RISK PERCEPTION AND RISK MANAGEMENT BY FARMERS IN BURKINA FASO

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- 1

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INTRODUCTION

This report[1] discusses the risk perceptions of and risk management by farmers in Burkina-Faso (formerly Upper Volta). It describes farmers' risk perceptions, their intraseasonal risk management practices and their implications for the development of agricultural technology.

During 1982, research was conducted by Purdue University Farming Systems Unit (FSU) in three villages. The villages of Bangasse and Nedogo are located on the densely-populated Central Plateau where the fallow system has largely broken down and, of necessity, farmers knowingly "mine the land". Bangasse, the poorest village, receives from 400 to 500 mm of rainfall annually while Nedogo receives from 700 to 800 mm. Diapangou, east of the Central Plateau, receives about the same rainfall as Nedogo, but is in a relatively more fertile zone of shifting cultivation. Accordingly, farmers there tend to be more prosperous than those in the other two villages.

During 1983, the FSU worked in two additional villages. These are: Poedogo, on the Central Plateau, but in a 800-900mm rainfall zone south of Nedogo, and Dissankuy, near the Malian border in a fertile, relatively land-abundant zone. Significantly more cotton is produced in Dissankuy than in the other villages and higher grain yields permit the export of cereals to other regions of Burkina-Faso. This brought the number of villages to five and provided a wider range of agroclimatic and economic environments in

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[1]The report is based on research conducted by the Purdue University Farming Systems Unit (FSU) (AFR-C-1472) and INTSORMIL(DSANG0149).

which to conduct research. All FSU survey villages are identified on Figure 1.

To understand the farmer's decision-making framework and thereby to aid researchers in identifying the characteristics of production technologies attractive to farmers, interviews were conducted in 1982 with 30 randomly-selected farmers in each of the three villages. An interview form was designed to identify factors farmers consider in making on-farm resource use decisions. The form required from one to two hours to complete and involved both objective and open-ended responses.

The farmers indicated that agronomic factors, principally fertility and water retention, are predominant considerations in cropping decisions. These factors strongly affect both yield and yield variability (risk) of crops. Farmers said they manage intraseasonal risk by incorporating land quality and risk considerations in their cropping decisions.

The findings of the decision-making interviews were largely qualitative. An additional study was undertaken in 1983 to test hypotheses generated by them and to expand upon their findings. Specifically, data on yield variability over time using subjective recall by farmers were collected and used to explain cropping patterns.

This paper is organized as follows. First, the findings of decision-making interviews are reported. Second, the findings of research on yield variability, risk perceptions and intraseasonal risk management are presented. A final section discusses the implications of these findings for the future of agriculture and agricultural research in Burkina-Faso.

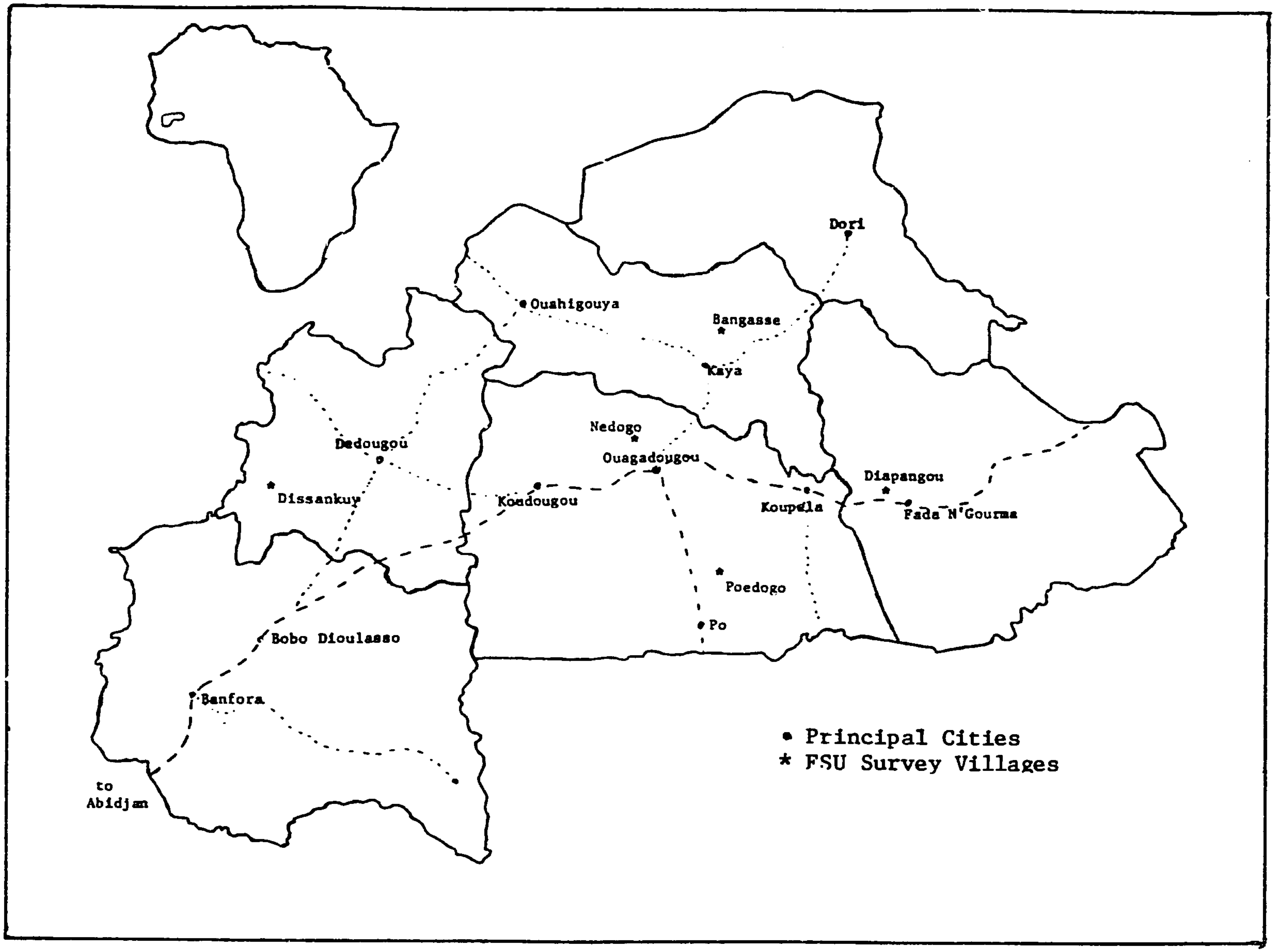

Figure 1: Map of Burkina Faso

THE ROLE OF RISK IN DECISION-MAKING BY FARMERS

Representative cropping patterns for each village are presented in Table 1. These data are derived from direct field measurement on 30 randomly-selected farms in each village.

