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Stored Available Soil Water and the Fallow/Recrop Decision—Critical Level Approach[1]

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ABSTRACT

The amount of stored soil water at seeding has long been appreciated as a critical factor in the success of annual spring wheat (*Triticum aestivum* L.) production in the semiarid region of the Northern Great Plains. Stored available soil water at seeding, growing season precipitation, and grain yield data from 53 spring wheat experiments in western North Dakota were analyzed by both multiple regression and an interaction chi-square approach. Soil types were generally fine-loamy, mixed Typic Haploborolls or Argiborolls. Regression equations explained too little of the variability of the data to be useful in drawing practical guidelines for future fallow/recrop decisions. The results suggest that stored soil moisture data are better analyzed by the interaction chi-square test, the results of which provide easy-to-interpret guidelines for making future fallow/recrop decisions. For example, for a minimum acceptable recrop wheat yield of 1350 kg/ha, the following critical levels were defined: stored available soil water at seeding less than 6.4 cm, crop failure is likely and summerfallow is advised; stored available soil moisture 6.4 to 9.4 cm, approximately equal odds of crop failure or success; stored available soil moisture > 9.4 cm, crop success is likely and recropping is advised.

Additional Index Words: **interaction chi-square analysis, continuous wheat production, summerfallow.**

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SUMMERFALLOWING has long been identified as a major contributing factor to soil erosion in the Great Plains. Technological advancements in tillage, varieties, herbicides, and fertilization have reduced the acreage of summerfallow in many areas and questioned its need in other areas. An additional technology which has evolved is the concept of "flexible cropping" in those areas where annual spring wheat production (recropping) is a marginal practice (e.g., western North Dakota and eastern Montana). In a flexible cropping system, a grower postpones the recrop/summerfallow decision until near planting time when the quantity of available stored soil water (SSW) in each field can be evaluated. This is normally estimated by measuring the depth of moist soil and estimating its texture (2). The grower can then use a

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computer program (5) or a series of maps and tables (2) to give a projected yield estimate for that field. These yield estimates are based on the amount of SSW and a likely figure for growing season precipitation (GSP) in a particular locale. The grower can then make his recrop/fallow decision based on this projected recrop yield. A problem exists with this approach. Growing season precipitation is highly variable in the Great Plains in total amount, intensity, and distribution. Even though a grower may know his 50% or 70% probable GSP, the actual amount to be received is absolutely unknown. Hence, a large amount of error is involved in providing the grower with a specific yield estimate when only SSW is known. Further, the accuracy of the yield estimates is limited by the fact that the multiple regression equations used to calibrate such yield models often have an overall R^2 value of < 50% (1).

The problems of yield forecasting under a recrop system were illustrated by Halvorson and Kresge (5). Their "Flexcrop" computer model was tested against field locations not used in model calibration. Very impressive agreement between actual and calculated yields was obtained when the actual growing season conditions (SSW, weed population, actual GSP, etc.) were used to calculate yield after the fact. However, poor agreement between actual and calculated yields was obtained when the model was used to predict future yields. Therefore, even a perfectly calibrated yield model can give disappointingly inaccurate yield forecasts in areas of high year-to-year climatic variability.

The purpose of this paper is to propose a critical level method rather than a yield prediction method of organizing stored soil water information so as to aid growers in the recrop/fallow decision.

METHODS

Data for this study came from 53 replicated recrop spring wheat fertilizer trials in western North Dakota from 1976–1982. These experiments were typically N rate and source trials. Initial profile nitrate-nitrogen levels were typically 30 to 60 kg N/ha and N rates were typically 0, 30, 60, and 90 kg N/ha. Basal levels of P, typically 20 kg P/ha, were applied to all plots. The sites were a combination of branch experiment station trials and studies on cooperating growers' production fields. Previous to seeding, the soil was sampled by 30-cm increments to a depth of 120 cm. Total soil water was determined and 1.5 MPa bar water percentage was determined by the standard pressure plate procedure. Bulk densities were measured by the saran procedure. Detailed soil classification data was obtained at each site. The majority of sites were fine-loamy, mixed Typic Haploborolls or Argiborolls (Don Patterson, personal communication). Growing season precipitation was recorded by the cooperating farmer, branch station, or nearest official recording station. The yield used for statistical analysis was the highest observed treatment average at each fertilizer trial. That is, N and P were not known to be limiting at any site. Herbicides were applied as necessary. Harvests were performed with small plot combines. The locations of the experimental sites by county are shown in Fig. 1. The majority of the sites were in northwestern North Dakota. The 50% probable growing season precipitation for western North Dakota is approximately 18 to 20 cm or greater and the 70% probable growing season precipitation is 14 to 15 cm or greater (2).

