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A WHEAT YIELD MODEL FOR BRAZIL

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Lyndon B. Johnson Space Center
Houston, Texas 77058

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A Wheat Yield Model for Brazil

Authorized by: Jerry D. Hill
Assistant Deputy Project Manager
for LACIE, NOAA

Center for Climatic and
Environmental Assessment
Federal Building, Room 116
Columbia, Missouri 65201

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A Wheat Yield Model for Brazil

C. M. Sakamoto[1]

INTRODUCTION

This particular study is in accord with the previously developed wheat models for other countries developed by CCEA. These models, known as the CCEA first generation type, are based on the following criteria: 1) it is a regression model; 2) it uses monthly temperature and precipitation data; 3) the model utilizes a heat stress term (temperature) and a moisture stress term (precipitation or some other moisture index); and 4) the trend term is described by a dummy variable or time (year) is used as a surrogate. Although this assumption is not totally adequate, this procedure must suffice until better quantitative inputs can be practically accomplished. The trend term consists of several technological factors that have changed yield over time. These include such factors as fertilizer, varietal improvements, use of better and bigger farm machinery, better pesticide management programs, etc. As additional information and techniques are gained by modelers, quantitative inputs by these factors, representing independent variables may be possible.

This study is based on a limited set of data, from 1961-1972. Since 1965, introduction of new varieties into Brazil, combined with increased acreage, has led to a rapid increase in wheat yield as well as in production. Consequently, the trend term needs to be monitored closely in the 1970's. Caution should be exercised by users of the model described herein, not

[1]Research Meteorologist, CCEA, Columbia, Missouri, December, 1976.

only because of the rapid potential technological changes in Brazil, but also because of the limited data upon which the model is based. However, as the reader will note, the selected variables are consistent with models developed in Brazil (see References) and do make agronomic sense.

DESCRIPTION OF WHEAT GROWING AREA

Wheat is grown primarily in the extreme southern region of Brazil (latitude 24° to 34°S) in the states of Rio Grande do Sul, Santa Catarina and Parana (Figure 1). Rio Grande do Sul, however, produces about 85 percent of the total wheat. Some wheat is also grown in Mato Grosso and Sao Paulo, but the amount is minor compared to that in Rio Grande do Sul.

Southern Brazil is atypical of wheat growing areas throughout the world. The area is relatively humid and warm. Furthermore, daylength at heading is between 12-14 hours. Consequently, locally adapted varieties that require low vernalization, high disease resistance and low photoperiod are desirable. The result is the introduction of varieties that are indifferent to daylength, have no or little response to vernalization, and are responsive to high temperatures from jointing to heading (da Mota and Acosta, 1973).

Depending on the variety, wheat is sown as early as April in Parana so that a double crop, including soybeans, can be planted in October (Beukenkamp, 1976). In Rio Grande do Sul, however, planting is usually in May or June while the major harvesting activity is in November and December.

By United States standards, farm sizes in southern Brazil are relatively small. According to Beukenkamp (1976), 42 percent of the farms average 5-6 hectares, 52 percent of the farms lie in the 10-100 hectares range and only 5 percent are over 300 hectares.

Annual precipitation ranges from a mean of 1300 mm to approximately 1700 mm in the wheat belt with three peaks in the year: June, October, and January (see Figure 2). Temperature ranges from about 11 to 13°C in July to about 20°C in November and December.

Frost at the critical heading and flowering period and summer hail are weather events that can reduce yield overnight in Brazil. Rust disease is a perennial problem but can be controlled by use of fungicide. It is estimated that yields can be boosted from an average of 1200 kilograms per hectare to 1600 kilograms per hectare by a program of fungicide application (Foreign Agriculture, 1976). However, the high cost of chemicals and equipment may limit its use.