On the Central Plateau villages of Bangasse, Nedogo and Poedogo, the cropping patterns are similar. Millet and sorghum are the dominant cereal crops, accounting for about 90% of cropped area. The principal cash crop is peanuts. Sorghums tend to be more important on the southern part of the Plateau, giving way to millet as one moves north. An exception is seen in Bangasse where due to the presence of a dam, there is more bottom land and clay soil than is characteristic of the region. The greater water retention and higher fertility of these soils make sorghum a preferred crop.

In Diapangou, cereals are equally important, although millet and sorghum are generally grown in association. Maize is more important than on the Central Plateau because some of the farmers are cattle traders and therefore have more animal manure with which to support its cultivation.

In Dissankuy, commercial farming is evident in the cropping pattern. Farmers devote more of their land to traditional cash crops and more cereals are marketed than is the case in any other FSU village. Cereals, principally sorghum and maize, occupy 70 percent of the cropped area while cash crops account for 25 percent. Cotton is the most important cash crop followed by peanuts and bambara nuts.

During 1982, interviews were conducted with at least 30 farmers each in the villages of Bangasse, Diapangou and Nedogo. One objective was to identify factors farmers consider most important in their cropping decisions. Specifically, farmers were asked why they did not plant more of each crop and why they planted as much as they did.

Table 1. Area Cultivated and Cropping Patterns Per Farm in Five Villages, Burkina-Faso, 1983.

	Central Plateau[a]			Frontier Regions[b]	
	Bangasse (north)	Nedogo (central)	Poedogo (south)	Diapangou (east)	Dissankuy (west)
Total Area Cultivated(ha.)	6.55	6.67	3.77	7.12	5.51
Cropping Proportions(%)					
Millet	46.8	56.7	34.3	20.4	13.8
White Sorghum	39.9	21.2	13.8	3.5	48.3
Red Sorghum	--	10.1	38.8	--	--
Associations[c]	--	--	--	61.7	--
Maize	1.9	2.1	1.5	4.0	6.7
Rice	--	0.3	3.9	0.1	1.2
Peanuts	11.0	8.2	7.1	9.0	6.0
Bambara Nuts	--	1.3	--	0.2	2.5
Cotton	0.4	--	--	--	16.0
Soybeans	--	--	0.5	0.3	--
Cowpeas(sole crop)	--	--	--	0.3	--
Other(okra, roselle)	--	0.1	0.1	0.5	5.5
Total Cereal Crops	88.6	90.4	92.3	89.7	70.0
Total Cash Crops	11.4	9.5	7.6	9.8	24.5
Total Other	--	0.1	0.1	0.5	5.5

(a) The Central Plateau covers an area as much as 250 km wide extending from near the Ghanaian border in the South to the Sahel in the North. (b) The frontier regions refer to areas off the Central Plateau where soils are more productive and population pressures less severe. (c) The millet/sorghum association in Diapangou includes from 75 to 90% millet. The remainder is white sorghum.

Farmers' responses to decision-making questions provided relatively clear decision rules explaining the cropping patterns seen on the Central Plateau villages of Bangasse and Nedogo. While Poedogo was not included in the 1982 study, these decision rules appear to apply there as well.

Maize is planted only around the compound where animal manure and human waste make the land the most fertile. Maize is preferred on this land because it typically yields more than other crops. More importantly, because maize is harvested in August, it meets the family's food needs during what is locally called "the hungry season"--the period prior to the harvest of major millet and sorghum fields. Thus, maize occupies a critical temporal consumption niche, particularly in years following a poor harvest season when cereal stocks run low.

Sorghums are generally planted on village and bush fields away from the compound. While sorghum is more drought-resistant than maize, it is less drought-resistant than millet and is generally planted on land referred to as "sorghum land." This land has better water retention and is more fertile than the marginal land where millet is planted. Farmers plant sorghum on their best soil (excluding compound land) because "in a good year it yields more than millet and it stores twice as long." They would prefer to plant more sorghum, but access to soils of adequate quality is limited. While maize may produce more on such soil in an exceptionally good year, sorghum is more drought-resistant and yields more than maize on these lands in normal or poor rainfall years.

Millet is planted on virtually all of the remaining land. On the Central Plateau, these are generally sandy or silty loams, the fertility of which has deteriorated as a result of continuous cropping and poor soil management. While sorghum may yield more on these soils when rainfall is consistent, the superior drought resistance and yield stability of millet make it a preferred crop in normal years. Farmers plant as much millet as their labor supply permits once they have allocated land to maize and sorghum (FSU Annual Reports 1983, 1984).

Peanuts, the principal cash crop, are planted almost exclusively because they can be harvested and ready for sale soonest after harvest when the head tax is due. When asked why they plant peanuts, farmers simply say "to pay taxes." When asked why they don't plant more, they say "because I would just have to sell them to buy cereals."

While the farmer expresses these decision rules in agronomic terms, he also indicates that risk is a part of the decision. As one moves from the more humid southwest to north in Burkina-Faso, rainfall decreases and the major cereal crop shifts from maize to sorghum to millet. A similar effect is seen west of the Central Plateau where the soil is more fertile. Maize is preferred to sorghum on compound land because it provides more edible kilograms per hectare. Planting maize further from the compound on less fertile soil with poor water retention increases the likelihood that maize will fail whereas sorghum is less likely to do so. On these soils, sorghum is preferred to millet because it yields more in a normal year. Sorghum is not generally planted on "millet land", however, because it is more likely to fail than is millet which, in farmers' words, "will provide a crop even if there is only one good rain." There are intermediate soils on which millet or sorghum may be planted depending on the farmer's willingness to accept risk.