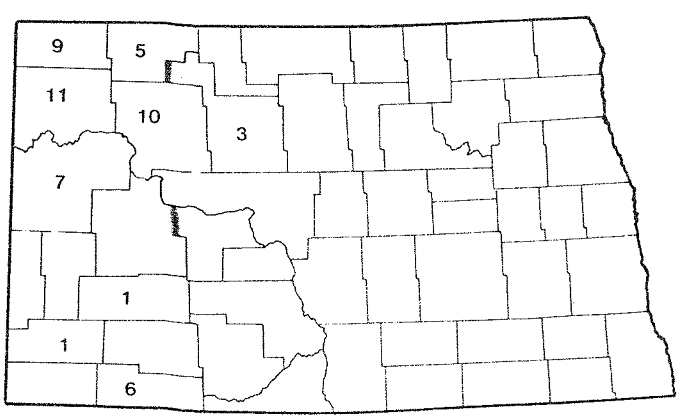

Fig. 1—Distribution of experimental sites by county, North Dakota.

Table 1—The relationship between available stored soil water at seeding and spring wheat yields, western North Dakota, 1976-1981.

SSW†	Number of observations	Yield Average	Yield Range	CV‡
cm		kg/ha	kg/ha	%
0-1.3	1	700	--	--
1.3-3.8	7	1500	300-2800	66
3.8-6.4	6	1400	300-3300	85
6.4-8.8	13	1500	500-2900	43
8.8-11.4	14	1800	1300-3100	31
11.4-16.5	9	2200	500-3800	42
16.5-21.6	3	2600	2300-2900	13

† SSW = stored available soil water at seeding to a depth of 120 cm.
‡ CV = coefficient of variability of the population of yield observations within each water category.

RESULTS

A summary of the stored soil moisture and yield data is presented in Table 1. The main point of this table is the large range in observed yields at each level of SSW. For example, with 1.3 to 3.8 cm of SSW, yields of 300 to 2800 kg/ha (5–41 bu/acre) were observed. The coefficient of variability (CV) of the pop-

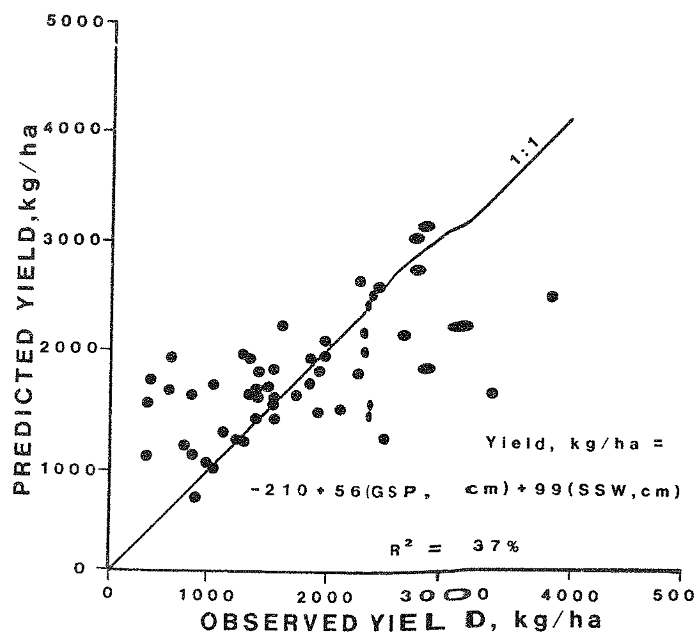

Fig. 2—Predicted vs. observed grain yields. Yields predicted by regression analysis.