In Parana, winter droughts have hampered yields. According to da Mota and Acosta (1973), initially low precipitation occurs 30 percent of the time in northern Parana. Parana is also where acreage as well as production of wheat is escalating. In 1975, it was estimated at 1.1 million hectares (Dalrymple, 1976). Introduction of Mexican semi-dwarf varieties will accelerate in 1976. Because of this variety's susceptibility to aluminum toxicity, it is estimated that the introduction of semi-dwarf varieties will be limited to certain areas of Brazil (Dalrymple, 1976).

SOURCE OF DATA

Meteorological data for Rio Grande do Sul were obtained from the publication Observacoes Meteorologicas (1974). Eight selected stations (Table 1) were used to find average temperature and precipitation for Rio Grande do Sul from 1962-1972. Yield data are shown in Table 2. As indicated earlier, data from 1962-1972 show that Rio Grande do Sul produces approximately 85 percent of Brazil's wheat, although this may change in the mid-1970's. However, the relationship between Rio Grande do Sul and Brazil (country) yield suggests that the model applied to the state may also be used for the country (Figure 3).

WHEAT MODEL

The basic form of the model is:

$$\hat{Y} = \text{Trend} + f(\text{weather})$$

where:

$\hat{Y}$ = estimated yield (kgm/ha)

Trend = time trend where 1962=1, 1963=1, ..., 1965=1, 1966=2, ..., 1972=8, ...

f(weather) = function of weather elements in July through October.

After several iterations of model testing, it was determined that the following model with final truncation in October provided the best fit as well as being consistent with known climatic hazards in Brazil.

$$\hat{Y} = \alpha + \beta_1 \text{Trend} + \beta_2 \text{ (July Temperature DFN)} + \beta_3 \text{ (September-October Weighted P-PET)} + \beta_4 \text{ (September-October Weighted P-PET)}^2 \quad (1)$$

where:

P = precipitation (mm)

PET = potential evapotranspiration by the Thornthwaite procedure

α = a constant while β_1, ..., β_4 are coefficients of the selected variables.

Other truncated models, including their coefficients are shown in Table 3.

Weighted September-October precipitation minus potential evapotranspiration is determined as follows:

$$\frac{(P\text{-}PET)_{Sep} \times .50 + (P\text{-}PET)_{Oct}}{1.50} = \text{Weighted } (P\text{-}PET)_{Sep\text{-}Oct}$$

The variables selected in equation (1) are consistent with that reported by da Mota and Acòsta (1973), da Mota and Wendt (1975), and da Mota (private communication, 1975). In the 1973 paper, July daily mean temperature and October rainfall were used in a regression model. However, as indicated by the authors, the introduction of improved varieties since 1965 may alter the correlation between temperature and yield. In the 1975 model, da Mota and Wendt (1975) used sunshine and relative humidity. Their equation is as follows:

$$Y = 5.99X_1 - 3.45X_2 - 20.72X_3 + 1871 \qquad (2)$$

where:

Y = average yield (kgm/ha) for Rio Grande do Sul

X_1 = September sunshine

X_2 = August sunshine

X_3 = October relative humidity.

A simple test referred to as "jackknife" was performed on the model. In this procedure, one year was left out of the model and the remaining years were used to develop the coefficients. Yield for the year left out was estimated from the developed model. This was accomplished ten times so that the year left out proceeds sequentially from 1963 through 1972 and the model recalculated each time. The results of the test showing its value with the observed yield are shown in Figure 4.

SUMMARY

In spite of only 11 years of data, the wheat model developed for Rio Grande do Sul, Brazil appears to be reasonable. Greater variability in the data series can be expected with additional years. Revision of the model is essential with added data, particularly since 1972.