Thus, the farmer, given available land types and labor resources, considers the trade-off between yield expectations and risk in his cropping decisions. This decision, which depends on the farmer's risk preference, is used to manage intraseasonal production risk.

MEASUREMENT OF RISK PERCEPTIONS AND INTRASEASONAL RISK MANAGEMENT

The basic assumption of this research is that the farmer's yield expectations and risk perceptions are based upon his recollection of yield during recent years. A survey instrument based on yield recall was designed to collect time series yield data for all major crops. This approach was designed to tap the strong tradition of oral history among local farmers. No other time series of yields at the village level were known to the authors. This made farmers' knowledge of production histories the only source of time series information available.

Methodology

During September and October of 1983, 30 randomly-selected farmers in each of the five villages were asked to recall production from their principal fields for each major crop for each of the preceeding ten years. The farmers do not have a common measure of surface area. Hence, the methodology was designed to derive information on yields per hectare from units the farmer is familiar with. This was paniers or baskets full of grain received on his principal fields. First, the size of the principal field for each crop for the current year was measured. Next, the farmer was asked if the same crop was planted on that field the preceeding year. If so, he

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There is no strong test for the accuracy of yield recall. However, the fact that yield is the major concern of the subsistence farmer and the strong tradition of oral history among those interviewed improves the likelihood of accuracy. Further, there is no other source of time-series yield data.

The interviewers were familiar with the kilogram volume of individual farmers' baskets both for threshed and unthreshed grain. The same interviewers collect stocks and transactions data from the same farmers on a monthly basis and had already measured these conversion rates.

A change of f: .ds, through crop rotations, likely causes changes in soil fertility. The effect of this on crop yields is diminished, however, by the tendency of farmers to plant crops in soil regimes to which they are best adapted thereby limiting ranges in fertility for a specific crop.

was asked what the production was and if the field was the same size. If the field was the same size, the production was recorded and converted to a per hectare yield. If the size of the field had changed, he was asked if the field was larger or smaller. In either case, he was asked what production would have been had the field been the same size. This answer was then recorded and converted to a per hectare value. This procedure was repeated to secure yield estimates for the ten year period from 1973 through 1982.

The interview process was relatively complicated and demanding both to the farmer and the interviewers. It is natural to question the capacity of farmers to recall production levels over a ten-year period, particularly when asked to adjust them for changes in field sizes. For this reason, interviewers were closely supervised and cautioned on when to accept farmers' responses during interviews. The farmer himself was told to respond only if he could remember his production levels and to indicate the degree of confidence in his response. If the farmer appeared to be fabricating responses to satisfy the interviewer or if he appeared to tire, the interview was to be terminated. Interviews in Diapangou, Dissankuy and Nedogo provided satisfactory data. However, as a result of a poor season in Bangasse, farmers were unwilling to discuss yields. In Poedogo, cooperation by farmers was poor. The reasons are not clear to the researchers since the same farmers were very helpful in all other survey work.

Validation

As a test of this survey method, several efforts to validate the data were employed. These were:

1) A comparison of average yields based on recall with objectively measured current yields;
2) A comparison of yield trends based on recall to trends anticipated by the researchers;

3) A comparison of the relative yield variability among crops, based on yield recall, with the variability described by farmers in prior interviews;

4) An independent interview with farmers asking them which in terms of yield, were the best and the worst of the last ten years;

5. A comparison of relative changes in yields based on recall among farms from one year to the next (sign test);

6) A comparison of observed cross-sectional yield variability with the same measure based on yield recall; and

7) The interviewers' accounts of how well the farmers felt they could recall their production histories.

Comparison of Yields. In Table 2, average yields based on ten years of recall are compared to average yields taken by direct measurement in 1982 (Nedogo, Diapangou) and 1983 (Dissankuy). As the data indicate, the observed yields are, in all but one case (peanuts, Nedogo), lower than the mean yields based on recall. There are several reasons for these differences. In Dissankuy, where the disparity is the greatest, there was much less rainfall in 1983 than usual. In Diapangou, the rainfall was relatively late and the effect was similar. As Table 3 indicates, the ten year yield (recall) trend in Nedogo is negative. This would lead one to expect that average yields based on ten-year recall would be higher than those observed at the period's end.

Comparison of Trends. Table 3 presents trend estimates based on yield recall. The results show negative trends in Nedogo. These are consistent with the hypothesis that yields have been declining on the Central Plateau due to the breakdown of the fallow system. Negative trends are neither evident nor expected in the frontier villages of Diapangou and Dissankuy,

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Rainfall is believed to have declined over this period as well, but village level data are unavailable to evaluate its affect on yields.

Table 2. Average Yields (kilograms per hectare) and Measures of Yield Variability, by Village, Based on Subjective Recall and Objective Yield Measurements.

Village	Crop	Subjective Yields(a) Mean Yield	Std. Dev.	Coefficient of Variation	Sample Size	Objective Yields(b)
Nedogo	Millet	389	176	45.2	240	342
	Cowpeas	27	21	77.4	230	
	White Sorghum	533	265	49.8	220	410
	Cowpeas	47	42	89.3	170	
	Red Sorghum	645	404	62.6	150	518
	Cowpeas	51	51	101.0	120	
	Peanuts	428	231	53.8	220	462
	Maize	1054	662	62.8	260	1040
Diapangou	Millet/Sorghum Association	572	227	39.5	270	384
	Cowpeas	76	73	95.7	240	
	Maize	2415	1105	45.8	290	1706
Dissankuy	White Sorghum	1036	291	28.1	170	617
	Maize	971	291	30.0	140	649
	Cotton	1290	259	20.1	80	

(a) Subjective yields are the product of farmer recall. Thirty (30) farmers in each village were asked to recall yields for a ten year period. Where n=240, ten yield observations were obtained from 24 farmers and six farmers were excluded because data were incomplete. Average yields reported here cover the entire ten year period. They include both temporal and interfarm variation.

(b) Objective yields were obtained by FSU through direct field measurement. Yields from Nedogo and Diapangou (1982) are reported by Jaeger (1983). Yields for Dissankuy are from 1983, an exceptionally dry year for the area.

