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ADAPTABILITY ANALYSIS OF FARMER-MANAGED TRIALS IN FARMING SYSTEMS RESEARCH

by

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*Both Ohm and Cantrell had major roles in the research upon which this paper is based. Neither has had the opportunity to review this draft.

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Often, agronomic research as conducted in western Africa has implicitly assumed that farmers are homogeneous. While this assumption appears justified on the surface, the yield distributions of agronomic trials are almost always skewed. These indicate disproportionately higher yield increases for some farmers. These results justify questions about the generalizability of trial results and the implications of non-homogeneity of farmers for the design and placement of agronomic trials in on-farm research.

This report illustrates the use of a simple statistical technique which permits the researcher to test the generalizability of trial results. These technique can also be used to indicate whether it is worthwhile to differentiate among farmers participating in the trial as an aid to research design and extension efforts.

Simple linear regression analysis is used here to assess the adaptability of farmer-managed agronomic trials as the agronomic and managerial environment varies. This is a variation on "stability analysis", a technique first reported by plant breeders. Yates and Cochran (1938), Finley and Wilkenson (1963) and others used linear regression to evaluate the stability of experiment station trials over space and time. More recently, Hildebrand used the adaptability analysis variation on this technique to evaluate the results of "farmer-managed" agronomic trails as a part of "farming systems" research.

In adaptability analysis, individual treatment yields are regressed on mean treatment yields for each replication of a trial.* The mean treatment yield is used as an "environmental index" or proxy for variations in fertility, moisture and managerial factors across replications of a trial. The intent of the analysis is to determine whether the treatment yield remains stable as factors uncontrolled by the trial vary.

The technique seems especially useful in farming systems research where "farmer-managed" agronomic trials are a central part of research to design new technology and to determine whether specific technologies are likely to be adopted by farmers. In farmer-managed trials, one replication with two or more treatments is placed on a random sample of farms. Such trials include a control treatment (traditional technology) with each replication.

To determine whether a given treatment leads to significantly greater yields than those achieved with traditional technology, treatments are compared using paired t-tests. Paired tests are superior to tests for independent groups and provide more information than independent group tests because there can be substantial variation in the environment (fertility, soil structure and management) for replications, all of which are on different farms.

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*To illustrate, if there are 25 replications of a trial with 4 treatments, T1(1), T2(2), T3(1) and T4(1) represent the results of the first replication. T1(25), T2(25), T3(25) and T4(25) represent the results of the 25th replication. The mean treatment yield or environmental index for the first replication is the mean of T1(1) through T4(1) or MTY(1). The mean treatment yield for the 25th replication is the mean of T1(25) through T4(25) or MTY(25). Thus, to conduct stability analysis of treatment 2, one would regress T2(i) for i = 1..25 on MTY(i) for i = 1..25.

When the environment for replications of a trial varies, trial results provide information about the effect of variation in the environment on treatment yields. This information is not exploited in the yield comparisons made by t-tests.

Adaptability analysis permits the researcher to exploit such information. When individual treatment yields are regressed on mean treatment yields, a unitary regression coefficient (b=1) indicates that the treatment is stable across all environment represented by the replications. A one unit change in the mean treatment yield is associated with a one unit change in the treatment yield. A coefficient significantly greater than unity (b>1) implies that the treatment has increasing adaptability to high-yielding environments whereas a coefficient significantly lower than unity (b<1) indicates greater adaptability to lower yielding environments (Finlay and Wilkenson). These distinctions are used by Hildebrand to identify different "recommendation domains" (CIMMYT) or environments to which particular technologies are best suited.

As used by plant breeders, stability analysis has historically included both locational and temporal dimensions, incorporating yield data from cross-sectional (location) and time series observations. Hildebrand used only cross-sectional data in his analysis of farmer-managed trials.

In evaluating the limitations of this type of analysis, Binswanger and Barah distinguish between stability and adaptability analysis. They refer to stability in the temporal risk sense and to adaptability in the locational consistency of results sense. They argue (p. 11) that "it is impossible to estimate the stability and adaptability components of overall variance separately. This is because the use of a single season's data incorporates certain of the variables (rainfall) that one would consider explicitly in estimating stability with multi-year data.

This is a telling argument, particularly in environments such as those in Burkina-Faso, where significant differences in rainfall are frequently observed on the same day within a small village. In such cases, the effects of differences in rainfall can be falsely attributed to differences in fertility, soil structure or management practices, thereby introducing bias to adaptability estimates.

