CHAPTER 3

RESEARCH METHODOLOGY

3.1 EVALUATION OF CYSLAMB MAIZE YIELD SIMULATION

The evaluation of CYSLAMB using statistical methods recommended by Willmott (1981) was done only for maize crop yields in the Northwest Province. The main objective was to verify the applicability of the model for the quantification of the risks associated with maize production in the marginal areas. The three stations used in this study, viz. Setlagole situated towards the west, Potchefstroom in the Southeast and Ottosdal in the central region, were chosen as they are representative of the environmental conditions prevailing in the Northwest Province and also because of the availability of input data required to run the model.

3.1.1 CRITERIA FOR MODEL EVALUATION

The simulated results were compared with the results obtained in field experiments, thereby testing the accuracy with which the model describes the actual system, thus evaluating its performance (Willmott, 1981; Du Toit, Booysen and Human, 1997). There are quite a number of quantitative methodologies for the evaluation of model performance in the literature. Amongst others the D-index (the index of agreement which is the measure of the degree to which the model's predictions are error free), mean absolute errors (MAE), systematic and unsystematic mean square errors (RMSEs and RMSEu respectively), are recommended for model evaluation by Willmott (1982). Willmott (1982) also recommended that researchers compute and report the root mean square error or the mean absolute error, as well as their systematic and unsystematic proportions or magnitudes and the average relative error represented by the index of agreement. The interpretation of these measures should be descriptive and based on scientific grounds; not on the basis of the measures of statistical significance. The average error produced by a model is encapsulated in the root mean squared error (RMSE) especially that it provides information about the actual size of the error produced by the model. Du Toit *et al.* (1997) also applied these methodologies in the evaluation of the CERES3 (Maize) model.

3.1.2 MATERIALS AND METHODS FOR EVALUATION

Trial records for the maize cultivar PAN 473 from the following three locations were used to obtain the observed maize yield and management practices indicated in Table 3.1:

Potchefstroom (Lat. 26°44′ S, Long. 27°06′ E: Alt. 1345 m a.s.l.): Hutton form soils (Soil Classification Working Group, 1991). Dark reddish brown apedal soil; medium sandy loam in the topsoil to medium sandy clay loam texture in the subsoil (Appendix 1.1.1-1.1.2). Three different planting dates in one season (1986), on soil with a depth of 1.2 m. A constant plant population of 18000 plants.ha^{-1} was used. Soil P content (Bray-1 method): 40 mg.kg^{-1}

Ottosdal (Lat. 26°57′S, Long. 26°00′ E: Alt. 1341 m a.s.l): Clovelly form soil (Soil Classification Working Group, 1991), brown to dark-brown apedal soil; coarse sandy loam to medium sandy clay loam texture (Appendix 1.2.1-1.2.2). Three different planting dates, but in three different seasons. Different population densities of 15000, 16000 and 19000 plants.ha^{-1}, respectively in the three different seasons. Soil P content: 20 mg.kg^{-1}

Setlagole (Lat. 26°18′ S, Long. 24°57′ E; Alt.1270 m a.s.l) Clovelly form soil, a yellow brown apedal soil (loamy fine sand texture) with a potentially very deep root zone (2.1 m deep) (Appendix 1.3.1-1.3.2). Two different planting dates in three seasons. Constant population density of 14000 plants.ha^{-1}. Soil P content: 23 mg.kg^{-1}.

The above information together with the dekad (10 day period) climate data including the actual rainfall, mean dekad minimum and maximum temperature, sunshine hours per dekad, rainfall frequency and Potential Evapotranspiration were included into the CYSLAMB runs to simulate maize yield potential at the sites. The simulated yields were compared with the observed yield using the statistical procedures proposed by Willmott (1981) to test the model performance. The specific parameters describing the programme environment within which the model was run in terms of plant density classes, crop co-efficient and crop yield response factors are as described in Chapter 2.