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Figure 1. Wheat Growing State of Brazil: Rio Grande do Sul, Santa Catarina and Parana

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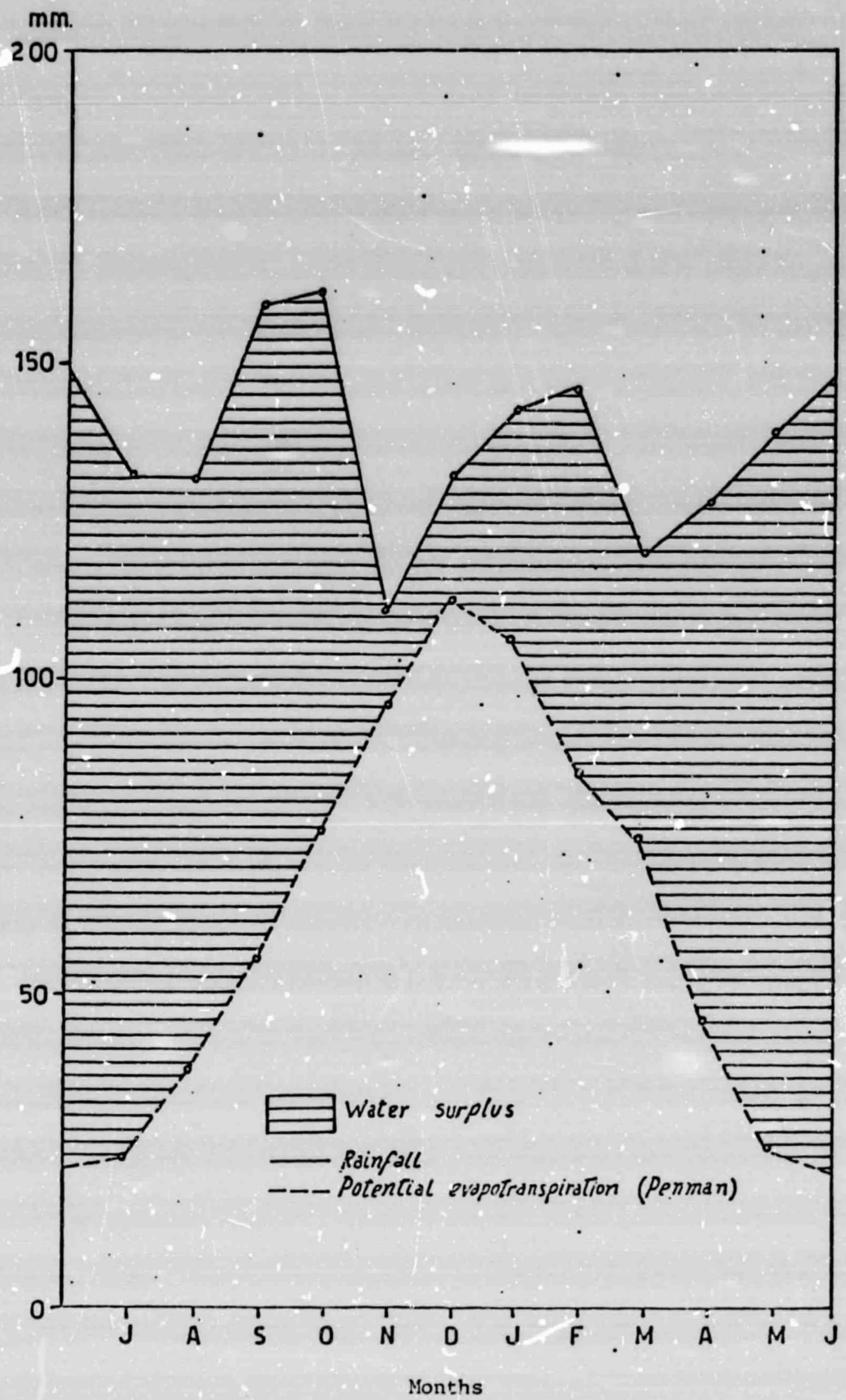
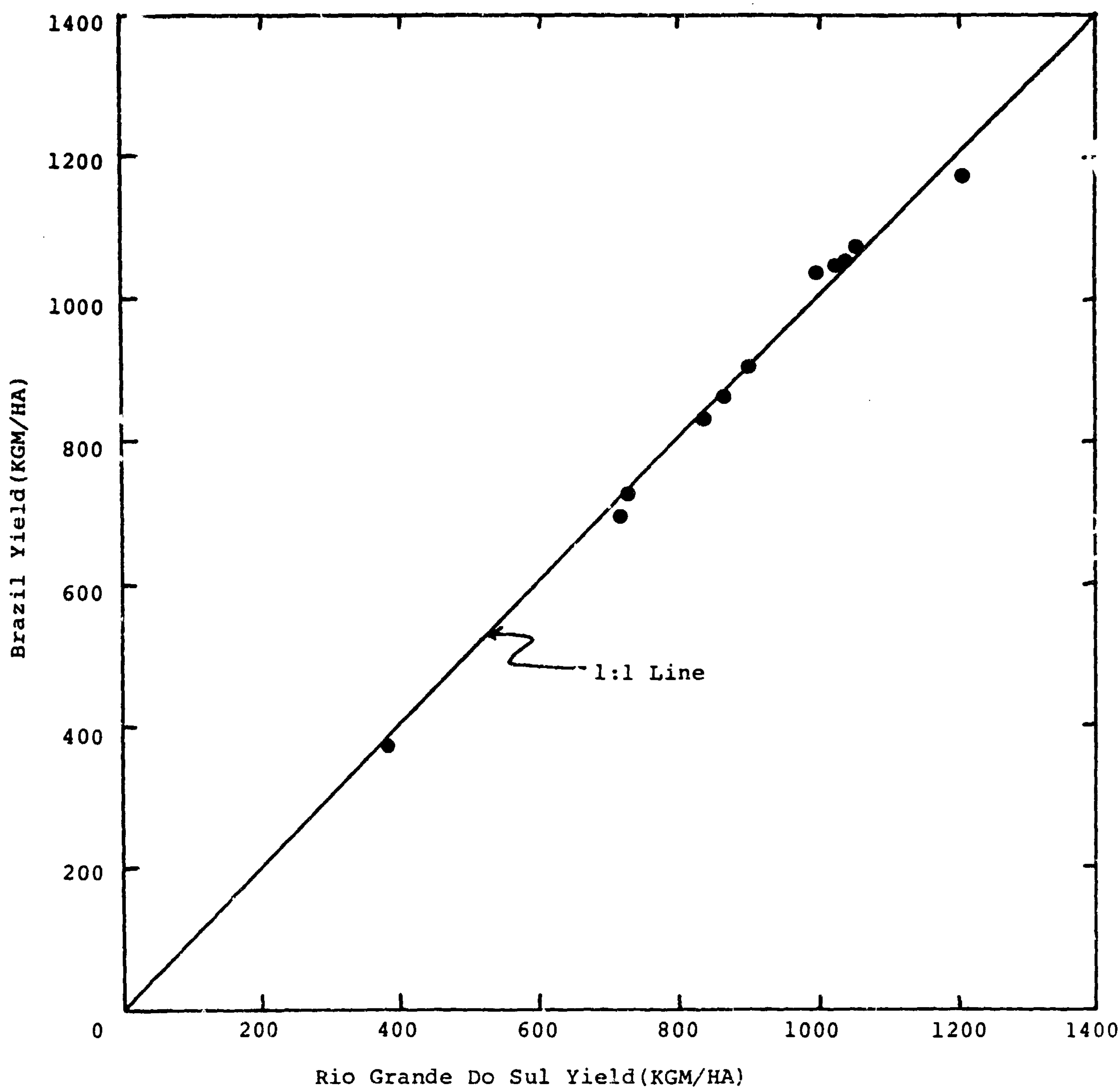