Table 3. Yield Trends and Yield Growth Rates Based on Subjective Recall of Yields by Farmers in Burkina-Faso, 1973-82.

		--------------Linear Time Trend[a]------			------Geometric[a] Rate of Growth	
		Y = A + B (yr)				
Village	Crop	A	B	F Sifnif.	Rate (r * 100)	Sample Size
Nedogo						
	Millet	627**	-3.06	.60	-.42	240
	Cowpeas	161**	-1.73*	14.2*	-6.47*	230
	W. Sorghum	1638**	-14.26**	5.34**	-2.11*	220
	Cowpeas	261**	-2.77**	6.28**	-6.45**	170
	R. Sorghum	1880**	-15.93	1.94	-1.92	150
	Cowpeas	240*	-2.44	2.28	-4.43	120
	Maize	4514**	-44.65**	10.11**	-3.47	260
	Peanuts	1813**	-17.86**	10.41**	-3.61**	220
Diapangou						
	Millet/ Sorghum Assoc.	532	0.52	0.01	0.57	270
	Cowpeas	240*	-2.10	1.63	.001	240
	Maize	255.0	27.87	1.52	1.99*	290
Dissankuy						
	W. Sorghum	1592**	-7.17	0.85	-0.80	170
	Maize	887	1.09	0.02	.003	140
	Cotton	241	13.54	1.82	1.00	80

(a) Two stars (**) indicate coefficients are significant at the .05 level. One star indicates significance at the .10 level.

(b) The geometric growth rate was calculated from the equation $Y = a(1+r)^t$. using the least squares method.

where population pressure is less severe and land is relatively abundant. Appendix 1 shows mean annual yields by village.

Comparison of Relative Yield Variability. In the decision-making interviews conducted earlier, farmers reported that millet is the least risky and maize the most risky of crops to grow. Sorghums fall in between, with red sorghum yields said to be more variable than those of white sorghum. The standard deviations presented in Table 2 support these claims. The standard deviations are lowest for millet, followed by white sorghum, peanuts, red sorghum and maize.

Best Year-Worst Year Recall. In an independent interview with the same group of farmers, each was asked to indicate which of the preceeding ten years were the best and the worst in terms of yield for each crop. These were then compared with the highest and lowest yields calculated from the yield recall data for each farmer, respectively. The two sets of extremes were consistent, providing support for validity of the yield estimation procedure. Next, comparisons of best and worst years among farmers were made to test for uniformity among responses. The data in Appendix 2 show that 82 to 96 percent (depending on the crop) of farmers in Nedogo reported 1977 as the worst year for all crops cultivated. This is consistent with the mean yields reported in Appendix 1. A lesser but still high percentage of farmers (40 to 65 percent depending on the crop and village) provided similar responses for what were the best years.

Comparison of Year to Year Changes in Yields. Changes in yields from year to year were compared across farms for selected crops. An increase is indicated by a (+); a decrease by a (-). The results are presented in Table 4. Yields for most farmers declined from 1976 to 1977 due to a severe drought. This is the corollary to the worst year case discussed above.

Table 4. Comparisons of Year to Year Changes in Yields Among Farms, Yield Recall Data, Selected Crops[a]

Village	Crop	Sample Size	Change	73 to 74	74 to 75	75 to 76	76 to 77	77 to 78	78 to 79	79 to 80	80 to 81	81 to 82
Nedogo	Millet	25	(+)	7	9	11	-	24	13	13	8	7
			(-)	16	12	14	24	-	9	10	16	15
	White Sorghum	22	(+)	6	5	7	3	21	5	14	9	12
			(-)	13	16	15	19	1	14	6	11	8
	Red Sorghum	15	(+)	3	7	1	1	15	7	6	5	5
			(-)	9	7	13	14	-	6	6	5	7
	Peanuts	23	(+)	8	7	12	4	21	9	12	12	11
			(-)	13	16	9	19	2	13	11	9	10
	Maize	26	(+)	4	4	9	1	24	17	13	7	16
			(-)	17	18	16	24	2	9	11	17	10
Diapangou	Millet/ Sorghum Association	27	(+)	7	15	10	8	10	14	12	14	7
			(-)	15	9	14	15	14	9	11	11	18
	Maize	29	(+)	6	17	10	7	15	7	16	14	11
			(-)	13	5	9	14	7	14	7	8	12
Dissankuy	White Sorghum	17	(+)	12	3	6	5	8	8	12	6	7
			(-)	3	13	7	10	9	7	4	9	7
	Maize	14	(+)	11	6	5	4	8	8	11	5	10
			(-)	3	6	8	9	6	3	3	9	3

[a]Responses are the number of farms whose yields increased (+) or decreased (-) from one year to the next. Their sum may not equal the sample size due to yields which remained unchanged.

Yields also uniformly declined from 1973 to 1974 in Nedogo and Diapangou but increased in Dissankuy. Strong similarities exist in other years but are mixed among crops and villages. Hence, there appears to be evidence that farmers recalled the exceptional years of good or poor yields at similar points in time. The fact that farmers reported mixed increases and decreases in other years suggests the lack of a predominant factor (a severe drought) or set of factors which strongly and uniformly influenced yields.

Objective Cross-Sectional Yield Measurements. In Nedogo and Diapangou during 1982, and Dissankuy in 1983, yield measurements were taken on all fields for selected crops. In Table 5, the standard deviations of these objective yield values are compared to the standard deviations of yield recall values for 1982. As the table shows, standard deviations of the yield recall data compare reasonably well with those actually observed. Some differences are to be expected for the following reasons. First, the samples of farmers are different. Second, standard deviations based on recall are drawn from principal, and presumably higher quality fields for each crop, whereas the objective data are based on measured yields from all fields. This would lead one to expect lower standard deviations for data based on recall. Third, estimates for small fields, such as those on which peanuts are grown are smaller and subject to greater measurement error.

Farmers' Accounts of Their Own Yield Recall. Interviewers asked farmers to be frank about their confidence in recall. Farmers expressed high confidence in their abilities to recall yields for the preceeding five years, they were fairly confident about their recall up to seven years and were much less confident about their recall beyond the seven year period.