TABLE 3.1 Planting date, planting density and observed maize grain yields for experiments used for validation of CYSLAMB

Station name	Planting date (dekads)	Planting density (plants.ha^{-1})	Observed Yield (kg.ha^{-1})
POTCHEFSTROOM	Oct 2 1986	18000	3401
	Nov1 1986	18000	3322
	Nov3 1986	18000	1799
OTTOSDAL	Dec2 1990	15000	4399
	Dec1 1991	16000	781
	Nov3 1992	19000	3723
SETLAGOLE	Dec1 1993	14000	3800
	Nov2 1994	14000	750
	Nov2 1995	14000	4570

3.1.3 APPLICATION OF THE CYSLAMB MODEL

The model was applied to screen or test the impact of a number of management systems or decisions on maize yield production. Data on both physical and fertility status of soils that occur in the study area (Clovelly and Hutton, also shown in Appendix 1), as well as long term climatic data were captured into the model. Different input levels and management systems were also captured. The model was calibrated for this study to consider toxicity, salinity, nitrogen (N) and potassium (K) as not limiting and therefore not affecting yield. The model could respond to changes in phosphorus (P) and sodium (Na) content in the soil. The management systems that were simulated included the following:

⇒ The choice of suitable planting dates, whereby the model simulated maize yield at different planting dates (in dekads) over a period of 56 years in Potchefstroom and 13 years in Mmabatho. The date with the highest yield under a particular set of soil and climate conditions within a specific management operation was regarded as the suitable date for planting.

⇒ The model also simulated the effects of different levels of planting densities on maize yield under marginal rainfall conditions. The density class with the highest yield potential was regarded as ideal for the area (see density classes in Table 2.4)

⇒ Another simulation was run to determine the frequency of occurrence of a planting opportunity, whereby the specified conditions required to initiate planting were defined and captured into the model to simulate the probability of having those conditions met during the specified planting dekads. These simulations were run over 56 years in Potchefstroom and 13 years in Mmabatho.

3.2 PROCEDURES APPLIED FOR DETERMINING MANAGEMENT DECISIONS

As outlined in the previous chapters, the sustainability and production potential of natural resources in the fragile ecosystems depends to a large extent on the way they are managed. In such marginal rainfall areas as these, the erratic nature of rainfall, including the occurrence of dry and wet cycles, is the main point of concern for maize farmers. Some of the critical factors that need to be taken into consideration when deciding on crop management practices include the interaction between rainfall, timing of crop planting and soil properties (since the infiltration rate and the water holding capacity of the soil determine soil moisture). Further, the plant response to soil moisture, in turn, plays a significant role in crop yield in the sense that if plant demand for water exceeds available soil moisture levels, plants will experience moisture stress and in most cases yield will be negatively affected. Hence a marked difference in target yields between dry and wet cycles could be expected depending on soil type and rainfall regime (Du Pisani, 1985). The above factors will in turn determine to a large degree the appropriate plant populations to be used as well as the appropriate level of fertiliser application necessary to ensure an economic and sustainable crop production system.

3.2.1 IDENTIFICATION OF A PLANTING OPPORTUNITY

By definition a planting opportunity is identified when the pre-defined effective dekad rainfall and topsoil moisture conditions are fulfilled. The topsoil moisture content is more important than the amount of rainfall received, to ensure that planting is not initiated on soils with very low available water contents at planting. The planting opportunity in any particular season is usually limited due to the fact that the date of planting is one of the most important parameters affecting yield. Hence the choice of an appropriate planting date ensures that after a planting opportunity has been identified, the young plants are well established before the major rains fall and are also strong enough to resist possible dry spells during the growing season.

However, in resource poor farming systems, besides moisture determined planting opportunity the availability of resources such as labour or draught power and inputs determine the timing during which planting occurs. Consequently, planting is often spread over a certain period, for example over two or three dekads, in which case the model will simulate yield based on the specific dekad that suits the pre-defined moisture conditions. This in turn is another way of minimizing risk of crop failure due to poor germination. For the purpose of this study the model was allowed to simulate long-term maize yield taking only one planting opportunity into consideration.

For the purpose of this study the model was calibrated to identify the planting opportunity based on the requirements that the amount of rainfall received should exceed 10mm and/or available soil moisture content of 15 mm and above is required. This was done to accommodate the fact that sufficient amounts of rainfall are received before the actual planting date and in case of a good soil moisture storage germination can still take place. The rainfall amount of 10 mm seems very low considering the fact that at least 20-25 mm is the general required amount to initiate planting in most places. However, in marginal rainfall areas one needs to look beyond what is occurring at planting and forecast what is expected later in the season when the maize plant requires higher moisture levels.

