	86.2	76.7	43.7	49.3	47.8	59.2	0.9	1.1
494	MAR	68.2	72.2	56.4	64.5	42.2	34.8	61.9	48.2	0.8	0.7
494	APR	40.6	39	32.3	37.2	31.4	30.7	77.4	78.7	1.1	1.5
494	MAY	18.6	17.9	9.3	13.5	24.7	19.2	132.6	107.4	2.7	1.3
494	JUN	8	6.4	3	0	15.3	11.1	190.4	174.4	3.3	2.1
494	JUL	7.5	5.2	0	0	16.5	9.2	221.3	177.2	2.8	2.1
494	AUG	6.4	7	0	0.8	10.9	12.5	171.7	179.4	2.1	3.2
494	SEP	18.8	21.9	9	19.4	24.1	17.4	128	79.2	1.8	0.9
494	OCT	63.2	55.2	60.4	45.6	33	36.9	52.2	66.8	0.3	0.7
494	NOV	92	87.4	82.8	82.7	50.4	47.3	54.7	54.2	0.5	0.4
494	DEC	101.3	117.4	96.5	113.2	51.5	49.4	50.8	42	0.6	0.4
495	JAN	119.7	122	100.5	110.4	68	59.4	56.8	48.6	1.4	1.3
495	FEB	97.8	105.9	94.3	99.5	55.7	50.2	57	47.4	1	0.7
495	MAR	87.1	89.9	79	88.4	48.7	44.7	55.9	49.7	1	0.5
495	APR	45.9	46.2	41.9	33.9	34.9	38	76.1	82.2	1	1.2
495	MAY	19.2	17.9	11.1	13.9	22.2	18	115.5	100.7	1.7	1.5
495	JUN	6.6	7.7	0.3	1.6	13.5	13.4	206.6	175.6	3.1	2.5
495	JUL	10.5	7	0	0	29.2	14.8	278.6	210.1	5.6	2.8
495	AUG	7	8.4	0.3	2.8	11.9	11.9	170.4	142	1.7	2
495	SEP	21.3	21.4	13.5	13.7	24.7	24.9	115.7	116.6	1.9	1.7
495	OCT	61.4	57.7	55.4	46.7	38.9	41.1	63.3	71.4	1	1.4
495	NOV	97.4	95.3	90.7	84.4	57.1	48.6	58.6	51	0.7	0.9
495	DEC	112.9	123.2	107.4	112.9	57.3	54.6	50.8	44.3	0.4	0.8
496	JAN	123.2	119.1	110.3	103.7	63.1	62.9	51.2	52.8	1.5	0.8
496	FEB	96.3	95	85.1	86.1	57.1	47	59.3	49.4	2.2	0.5
496	MAR	86	80.5	75.4	71.4	46.8	50	54.4	62.2	0.7	1.2
496	APR	41.7	46.1	32.6	36.3	34.9	35.7	83.9	77.4	1	1.5
496	MAY	18.6	21.4	7.9	13.5	25.3	26.2	135.6	122.6	2.3	3.1
496	JUN	6.3	8.4	1	1.3	11.5	13.2	183.9	158.6	2.7	1.9
496	JUL	7.2	5	0	0	14.8	8.9	205.9	178.7	2.6	2.4

HCZ	MONTH	MEAS MEAN	GEN MEAN	MEAS MEDN	GEN MEDN	MEAS STD	GEN STD	MEAS C.V.	GEN C.V.	MEAS SKEW	GEN SKEW
496	AUG	7.9	7.8	1	1.2	14.4	13.7	182.7	174.4	2.6	2.3
496	SEP	23.6	21.5	14.2	16.8	27.8	19.8	117.7	92.1	1.9	1.3
496	OCT	62.9	57.5	55.5	50.2	37.3	34.9	59.4	60.7	0.6	0.7
496	NOV	109.7	97.6	106.3	83.9	61.1	53.5	55.7	54.8	1.1	1.2
496	DEC	108.7	131.6	103.7	127.2	49.2	52.2	45.2	39.7	0.7	0.5