For the remainder of this paper, ten years of data are used in the analysis. This is done because the data appear relatively well behaved when examined by earlier validity tests. Further, the data (7 years to 10) contain valuable information on farmers' perceptions of yields even if they are biased relative to actual yields.

Table 5. Comparison of Objective Cross-Sectional Yield Variation and Subjective Cross-Sectional Yield Variation, Selected Crops.

Village/Crop	Standard Deviation Based On: Farmers' Recall 1982	Objective Measurement 1982
Nedogo		
Millet	134	125
White Sorghum	212	287
Peanuts	190	325
Dissankuy		
White Sorghum	290	207*
Diapangou		
Millet/Sorghum**	190	
Millet		153
White Sorghum		229

* Measurements for Dissankuy are from 1983.
** The millet/sorghum association includes 75-90 percent millet. The remainder is white sorghum.

Analysis of Risk Measures

The remainder of this analysis focuses largely on the village of Nedogo. This is because 1) the survey data for Nedogo included observations on more crops, and 2) more farmers in Nedogo provided data for each crop for the entire ten-year period. Analysis of these data include four steps. These are: 1) to quantify farmers' risk perceptions, 2) to compare the risk associated with alternative crops, 3) to evaluate the implications of these risk perceptions for alternative crops under drought conditions, and 4) to determine the effects of risk in a representative farm model assuming risk aversion.

In examining the following analysis, the reader should bear in mind that the data are derived from yield histories for crops planted on soils for which they are best suited. For example, maize data is taken from yield histories on compound land, white sorghum data from "sorghum land" and millet data from yields on lower quality soils. Thus the data do not reflect the risk one would assume in planting a crop on land for which it is marginally suited. The farmers' cropping decision rules offer insight regarding the direction of bias. To plant maize on lower quality land would increase the risk of crop failure. Therefore, yield variability for maize is likely understated if the farmer considers planting the same crop on other than compound land. The same argument applies to data collected for white sorghum, though to a lesser degree than for maize. Alternatively, millet, usually planted on the worst soils, may be a less risky crop if planted on better soils. Thus, the analysis does not consider all the information used by the farmer in making marginal cropping decisions.

The variation measures presented to this point have included both interfarm and annual variation. While such measures are useful for broad comparisons of yield variability at the village level, they are not, because of interfarm variation, appropriate estimates of the risk levels perceived by an individual farmer. To secure appropriate estimates, data were adjusted to remove the variation resulting from differences in mean yields among farms. The resulting measures, used in the remainder of this analysis, are therefore lower than those in Table 2.

Standard deviations of yields (excluding interfarm variation) for individual crops are presented as risk measures in Table 6. These values are consistent with farmers' claims about the relative riskiness of major crops. In Nedogo, the highest risk is associated with maize. This is followed by red sorghum, peanuts, and white sorghum. Millet has the lowest risk. Similar relationships are seen in Diapangou. The only result differing greatly is the low value for maize in Dissankuy.

The standard deviations of yields for millet and sorghum do not vary greatly by village. Thus, the higher coefficients of variation in Nedogo reflect lower yields rather than greater yield variability. This places the farmers in Nedogo at a disadvantage in two ways. First, lower yields limit the ability to cushion themselves against a bad harvest. Second, higher variability relative to those yield levels increases the insecurity of food stocks. Thus, a bad season in this zone is more devastating than in other villages.

Adjustments were made by applying the transformation

$$(X_{ijk} - X_{jk})\ (X_k/X_{jk})$$

to the data where X_{ijk} refers to the ith observation for the jth farmer and kth crop, X_{jk} is the mean yield for farmer j on the kth crop and X_k is the sample mean for the kth crop. This conversion transforms the data from actual yield observations to adjusted deviations around a group mean of zero. Risk measures compiled from this data can be interpreted as the average variance faced by an average farmer free of inter-farm variation.

Table 6. Absolute and Relative Measures of Risk by Crop and Village Using Adjusted Recall Data.[a]

Crop	Diapangou		Dissankuy		Nedogo	
	Std. Deviation	CV	Std. Deviation	CV	Std. Deviation	CV
Millet	123[b]	21.5			106	27.2
(n)	(270)				(240)	
W. Sorghum			180	17.4	156	29.3
(n)			(170)		(240)	
Peanuts					153	35.7
(n)					(220)	
R. Sorghum					189	29.3
(n)					(150)	
Maize	710	29.4	134	13.8	421	39.9
(n)	(290)		(140)		(260)	
Cotton			132	10.2		
(n)			(80)			

[a]Statistics are calculated from data adjusted for interfarm variation. Hence, the values are lower than those on Table 2 which include variation between households.

[b]Millet/Sorghum Association is 75-90% millet. The remainder is white sorghum.

The data show that the crops with lower yield also have lower yield variability. But it is not clear that differences in variance are so great that a crop with low average yields would rationally be chosen over those with higher average yields. To determine whether this is the case, the effects of drought conditions on crop yields are simulated in Table 7. In Nedogo, if one assumes that yields fall two standard deviations below the mean, the yield for white sorghum (221 kilograms per hectare) remains higher than the yield for millet (177 kilograms per hectare). However, if one accepts the yield estimates for the year 1985 (derived from Table 3), millet has the highest yield (155 kg./ha.) when drought conditions occur. In the other villages, where there is no evidence of declining yields, the higher yielding crops retain the highest yields under drought conditions. These findings suggest that in Nedogo, crops with a low average yield may rationally be chosen over others because they produce the most food in a bad year ("safety first" approach). In the villages of Dissankuy and Diapangou, farmers may have more flexibility to pursue other objectives (e.g., profit-maximization).

Coefficients of yield variation (for the 10 year period) were calculated by crop for each farmer. These were then compared for all combinations of crops using paired t-tests. The results are presented in Table 8. They indicate that differences in coefficients of variation are not

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Attention needs to be drawn to interpretation of these results. The comparison of yields under a drought scenario are based on yield histories for crops planted on soils for which they are best suited. Extrapolation of these results to other soil types alters yield expectations and would likely bias variance estimates. The direction of this bias is hypothesized in an earlier section. Moreover, whether farmers pursue such objectives as maximizing profits or achieving food security depends on levels of food stocks, total household production, wealth, nature of markets and producer utility. The point of the analysis here is to demonstrate the importance of the trade-offs between yields and risk which face subsistence farmers.