If aware of this pitfall, however, the researcher can still employ adaptability analysis productively in the evaluation of farmer-managed trials. Further, it is important that they do so. This is because ideally, farming systems researchers base the selection of farmer-managed trials on their research findings from the preceeding year. This is not possible if one requires that a temporal component be included in the analysis.

Adaptability analysis is easy to conduct and can provide information useful in making decisions on the design of trials. If researchers are close to the trials during the year and aware of locational variation in rainfall, they are able to discount the results of analysis which they know are largely attributable to intra-sample differences in rainfall.

If researchers can, using adaptability analysis, identify technologies apparently adaptable across all environments, more adaptable to favorable environments, or to unfavorable environments, adaptability analysis can alert them to identify factors explaining differences in yield response to particular treatments. Such information can be used to design new trials and to select settings in which specific treaments can reasonably be expected to perform well.

Farming Systems Research at Purdue University

The Purdue University Farming Systems Research Unit (FSU) conducts agronomic and research to identify obstacles to increased food production

and uses this information to design and evaluate production technologies hopefully attractive to farmers. Two types of on-farm agronomic trials are used in this research.

The first type of trial is research-managed. It is of split plot, randomized complete block design and is conducted in farmers' fields entirely by the FSU staff. Treatments are selected mainly on the basis of results from the more promising trials conducted on experiment stations.

The second type, farmer-managed trials, are conducted by farmers under the supervision of the FSU staff. There is one replication of each farmer managed trial on each of 25 randomly-selected farms in each village. These trials are designed on the basis of findings from research managed trials, prior farmer-managed trials and the results of socio-economic research to identify the characteristics of technologies that will fit farmers' circumstances. The trials are conducted on a relatively large scale (.04 to .12 hectars per treatment) in an effort to approximate the environmental conditions in which they would be placed if adopted by farmers.

While conducted in the farmers' principal fields for each crop, the quality of principal fields and management skills vary greatly among farmers. Thus, while trial conditions are realistic, the degree of control achieved in farmer-managed trials with a control treatment does not approach that in experiment station trials.

To deal with the variation in the conditions in which trial replications are conducted, paired t-tests are used to compare treatment yield results with the control treatment yield. But the variation in environments limits the degree to which one can generalize about the conditions under which the results are applicable.

This presents a need for a technique to identify the range of conditions under which the results of such trials are valid. This paper employs the results of adaptability analysis to do so.

Research Setting

During the 1983 cropping season, farmer-managed trials were conducted in three villages. These were Bangasse, Diapangou and Nedogo (See Figure 1).

Bangasse and Nedogo are located on the densely-populated Central Plateau in rainfall zones of 400 to 500mm and 700 to 800mm respectively. Bangasse has the lowest agricultural potential of the three villages. Only one in six farmers in Bangasse use animal traction whereas more than half do so in Nedogo. Diapangou is located just off the eastern edge of the Central Plateau in a relatively fertile zone of shifting cultivation. The average annual rainfall is between 700 and 800mm and technology is relatively advanced in this region. Ox and donkey traction are commonly used by farmers in Diapangou. Those using hand tillage are in a minority.

Farmer Managed Trials and Results

Three farmer managed trials were conducted by the FSU during 1983. These involved water conservation and fertility treatments on millet, sorghum and maize.

The millet trial included 5 treatments. These were: 1) traditional tillage (treatment 80), 2) tied ridges only (treatment 81), 3) tied ridges with rock phosphate (100 kg./ha.) in the seed pocket with urea (50 kg./ha) side dressing (treatment 82), 4) broadcast rock phosphate (200 kg./ha) with urea (50 kg./ha.) side dressing (treatment 83), and 5) rock phosphate in the seed pocket with a area (50 kg./ha.) side dressing (treatment 84).