497	JAN	131.7	137.1	117.4	128.8	76.8	59.4	58.3	43.4	1.2	1.1
497	FEB	115.1	113.3	100.1	101.2	70.1	54.4	60.9	48	2	0.8
497	MAR	100.3	92.1	92.8	85.6	52.2	52.4	52	56.9	1	0.5
497	APR	48.4	45.3	41	40.3	37.4	33	77.1	72.7	0.9	1
497	MAY	19.5	21.8	9.9	15	26	21.3	133.5	97.7	2.7	1.1
497	JUN	8	5	1	0.3	17.6	8.2	219.6	163.6	4.1	2
497	JUL	9.7	7.4	0.5	0	21.6	15.2	223.4	205.5	3.1	3
497	AUG	10.3	11.5	1.7	3.8	19	17	185.1	147.4	3.6	2
497	SEP	25	26.3	15.3	20.9	29.2	26.5	116.7	100.7	1.7	2.3
497	OCT	70.3	72.6	64.5	64.2	49.1	41.4	69.8	57.1	1.3	0.5
497	NOV	118.7	109.4	120.8	105	63.7	52.8	53.7	48.3	1.2	0.7
497	DEC	123	139.7	107.1	141.5	62.5	62.9	50.8	45	0.7	0.5
498	JAN	138.5	142.8	122.1	144.2	77.9	58.8	56.3	41.1	1.7	0.4
498	FEB	115.9	126.8	108.1	116.9	67.1	60.8	57.9	48	2.1	0.7
498	MAR	99.9	92.4	91.3	82.6	52.1	50.7	52.2	54.8	0.7	0.9
498	APR	49.2	55.2	39.2	47.3	37.7	34.7	76.7	62.9	0.8	1.1
498	MAY	20.7	24.8	14.8	21.1	24.7	22.5	119.7	90.9	2	1.7
498	JUN	7.5	8.3	1.1	3.6	15.6	12.1	207.7	145.2	3.9	2.3
498	JUL	9.4	6.7	0.3	0	20.1	12.9	212.7	192.1	2.9	2.6
498	AUG	9.3	12	1.7	3.6	17.4	17.3	186.9	144.6	2.9	2.1
498	SEP	24.1	30.9	14.7	22.3	30.1	29.1	125.2	94.2	2.3	1.6
498	OCT	70.9	76.5	64.8	72.3	41.3	44.2	58.2	57.8	0.7	0.6
498	NOV	122	117.1	111.1	108.5	68.5	54.1	56.1	46.2	1.6	0.9
498	DEC	132.4	144.1	118.1	126	60.4	72.4	45.7	50.2	0.6	0.8
499	JAN	121.3	121.8	103.6	107.5	71	55.6	58.5	45.7	2.2	0.6
499	FEB	104.9	98.3	95.5	93.3	62.9	53.7	59.9	54.6	1.3	0.5
499	MAR	80.5	80.4	68.7	70.6	49.6	52.2	61.6	64.9	0.8	0.9
499	APR	42.2	39.5	36.2	31.8	33.7	32.8	79.8	83.1	0.6	1.5
499	MAY	15.2	16.4	8.9	12.9	19.2	16.9	126.5	103.2	1.6	1.5
499	JUN	7.6	7.2	0	1.5	17.2	11.6	226.7	159.5	2.7	2.1
499	JUL	8.7	5.2	0	0	20	11.6	229.8	223.8	2.6	3.7
499	AUG	9.7	11.8	0	2.3	20.1	19.9	207.8	168.8	2.9	2.4
499	SEP	20.8	22.3	11.4	11.2	28.9	29.8	139.4	133.9	2	2.4
499	OCT	56.4	73.7	50.5	74.7	41.4	42.9	73.4	58.2	0.8	0.3
499	NOV	108.2	90.7	97.1	85.1	65.5	47.2	60.6	52	1.1	0.6