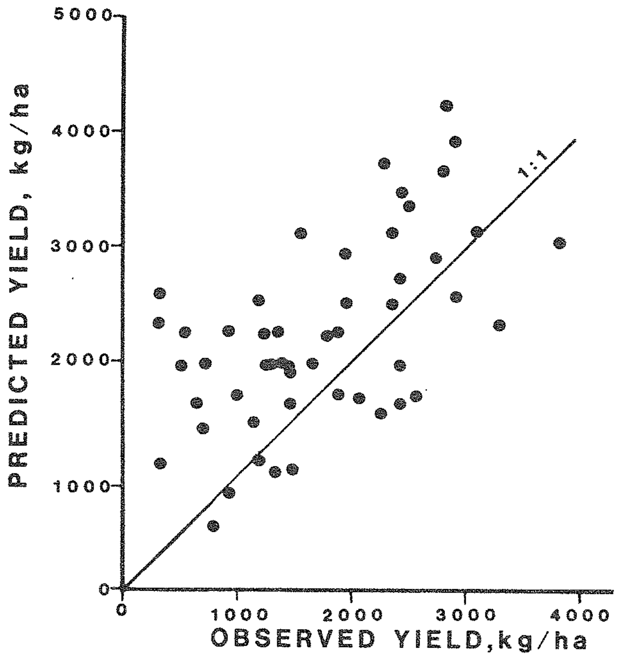

Fig. 3—Predicted vs. observed yields. Yields predicted by the model of Brown et al. (2).

ulation of yield observations within each category of SSW was quite high, especially at lower levels of SSW. This illustrates a difficulty in modeling future yields in the Great Plains. When a grower attempts to predict a future yield using a yield model, SSW is the only variable known at the time of the recrop/fallow decision.

A multiple linear regression was performed with grain yield as the dependent variable and SSW and GSP as independent variables. Figure 2 shows that the regression model does not explain enough of the variability in the data (37%) to make it a useful model for prediction of future yields, even if future GSP were known.

A comparison was made of the actual yields and predicted yields using a previously published model for this locale (1). This comparison is summarized in Fig. 3. The published model usually overestimated yield. A general relationship exists but agreement is poor.

Since SSW appears to be a weak predictor of future grain yield, using a regression approach, does this mean that it is of no value in the recrop/fallow decision? On the contrary, much information can be obtained if the yield data are analyzed as populations of crop "failures" and crop "successes." Figure 4 shows that most of the crop "failures" (yields < 1350 kg/ha for this example) were associated with lower levels of SSW,