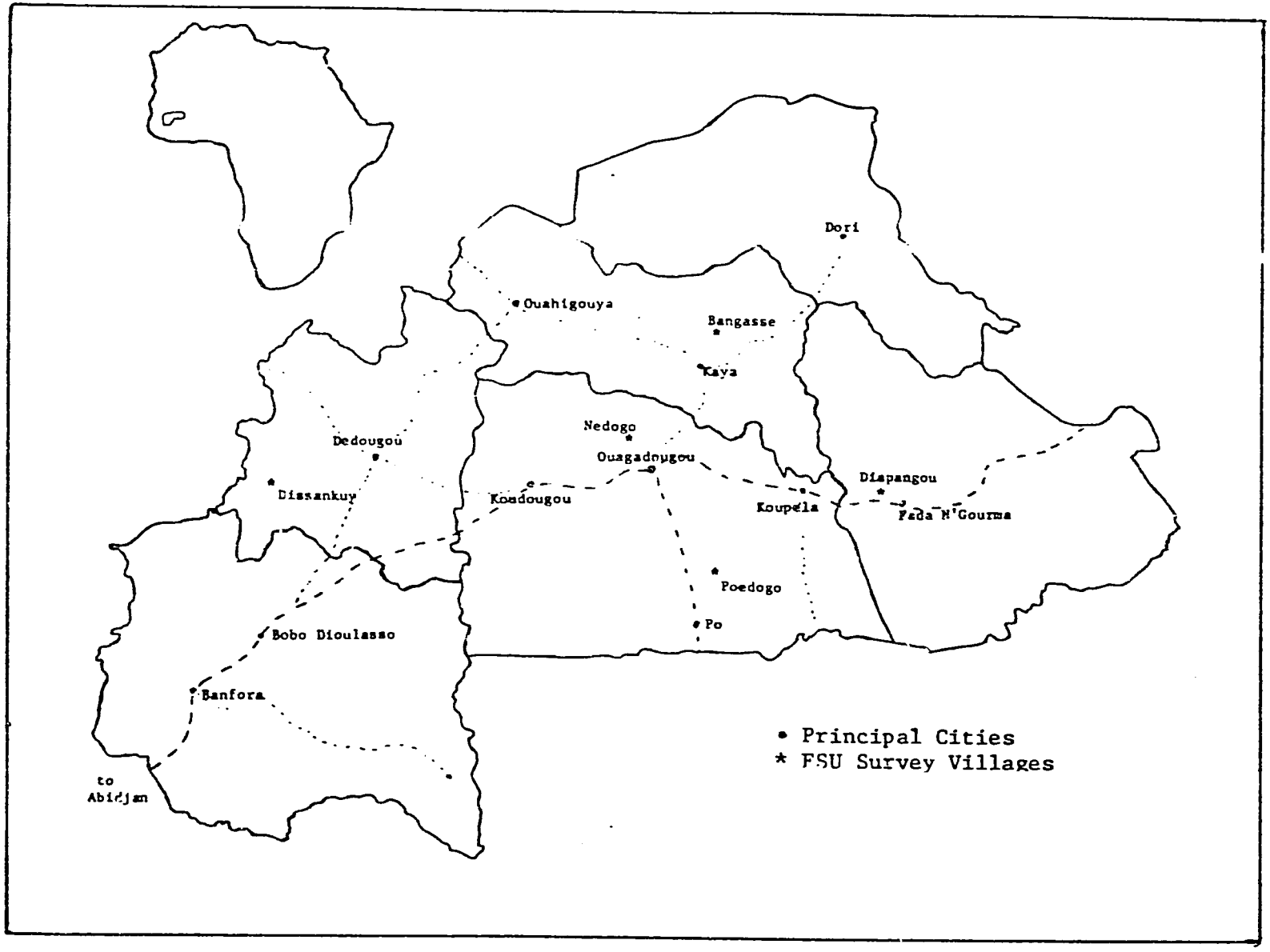

Figure 1: Map of Burkina Faso

The trial was conducted with 25 replications each in Bangasse and Nedogo. The results showed statistically significant yield increases in both villages but only for treatment 82. In neither case were the results economically promising (FSU Annual Report 1983).

The sorghum trial included four treatments. These were: 1) traditional tillage (treatment 87), 2) tied ridges only (treatment 88), 3) NPK 12-25-12 (100 kg./ha.) and urea (50 kg./ha.) applied as side dressings (treatment 89), and 4) tied ridges with fertilizer as in treatment 89 (treatment 90).

These trials were conducted in all three villages under as many as 3 tillage types with 25 replications in each case. These included manual tillage in Bangasse, manual and donkey tillage in Nedogo and manual, donkey and ox tillage in Diapangou. With two exceptions, manual tillage in Bangasse and Nedogo, all treatments in all trials showed statistically significant yield increases. Of these, all, particularly treatment 90, were economically promising (Annual Report 1983).

The maize trial included two treatments. Treatment 85 was traditional tillage and treatment 86 used tied ridges. Treatment 86 showed statistically significant yield increases in all locations. Further, the off-farm opportunity cost of labor was easily covered by the market value of yield increases.

Results of Adaptability Analysis

For each treatment in each trial, treatment yields were regressed on mean treatment yields. The results of these regressions are presented in Tables 1 through 5.

Tables 1 and 2 present results for the millet trial. Of 15 coefficients, only two differ significantly from 1 at the .05 level of

TABLE 1

REGRESSIONS OF TREATMENT YIELDS ON MEAN TREATMENT YIELDS MTY), FARMER-MANAGED MILLET TRIALS USING HAND TILLAGE, 1983 (STANDARD ERRORS IN PARENTHESES).