Figure 2. Water Balance of Passo Fundo, Typical of Wheat Zones in Southern Brazil (Source: da Mota and Acosta, 1973).

RELATIONSHIP OF RIO GRANDE DO SUL YIELD

TO BRAZIL(COUNTRY) YIELD

1962 - 1972



Source: Commissão Central de Levantamento Fiscalizacão das Safras Triticolas

Figure 3

"JACK-KNIFE" TEST

RIO GRANDE DO SUL, BRAZIL

1962 - 1972

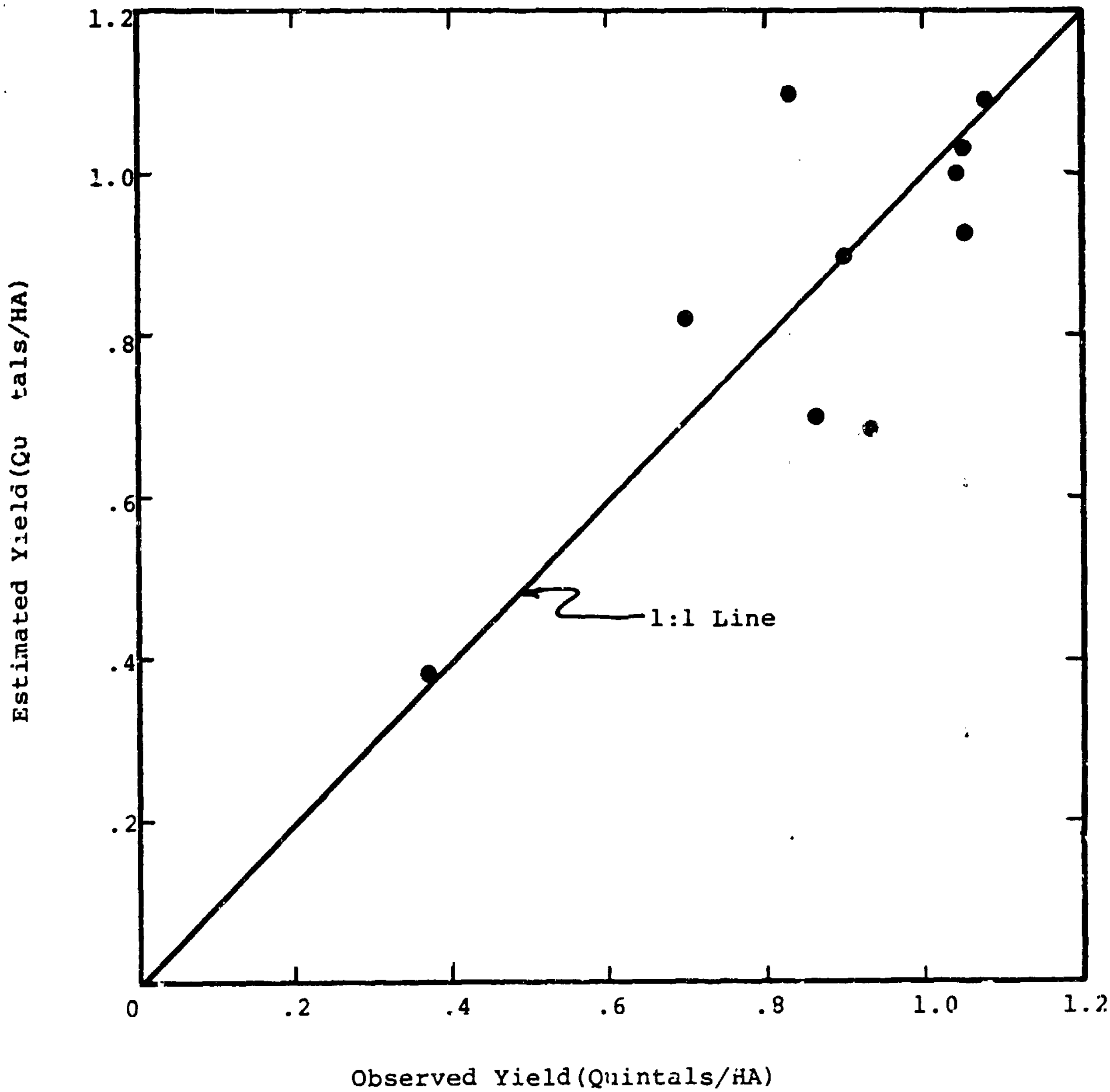


Figure 4

Table 1. List of Stations and Locations Used for Meteorological Data in Rio Grande do Sul Wheat Yield Model

Station	Altitude (M)	Latitude	Longitude
Bage'	214	31°21'13"	54°06'21"
Encruzilhado do Sul	420	30°32'35"	52°31'20"
Julio de Castilhos	514	29°13'26"	53°40'45"
Rio Grande	5	32°01'44"	52°15'37"
Sao Borja	99	28°39'44"	56°00'15"
Tramandai	3	29°56'22"	50°30'12"
Veranopolis	705	28°56'14"	51°33'11"

Table 2 . Acreage, Production and Yield in Rio Grande do Sul, Brazil and Brazil (Country), 1962-1972*

Harvest Year	Rio Grande do Sul Area (Ha)	Rio Grande do Sul Production (Qu)	Rio Grande do Sul Yield (Qu/Ha)	Brazil (Country) Area (Ha)	Brazil (Country) Production (Qu)	Brazil (Country) Yield (Qu/Ha)
1962	226,611.52	274,148.702	1.210	258,221.19	303,396.042	1.175
1963	218,877.30	103,591.763	.371	302,122.20	115,716.576	.383
1964	271,918.20	225,661.588	.830	300.542.60	250,452.634	.833
1965	325,390.60	236,951.433	.728	354,680.15	256,746.601	.724
1966	343,470.80	295,999.453	.862	384,960.26	333,516.981	.866