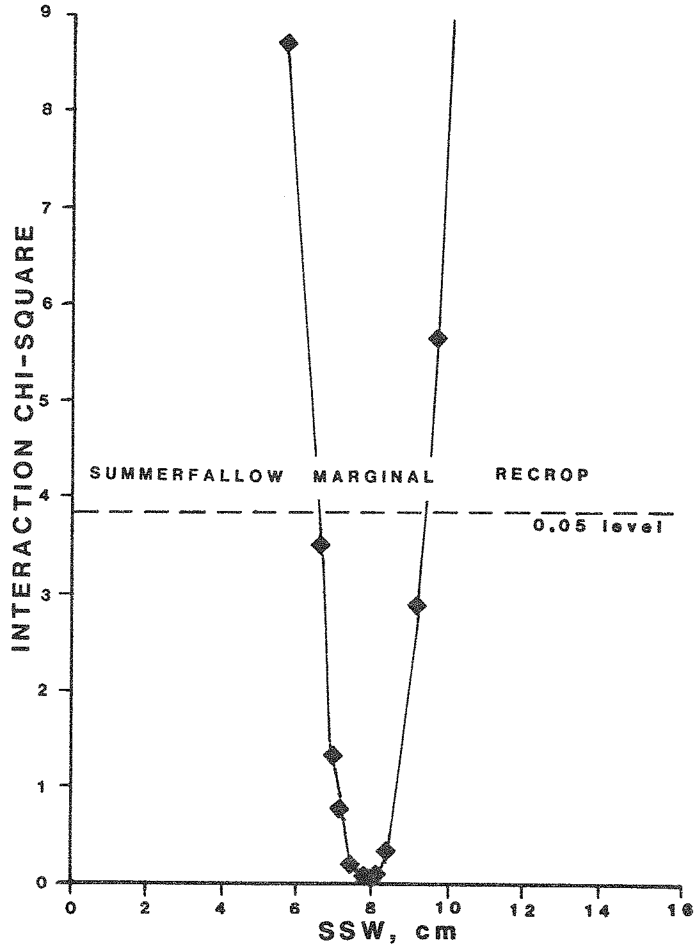

Fig. 5—Interaction chi-square plot used to define soil water and recropping guidelines, using a yield of 1350 kg/ha (20 bu/A) as the criteria for success or failure.

while crop "successes" (yields > 1350 kg/ha) were usually associated with higher levels of SSW. Overlap or "interaction" between the populations exists. The interaction chi-square test (3, 4, 6) can be used to estimate the most probable confines of the crop "failure" population, the crop "success" population and the most probable zone of overlap. This statistical procedure can be used to generalize the data into a set of "go or no go" SSW guidelines.

Figure 5 shows the chi-square plot using 1350 kg/ha as an arbitrary dividing line between crop success or failure. The important feature of this curve is where it intersects chi-square = 3.84 (chi-square at 1 d.f. at 0.05 level). The results of the interaction chi-square test are superimposed on Fig. 4. At levels of SSW < 6.4 cm, the majority of the observations (73%) are

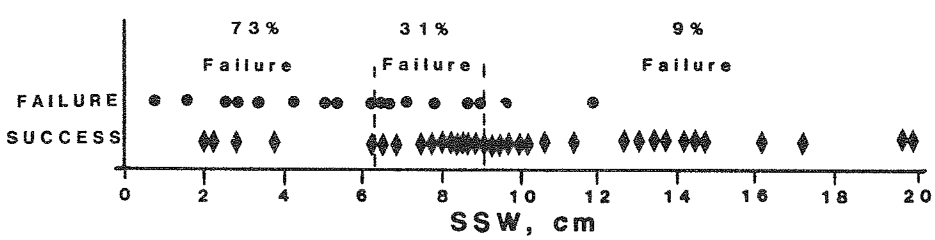

Fig. 4—Distribution of observations after classification as crop failure or success, using a yield of 1350 kg/ha (20 bu/A) as the criteria.

Table 2—Stored available soil water guidelines for recropping spring wheat in western North Dakota.

Minimum yield acceptable	Recommendation		
	Summerfallow	Uncertain	Recrop
kg/ha		SSW†, cm	
1000	<5.3	5.3–9.1	>9.1
1350	<6.4	6.4–9.4	>9.4
1700	<7.1	7.1–9.9	>9.9
2000	<7.6	7.6–10.2	>10.2

† Stored available soil water at seeding time to a depth of 120 cm.

crop failures and summerfallow is advised. Between 6.4 to 9.4 cm of SSW, approximately equal populations of crop failures and successes occur. At levels of SSW above 9.4 cm most of the observations are crop successes (91%) and recropping is advised. This type of analysis was repeated at various definitions of crop failure and the results are presented in Table 2.

In general, summerfallow is definitely advised at levels of SSW < 5.3 to 7.6 cm (2.0–3.0 inches), and recropping is definitely advised at levels of SSM > 9.1 to 10.2 cm (3.6–4.0 inches). It is felt that such a treatment of SSW data provides the grower with the type of information needed for the recrop/fallow decision without the serious errors involved with yield forecasting. This critical level approach of developing fallow/recrop soil moisture guidelines should prove to be a useful tool in other geographic areas where annual crop production is a marginal practice because of limited moisture. It is acknowledged that the specific guidelines presented may not apply to production areas outside the study area. A yield prediction model would still have utility in giving growers general guidance for fertilization yield goals, etc., but it is felt that the basic decision of whether to recrop or summerfallow is more reliably determined by a critical level approach.

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