Village	Equation	R^{-2}	n
Bangasse	Y80 = -44.6 + 1.09 MTY (51) (.232)	.68	11
Bangasse	Y81 = -28 + 1.39 MTY (98) (.445)	.47	11
Bangasse	Y82 = 35.3 + 1.06 MTY (57) (.26)	.61	11
Bangasse	Y83 = -22.7 + .878 MTY (63.4) (.288)	.45	11
Bangasse	Y84 = 59.88 + .574 MTY (43.5) (.198)	.43	11
Nedogo	Y80 = 55.74 + .822 MTY# (27.4) (.069)	.95	8
Nedogo	Y81 = -41.36 + 1.137 MTY (31.87) (.081)	.97	8
Nedogo	Y82 = 59.24 + 1.22 MTY* (41.8) (.105)	.95	8
Nedogo	Y83 = 67.9 + .746 MTY (73.5) (.185)	.68	8
Nedogo	Y84 = -36.77 + 1.06 MTY (29.3) (.074)	.68	8

#Coefficient significantly less than 1 at the .05 level.
*Coefficient significantly greater than 1 at the .05 level.

TABLE 2

REGRESSIONS OF TREATMENT YIELDS ON MEAN TREATMENT YIELDS (MTY), FARMER-MANAGED MILLET TRIALS USING ANIMAL TRACTION, 1983 STANDARD ERRORS IN PARENTHESES).

Village	Equation	R^{-2}	n
Nedogo	Y80 = -75.6 + 1.084 MTY (79.9) (.195)	.79	9
Nedogo	Y81 = 76.11 + 1.21 MTY (45.74) (.111)	.94	9
Nedogo	Y82 = 137.11 + .814 MTY (72.74) (.177)	.72	9
Nedogo	Y83 = 78.32 + .785 MTY (46.8) (.114)	.85	9
Nedogo	Y84 = 62.49 + 1.099 MTY (42.6) (.104)	.93	9

significance. The 13 coefficients that do not differ significantly from 1 indicate that the results of corresponding t-tests are generalizable across these farmers and comparable regions given the level of rainfall observed during the 1983 cropping season.

One coefficient (traditional technology for the hand tillage sample in Nedogo) is significantly less than 1. This result is unsurprising in that one would expect a traditional technology to perform better relative to improved technologies as the environmental index goes down. This is what is implied by a coefficient significantly lower than 1.

Another coefficient (treatment 82) is significantly greater than 1. This implies that the technology which involves both water conservation and fertilizer application responds better to an improved environment than do the other treatments. While mean differences in this treatment and others do not indicate economic promise, the adaptability analysis indicates that better environments strongly favor this technology. In fact, inspection of trial data show that the yield results are highly skewed such that a small group of farmers may find the treatment economically promising.

Tables 3 and 4 present the results of adaptability analysis as applied to the sorghum trials. Of 22 treatments analyzed, 18 coefficients do not differ from 1 at the .05 level of significance. The latter results suggest that the trial results are generalizable within these and comparable zones.

Of the four treatments for which the adaptability coefficient differs significantly from 1, two are lower than 1. These, as was the case with the millet trials, are for traditional tillage control treatments. Two of the coefficients were significantly greater than 1. In these cases, treatments of fertilizer (Diapangou-donkey tillage) or fertilizer and tied ridges (Bangasse-hand tillage) were involved. In effect, these findings both

TABLE 4

REGRESSIONS OF TREATMENT YIELDS ON MEAN TREATMENT YIELDS (MTY), FARMER-MANAGED SORGHUM TRIALS USING ANIMAL TRACTION, 1983. (STANDARD ERRORS IN PARENTHESES).

Village	Tillage	Equation	R^{-2}	n
Nedogo	Donkey	Y87 = -16.8 + .618 MTY# (121.9) (.167)	.57	11
Nedogo	Donkey	Y88 = 41.9 + .815 MTY (100) (.133)	.78	11
Nedogo	Donkey	Y89 = -72.4 + 1.15 MTY (110) (.147)	.85	11
Nedogo	Donkey	Y90 = 46.1 + 1.42 MTY (157) (.21)	.82	11
Diapangou	Donkey	Y87 = -140.6 +.906 MTY (67.6) (.094)	.79	25
Diapangou	Donkey	Y88 = 139.2 + .602 MTY# (61.3) (.085)	.67	25
Diapangou	Donkey	Y89 = -87.9 + 1.35 MTY* (91.6) (.128)	.82	25
Diapangou	Donkey	Y90 = 89.6 + 1.14 MTY (94) (.131)	.76	25
Diapangou	Oxen	Y87 = -20.78 + .741 MTY (158.6) (.21)	.32	25
Diapangou	Oxen	Y88 = 87.0 + .665 MTY (139.7) (.185)	.33	25
Diapangou	Oxen	Y89 = -32.78 + 1.205 MTY (133.1) (.176)	.65	25
Diapangou	Oxen	Y90 = -34.75 + 1.39 MTY (155) (.205)	.65	25

Coefficient significantly less than 1 at .05 level.
* Coefficient significantly greater than 1 at .05 level.