499	DEC	101.9	119.8	95.4	122.9	56.8	49.8	55.8	41.5	0.6	0.1
554	JAN	106.1	109	102.8	104	53.5	45.6	50.4	41.8	0.8	0.3
554	FEB	86.3	88.4	76.4	80.7	58.8	50.5	68.2	57.1	1.6	0.6
554	MAR	92.3	79.6	88.3	75.5	56.7	42.7	61.4	53.7	0.6	0.6
554	APR	42.9	48.2	35.8	38.9	36.1	37.2	84.1	77.3	1	0.8
554	MAY	18.3	18.1	9.6	9.4	22.1	23.3	121.1	128.3	1.1	2.5
554	JUN	9.1	5.3	0	0	23.4	11.4	257.2	214.7	4.6	3.1
554	JUL	4.7	4.2	0	0	13.1	9.7	278	234	3.3	3
554	AUG	5.6	8.4	0	0.1	16.7	13.1	299.4	157.3	5.1	1.7
554	SEP	15.6	18.9	3.6	10.3	24.9	23.9	159.6	126.6	2	1.6
554	OCT	45.7	50.4	40.4	43.7	32.7	38.8	71.7	77.1	0.9	1.7
554	NOV	76	74.2	76.7	69.5	39.3	40.7	51.7	54.9	0.2	0.9
554	DEC	102.4	100.1	96	99	55.2	47.1	53.9	47	0.9	0.5
571	JAN	130.3	109.5	113.2	93	76	64.8	58.4	59.2	0.9	1.1
571	FEB	99.1	93.1	88.9	87	67.9	50.6	68.5	54.3	1	0.7
571	MAR	89.8	91.6	80.7	81.7	62.2	52	69.2	56.8	1.4	0.9
571	APR	54.6	55.1	40.7	48	49.2	39.7	90.1	72.1	1.4	0.8
571	MAY	18.1	19.3	4.3	11.4	27	21.8	149.1	113.1	2	1.4
571	JUN	8	8.8	0	0	22.7	16.4	282	185.3	5.3	3.2
571	JUL	5	3.1	0	0	12.3	8.7	245.6	278.4	3.2	3.6
571	AUG	6	6.1	0	0	11.8	14.7	196.9	239.3	2	5
571	SEP	21.5	18.6	8	10.4	34	21.1	158.3	113.9	2.3	1.3
571	OCT	51.6	56	35.5	47.6	36.1	35.8	70	64	0.8	1.1
571	NOV	82.9	77.7	83.1	70.3	50.9	42.9	61.4	55.2	0.5	0.8
571	DEC	103.1	104.7	98.1	98.9	55.7	53.4	54	51	0.7	1.6
574	JAN	100.6	107.5	94	101.5	55.1	51.3	54.8	47.7	0.8	0.4
574	FEB	90.4	85.8	82.2	82.9	51	46.4	56.4	54.2	1.1	0.5
574	MAR	82.3	79.9	69.4	74.7	49.4	49.6	60	62.1	1	0.7
574	APR	46.1	41.5	34.8	32.8	38.6	33.8	83.8	81.5	1	0.8
574	MAY	16.6	16.9	9.5	6.9	23.3	21.6	140.4	127.2	2.7	1.4
574	JUN	9.8	8.3	0	0	26.9	17.8	274.6	214.8	4.7	2.4
574	JUL	5.8	4.4	0	0	14.4	11.5	249.8	263.3	3.8	4.2
574	AUG	7.1	6.4	0	0	14.1	13.1	199.5	203.4	3.3	2.3
574	SEP	18.2	16.6	10.5	9.8	24.5	21.4	134.5	129.1	2	1.8
574	OCT	47.4	44.1	40.6	38.4	29.5	30.5	62.1	69.2	0.5	1
574	NOV	76.6	66.2	75.7	63.1	42.5	34.8	55.4	52.7	0.4	0.7
574	DEC	96.8	102.5	89.4	97.2	49.7	50	51.4	48.8	0.3	0.9