Table 7. Effects of Yield Variability on Crop Yields Under a Bad Year Scenario

Crop	Mean Yields 1973-1982	Standard Deviations	Mean Yields Minus Two Std. Dev.	Expected Yield in 1985 (a)	Expected Yield Minus Two Std. Dev.
Nedogo					
Millet	389	106	177	367	155
White Sorghum	533	156	221	426	114
Red Sorghum	645	189	267	526	148
Maize	1054	421	212	719	-0-
Peanuts	428	153	122	295	-0-
Diapangou					
Millet/Sorghum Association	572	122	328	576	332
Maize	2415	710	995	2624	1204
Dissankuy					
White Sorghum	1036	180	676	983	623
Maize	971	134	703	980	712

(a) Expected yields for 1985 are calculated from trend equations on Table 3.

Table 8. Significance Levels of Paired t-Tests Comparing Coefficients of Variation for Major Crops, Subjective Recall Estimates for Nedogo, 1973-82.

	Millet	White Sorghum	Red Sorghum	Peanuts	Mean CV
Millet					27.8
(Farmers)					(24)
White Sorghum					28.8
Significance	0.307				
(Farmers)	21				(22)
Red Sorghum					29.2
Significance	0.287	0.141			
(Farmers)	15	12			(15)
Peanuts					36.7
Significance	0.004	0.042			
(Farmers)	22	19	*		(22)
Maize					38.7
Significance	0.001	0.001	0.009	0.076	
(Farmers)	24	21	14	22	(26)

*Insufficient data for computation.

significant among the major cereals (millet and sorghums). However, the coefficients for maize and peanuts are significantly greater than those for the cereal crops.

These findings indicate that farmers plan their cropping mix such that coefficients of yield variation are constant for major cereals. This implies a willingness to accept more risk if it is accompanied by proportionately higher yields. Yet farmers accept higher coefficients of variation for peanuts and maize. These findings indicate that farmers assume a greater cost in terms of risk in cultivating these crops; the former to assure that sufficient cash is available to pay taxes, the latter to assure food security during the "hungry season."

Effect of Risk on Choice of Crop Mix

Many of the techniques used to evaluate choice of production technology on the farm do so free of formal risk considerations. Simple partial budgeting, for example, compares net financial benefits across two or more crops or technologies given a set of expected or realized yields. Mathematical programming, which optimizes producer utility subject to a set of farm constraints, again frequently (not necessarily) ignores risk. The result is that highly profitable but risky activities in a risk-free analysis appear more economically attractive than would be the case if higher cost due to risk were considered.

To evaluate the effect of risk on choice of production technology, a representative farm model was constructed for the Nedogo region, using mathematical programming. Linear programming was first used to simulate producer behavior based on the profit maximization paradigmn and a constraint on minimum maize production. Later risk averse behavior is incorporated to evaluate its effect on cropping patterns. Details on the construction of this model, its assumptions and data utilized are available in Roth (forthcoming).

Briefly, the farm model permits cultivation with three types of tillage operation: manual, donkey and oxen cultivation. Farmers possess four types of resources: land of various qualities, family labor, animal traction and modern inputs. Land is disaggregated into five types including swampy land, high quality fields encircling the family compound, village fields and higher and lower quality bush fields. The farm has a fixed endowment of the first four land types, but is assumed to have an unlimited quantity of lower quality bush land at its disposal. Stocks and flows of labor are disaggregated into weekly time periods to capture critical labor constraints at planting and first weeding. A constraint on minimum area of maize is included to ensure the family has sufficient grain for the hungry season.

Cropping activities included in the farm model were selected from cropping patterns observed on the Central Plateau. A summary of crop activities, land types and yield levels under traditional management practices are given in Appendix 3.

The attempt to model the cropping patterns of farmers on the Central Plateau was relatively successful. The results presented in Table 9 compare actual cropping patterns with those predicted by the model. The major differences are that more maize and peanuts enter solution under the assumption of profit maximization than is observed in practice. These relatively profitable crops forced some sorghum and millet out of production. In the model, maize rep ced red sorghum on relatively high quality land while peanut plantings displaced millet on lower quality land.

See M. Roth and J. Sanders, "An Economic Evaluation of Selected Agricultural Technologies With Implications for Development Strategies in Burkina-Faso," 1984, for an application of the model for evaluating existing and new technologies on the farm.

Table 9. Demographic Characteristics, Area Cultivated, Land Use Patterns and Land-Labor Ratios Under Alternative Traction Scenarios, Central Mossi Plateau

(Per Farm Results)

	Representative Central Mossi Farm[a] Plateau			Jaeger-Nedogo[b] (1983)	
Variable	Hand Tillage	Donkey Tillage	Oxen Tillage	Hand Tillage	Donkey Tillage
Demographic Characteristics					
Residents	10.0	14.0	15.0	--	--
Active Workers	5.0	6.5	7.0	4.71	6.64
Total Area Cultivated (HA)	4.80	7.3	8.13	4.41	8.18
Cropping Proportions (%)					
Millet	65.6	68.9	68.1	62.0	63.0
White Sorghum	16.6	11.0	9.8	15.4	18.5
Red Sorghum	12.5	4.8	1.7	12.7	8.6
Maize	3.1	6.2	8.5	2.0	2.4
Peanuts	1.7	8.8	11.6	5.4	5.5
Bambara Nuts	--	--	--	1.8	1.2
Rice	0.5	0.3	0.3	0.5	0.1
Land-Labor Ratios:					
Area Cultivated/Worker	0.96	1.12	1.16	0.94	1.23
Area Cultivated/Resident	0.48	0.52	0.54		

[a]Representative Farm refers to a farming system which has been developed from farm data collected by ICRISAT, IRAT, Purdue SAFGRAD/FSU, etc. The information was incorporated in a mathematical farm model which produced the results shown here.

[b]Nedogo is a Purdue SAFGRAD survey village located about 30 kms from Ouagadougou on the Central Mossi plateau.