3.2.2 DETERMINATION OF APPROPRIATE PLANTING DATES

In addition to the identification of planting opportunities, as described in Section 3.2.1, the soil must contain an adequate amount of plant-available water before planting in order to supplement rainfall during growth. High risk is a major problem in view of the uncertainty of the prediction of the rainfall pattern in a particular season. In low rainfall areas under dryland production the choice of planting date can be a hazardous process in the sense that the producer may be tempted to plant after the first summer rains while ignoring what is to be expected later in the season (De Bruyn, 1979). This part of the country usually experiences midsummer drought conditions around mid-January to February at Ottosdal, Setlagole, Mmabatho and surrounding areas in the western parts but in areas around Potchefstroom it occurs during late December and early January. Should this period coincide with the stage of crop growth when the crop is very sensitive to moisture stress, this will have drastic effects on maize yield. The management must be of such a nature that flowering (silking) does not coincide with midsummer drought. If sufficient moisture is retained in the profile the impact of moisture deficit is reduced until mid-January, after which the moisture demand of the maize crop demands that the profile be recharged with rainwater for sufficient growth.

A number of techniques have been developed in order to determine the most suitable planting dates in different parts of South Africa, including the study area. But the ideal method to give better estimates would be the one that considers amongst other factors: long term rainfall data, evapotranspiration and water holding capacity of different soils. A computer model like CYSLAMB, which includes such factors amongst others to simulate maize yield for different planting dates could give the appropriate planting date. The ideal planting date is the one that gives relatively high yield at high probability. For this study the CYSLAMB model was used to simulate yield over the period of 57 years (available climate data) in Potchefstroom on well-drained Hutton soil, 1.2 m deep and 100 mm/m available water content. The simulations were run starting from the third dekad in October (Oct3) to the third dekad in December (Dec3). A similar exercise was conducted for the Mmabatho area on Clovelly soil, 2.1 m deep with water holding capacity of 100 mm/m. The simulations were run from November (Nov1 dekad) to January (Jan1 dekad).

3.2.3 DETERMINATION OF THE APPROPRIATE PLANT POPULATION

Low plant populations in combination with wide rows and adapted cultivars as well as low inputs are some of the major management practices that make it possible to produce reasonable maize yields under climatically marginal conditions. In low plant populations the roots, being supplied with adequate assimilate by the well-illuminated lower leaves, provide sufficient cytokinins to the shoots where they attract assimilate to the various sinks. In the ear this may promote growth of large and many kernels (Wilson and Allison, 1976). Whereas in large densities, according to these authors, during drought stress the supply to the shoots is probably restricted because of the reduced root activity resulting from the shortage of assimilate, aggravated in the drought-stressed plant by the dry soil conditions. According to the research findings by Van Averbeke (1991) one of the implications of the practice of adjusting planting density in maize as an applied management tool is that during dry years a farmer would get better yield at low planting density and avoid total yield failure, while possibly sacrificing bumper yield in good years. In this study, the effects of low plant populations on maize yield production were determined for Potchefstroom and Mmabatho using CYSLAMB. Simulations were run for densities of 10 000 to 30 000 plants ha^{-1} in Potchefstroom on three different planting dates (Nov3 to Dec2). For Mmabatho, simulations were run for densities of 10 000 up to 20 000 plants ha^{-1}.

3.2.4 THE FARMER'S MANAGEMENT SYSTEMS

For the purpose of this study, the management systems adopted by different farmers in the study area were regarded to be very important. Informal interviews were conducted with some farmers (both large-scale commercial and small scale commercial) in order to learn how and why they manage their farms. Farmers were asked about the cultivars they plant at what populations, their planting dates, fertiliser applications, the kinds of soils on their farms. Where yield records for previous seasons were available, these were also taken into consideration to see if the simulated yields were close to the yields obtained by the farmers. (Appendix 3 contains a checklist with most of the questions that were asked during consultations held with the farmers.)