1967	487,687.66	339,628.440	.696	561,987.16	405,748.371	.721
1968	689,139.17	618,712.086	.897	845,693.69	765,076.711	.904
1969	1,044,731.06	1,090,107.567	1.043	1,299,518.52	1,303,426.759	1.004
1970	1,584,414.78	1,706,756.933	1.077	1,861,204.59	1,946,044.839	1.045
1971+	1,800,000.00	1,900,000.000	1.055	2,126,570.00	2,214,400.000	1.041
1972+	2,100,000.00	2,200,000.000	1.047	2,538,000.00	2,622,500.000	1.033

*Source: Commissao Central Levantamento e Fiscalizacao das Safras Triticolas, Brazil.

+Estimated

TABLE 3. CONSTANTS AND COEFFICIENTS FOR TRUNC. D MODEL AT: RIO GRANDE DO SUL, BRAZIL

Variable		Trend		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Constant (52)	892.4	728.5				688.8	688.9	715.6	804.9		
Trend (50)		46.2				57.4	57.4	49.8	47.9		
Jul Temp DFN (29)						-107.4	-120.9	-103.4	- 78.3		
Aug Prec-PET DFN (30)							- 1.250				
Sep Prec-PET DFN (32)								- 1.044			
Sep-Oct Weighted Prec-PET (46)									- 1.673		
SDFN (47)									- .029		
S	234.6	211.8				166.3	140.3	150.3	107.4		
R^2		.27				.60	.75	.71	.87		

AVERAGES (1962-72)
Jul Mean Temp = 13.6°C
Aug Prec-PET = 112.0 mm
Sep Prec-PET = 100.7 mm
Oct Prec-PET = 63.1 mm
Weights Sep = .50; Oct = 1.00

NOTES:
Data Base: 1961-72
PET = Potential Evapotranspiration by Thornthwaite Procedure DFN = Departure from Normal
Units: Precipitation (mm), Temperature (°C), Yield (Kgm/Ha)

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