SOURCE: Roth and Sanders, "An Economic Evaluation of Selected Agricultural Technologies With Implications for Development Strategies in Burkina-Faso", 1984, p.16.

A preliminary effort was made to incorporate risk averse behavior in the model. Our primary objective was to incorporate aversion to yield variability rather than price variability. For simplicity, an expected utility maximization problem is assumed. Yields per hectare are assumed to have a joint normal distribution and farmers utility is assumed to be an exponential function of profits (U( )=-exp[-a]). (The variance-covariance matrix and associated correlation matrix for Nedogo are presented in Tables 10 and 11, respectively.) As shown by Freund (1956) this problem is equivalent to a quadratic program where the objective is the expected profits less a constant ("a" from the utility function) times the variance of profits. The constant "a" is frequently referred to as the "risk aversion coefficient."

For this analysis, several values of the risk aversion coefficient were considered. Table 12 displays the model's response for risk neutral producers and for two different levels of "a". These levels were chosen so as to "bracket" the observed cropping pattern as nearly as possible. The two crops which did not satisfy this condition were millet and peanuts.

Maize, with higher expected yields, enters the solution on sorghum land in the risk-neutral case. It is drawn back to compound land when risk is incorporated and is replaced by red sorghum which has a lower yield but also less risk. This behavior is consistent with the risk-averse attitudes expressed by farmers on the Central Plateau. On the other hand, the model tends to overestimate the area planted in peanuts. This raises some questions regarding the quality of variance estimates for peanuts which are relatively low compared to other sources (e.g., SAFGRAD-FSU, 1983, p. 27).

The discrepancy for millet is negligible (less than 3%) but not for peanuts. The simulated cropping intensities for peanuts are more than double the observed levels.

Table 10. Variance-Covariance Matrix for Yields, Based on Subjective Recall Estimates, Nedogo, 1973-82.[a]

	White Sorghum	Red Sorghum	Millet	Maize	Peanuts	Cowpeas	Rice
White Sorghum	24,438						
Red Sorghum	19,781	35,713					
Millet	7,794	8,671	11,214				
Maize	33,991	38,669	18,376	177,450			
Peanuts	10,440	14,025	6,700	26,199	23,495		
Cowpeas	1,764	1,660	1,083	4,793	1,389	433	
Rice	12,179	16,949	13,679	43,229	13,808	4,137	54,556

[a]Those estimates are derived from the correlation matrix in Table 11 and variance estimates in Table 6.

Table 11. Correlation Matrix for Yield Estimates Based Upon Subjective Yield Recall, Nedogo, 1973-82.[a]

	White Sorghum	Red Sorghum	Millet	Maize	Peanuts	Cowpeas	Rice
White Sorghum	1,000						
n	220						
p	0.001						
Red Sorghum	0.6476	1.0000					
n	120	150					
p	0.001	0.001					
Millet	0.4779	0.4407	1.0000				
n	200	150	240				
p	0.006	0.001	0.001				
Maize	0.5322	0.4507	0.4175	1.000			
n	220	150	240	240			
p	0.001	0.001	0.001	0.001			
Peanuts	0.4177	0.4692	0.4131	0.3916	1.0000		
n	180	120	200	220	220		
p	0.001	0.001	0.001	0.002	0.001		
Cowpeas	0.5497	0.3824	0.5160	0.6155	0.4400	1.0000	
n	170	80	150	170	140	170	
p	0.001	0.208	0.085	0.001	0.001	0.001	
Rice	0.4344	0.5307	0.5565	0.3358	0.3646	0.6291	1.0000
n	30	30	30	30	20	10	30
p	0.084	0.063	0.003	0.004	0.092	0.026	0.001

[a]These estimates are based on yield recall data adjusted for inter-farm variation (see Table 6).

Table 12. Cropping Patterns Under Observed, Risk Neutral and Risk-Aversion Assumptions, Donkey Traction Solution, Nedogo.

(Percent)

Crop	Observed[a] Cropping Pattern	Risk[b] Neutral Pattern	Risk Aversion Coefficient (.10 x 10⁻)	Risk Aversion Coefficient (.90 x 10⁻)
	----------Profit Maximization Assumed----------			
Millet	(63.0)	(68.9)	(64.6)	(64.9)
White Sorghum	(18.5)	(11.0)	(11.3)	(19.2)
Red Sorghum	(8.6)	(4.8)	(8.5)	(0.3)
Maize	(2.4)	(6.2)	(2.8)	(1.9)
Peanuts	(5.5)	(8.8)	(12.5)	(13.5)
Rice	(0.1	(0.3)	(0.4)	(0.3)
Total Hectares	8.18	7.30	7.07	7.28

[a]Cropping percentages are taken from Jaeger (1983).

[b]Cropping percentages are taken from Table 8 for the donkey traction solution. A representative farm linear programming model was used to generate the results.

In the above application, incorporation of risk made only minor improvements in evaluation of farmers cropping behavior. But, the importance of risk depends on the level of expected yields among crops on a given land type for which the data here are sketchy. If for instance sorghum yields more than millet on the poorest quality land (rather than vice versa, Appendix 3) but is riskier, then incorporation of yield-risk trade-offs is significantly more important. This is an area where more empirical work is needed. A more useful application would be in the evaluation of new technology where higher yields are often accompanied by increased financial and production risk. The results of the above analysis suggest this is one area where further risk modelling would be useful.

Further analyses are planned. These include: 1) the use of modified risk measures, 2) sensitivity analysis on risk measures and yields, 3) additional constraints on the use of land for peanuts and maize, and 4) attempts to determine the effects of changing yield variances as farmers shift crops from one land type to another.

CONCLUSIONS, IMPLICATIONS AND NEEDED RESEARCH

The objectives of this study were to evaluate the risk perceptions and intraseasonal risk management practices of farmers in several areas of Burkina-Faso. A methodology was used which enabled collection of time series information on yields based on farmers recall of yield histories. The results of seven validity tests showed the data to be well behaved and generally consistent among farms.