TABLE 5

REGRESSIONS OF TREATMENT YIELDS ON MEAN TREATMENT YIELDS (MTY), FARMER-MANAGED MAIZE TRIALS, 1983. (STANDARD ERRORS IN PARENTHESES).

Village	Tillage	Equation	R^{-2}	n
Bangasse	Manual	Y85 = 30.15 + .659 MTY# (50.51) (.117)	.75	11
Bangasse	Manual	Y86 = -30.81 + 1.34 MTY* (50.56) (.117)	.92	11
Diapangou	Manual	Y85 = 26.08 + .873 MTY# (99.6) (.061)	.90	23
Diapangou	Manual	Y86 = -26.4 + 1.127 MTY* (99.5) (.061)	.94	23
Nedogo	Manual	Y85 = -2.88 + .864 MTY (126) (.115)	.68	25
Nedogo	Manual	Y86 = +2.88 + 1.126 MTY (120) (.113)	.80	25
Diapangou	Donkey/Ox	Y85 = 217 + .71 MTY# (99.9) (.064)	.85	22
Diapangou	Donkey/Ox	Y86 = -217 + 1.29 MTY* (100 (.064)	.95	22

Coefficient significantly less than 1 at .05 level.
* Coefficient significantly greater than 1 at .05 level.

indicate that the treatments will respond better relative to other treatments as the environment improves. The trial results are consistent with these implications, showing that the yield increments achieved with these treatments increase as one moves from hand tillage in Bangasse to better agroclimatic environments and from donkey tillage to Ox traction in Diapangou.

Table 5 presents the results of the same analysis on maize trials. In this case, 6 of 8 adaptability coefficients differ significantly from 1 at the .05 level. In three cases, the traditional treatment coefficient is significantly lower than one. In the other three cases, the tied ridge treatment coefficient is significantly greater than 1. These results strongly suggest increasing returns to improvements in the environment where tied ridges are applied to compound maize fields.

Conclusions

The results of adaptability analysis as applied to the 1983 FSU trials indicate that, in general, the conclusions based on paired t-tests are generalizable to the zones in which the trials were conducted. Nevertheless, analysis of certain trials showed adaptability coefficients that are significant at the .05 level. Where these results include coefficients significantly greater than 1, they suggest that the trial results are not necessarily generalizable for farmers to farms with low environmental indices, but may offer more promise for farms on which fertility, soil structure and management skills are higher than average for the sample.

In general the results show relatively high, if not significant, coefficients for most treatments including applications of fertilizer. This

indicates that these treatments tend to have an interaction effect with the soil characteristics or management practices in the "better environments". A further generalization is that treatments with the highest adaptability coefficients tend to be the same treatments as those with the highest yield increments in a given trial. This indicates that a treatment with a significant yield increase which is not economically promising for the sample may be promising in a more desireable environment.

Implications

Much on farm research in Burkina-Faso and other western African countries implicitly assumes that farmers and farms are homogeneous. As a result, agronomic research is designed for the "average" farmer and agro-economic evaluations of trials are conducted with that farmer in mind. The findings of this analysis indicate that agronomic and economic research should begin to identify the characteristics of farms which differentiate them in terms of the "environmental index." As used in this analysis, the index is a "catch-all" proxy for factors which favor a given technology. Researchers would do well to identify the factors which differentiate farms in terms of this index if adaptability analysis indicates that the effect of the index on treatment yield is significant. Such efforts would be useful in at least three ways.

First, by differentiating the farms, researchers would create a basis for defining "recommendation domains". These could be used for further trials and may show that a treatment not promising for some farmers would be promising for others.

Second, if differentiation shows that soil characteristics explain differences in treatment response among farmers, researchers would acquire information useful in the design of future trials.

Third, if differentiation of farms shows that management practices of farmers explain differences in treatment responses, this information would be useful to extension personnel in the identification of desireable management practices and of farmer leaders for use in efforts by extension personnel to facilitate increased food production.

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