The methodology appears to offer several advantages over traditional methods of data collection. One, time series information on yields at the village level are scarce making studies of production dynamics of the household difficult. Two, collection of actual yield data are costly and time consuming. Three, institutional factors frequently constrain the time frame of research and the length of time series which can be developed. The above methodology provides a favorable alternative to these problems, but at a higher cost of inaccuracy. A potentially useful area of application is in 'rapid research appraisal' where researchers, at low costs can monitor technological adoption or evaluate benefits to a technology over time.

Analysis of the data supports farmers' claims that risk considerations play a role in intraseasonal decision-making. There is evidence that aversion to production risk prevents farmers from planting as much maize as they would if they were not risk-averse. While these results support the hypothesis that risk aversion prevents farmers from planting higher-yielding crops, another explanation may lie in fundamental characteristics of the farmers' soil resources. An alternative cropping pattern may require putting crops on land for which they are fundamentally unsuited and which would lead to drastic reductions in yield levels and or extreme increases in yield variability.

These findings show that, while production risk affects farmers' cropping patterns, these effects do not drive those patterns far from the profit maximizing cropping pattern for major cereals. This is not the case for maize. Accordingly, technologies designed to raise maize yields must consider the role of risk in farmers' cropping decisions much more than those designed for millet and sorghum.

Research is still needed to better understand the differences in land quality which lead farmers to refer to "millet land" and "sorghum land." Because the data reported here are drawn from yield histories on land that is presumably best suited to particular crops, there are no data on yield and yield variability when crops are planted on less suitable land. This research would be largely agronomic. In addition to providing insights with respect to the effects of such cropping changes and what farmers mean by risk, such research would add to knowledge about soil chemistry and permit more informed decisions with respect to technology design in this environment.

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Appendix 1. Change in Average Yields for Various Crops Over Time Calculated From Farmers Subjective Recall of Yields, Three Villages, 1973-1982

	Nedogo					Diapangou		Dissankuy		
	Millet	White Sorghum	Red Sorghum	Maize	Peanuts	Millet/ Sorghum	Maize	White Sorghum	Maize	Cotton
1982	371.3	505.7	595.3	1014.4	388.5	559.8	2655.6	1011.4	1015.4	1315.6
1981	406.1	485.5	633.8	929.7	387.9	630.1	2654.3	1068.4	932.7	1317.0
1980	429.8	556.4	676.6	1113.1	420.6	579.9	2429.1	1060.1	1034.9	1392.4
1979	417.4	548.3	674.6	1063.1	404.8	569.4	2287.8	958.9	971.5	1329.6
1978	393.5	554.1	637.2	962.5	423.6	543.0	2392.4	972.6	896.0	1312.5
1977	205.6	275.0	315.1	393.0	223.7	517.5	2231.3	988.2	929.6	1240.3
1976	383.8	515.3	582.9	1015.3	443.9	565.0	2351.2	1037.8	974.4	1216.5
1975	388.3	550.6	778.1	1106.2	464.3	585.8	2479.1	1078.0	997.8	1322.0
1974	438.6	654.5	738.8	1345.9	560.9	558.7	2198.9	1122.9	1011.1	1242.1
1973	457.3	680.9	815.7	1592.3	566.4	606.9	2467.9	1062.5	950.4	1210.5
x	389.2	532.6	644.8	1053.6	428.4	571.6	2414.7	1036.1	971.4	1289.9
n	24	22	15	26	22	27	29	17	14	8

Average yields reported for each crop were calculated only for those farms reporting a complete history of yield information. Some farms in a village sample cultivated a crop only periodically; others not at all. Hence n=24 says that 24 farms could recall a complete history of yield information.

Appendix 2: Validation of Farmer Recall Data Using Independent Observations of Good-Bad Year Scenarios.

		Best Years[b]			Worst Years[b]		
	n[a]	Best Year	Second Best	%	Worst Year	Second Worst	%
Nedogo							
Millet	24	1973(8)	1974(2)	42	1977(22)	1982(1)	96
White Sorghum	22	1973(7)	1974(2)	41	1977(18)	1981(0)	82
Red Sorghum	15	1973(3)	1975(3)	40	1977(13)	1976(1)	93
Maize	26	1973(10)	1974(6)	62	1977(23)	1981(1)	92
Peanuts	22	1973(7)	1974(6)	59	1977(18)	1981(0)	82
Diapangou							
Millet/Sorghum	27	1981(6)	1973(3)	33	1977(6)	1978(3)	33
Maize	29	1982(13)	1981(7)	69	c/	c/	
Dissankuy							
White Sorghum	17	1974(9)	1975(2)	65	1979(2)	1978(1)	18
Maize	14	1980(7)	1982(1)	57	c/	c/	
Cotton	8	1980(4)	1979(1)	63	c/	c/	

[a]Number of farms with a complete 10 year yield history for which statistics were computed.

[b]Best years correspond to the first and second highest yields taken from annual averages computed in Appendix 1. Worst years correspond to the first and second worst years of production. Figures in parenthesis are the number of farmers who in an independent survey recalled the respective year as being the best or worst accordingly. Percentages are the proportion of farmers whose recollection of best and worst years allign with best and worst years computed from yield histories.

[c]Incomplete information is available on farmers' independent recall of good or bad years.

Appendix 3. Yield Levels for Sole Crops and Crop Mixtures by Type of Land and Traction Technology Assumed for the Central Plateau Representative Farm

Type of Land	Crop Mixture	Hand Tillage
Swamp Land	Rice	850
Compound Land	R. Sorghum	850
	W. Sorghum	770
	R. Sorghum/W. Sorghum	638/185
	Maize	1000
Red Sorghum Land	R. Sorghum	640
	R. Sorghum/Cowpeas	640/55
	W. Sorghum	590
	W. Sorghum/Cowpeas	590/55
	Maize	625
White Sorghum Land	R. Sorghum	430
	R. Sorghum/Cowpeas	430/45
	W. Sorghum	450
	W. Sorghum/Cowpeas	450/45
	Millet	420
	Millet/Cowpeas	420/45
	W. Sorghum/R. Sorghum	340/105
	Millet/W. Sorghum	315/115
	Maize	350
	Peanuts	520
Millet Land	W. Sorghum	310
	W. Sorghum/Cowpeas	310/35
	Millet	340
	Millet/Cowpeas	340/35
	Millet/W. Sorghum	255/78
	Peanuts	480