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Modified Stability Analysis of Farmer Managed, On-Farm Trials[1]

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ABSTRACT

The Farming Systems Research and Extension (FSR/E) approach to technology generation and promotion is creating interest in on-farm research. Described is a form of research design and analysis that explicitly incorporates variation in farmer management as well as in soils and climate, to help agronomists evaluate responses to treatments and partition farmers into recommendation domains. Mean treatment yields at each location are used as an "environmental index." Individual treatment results are regressed on environmental index. A graphic distribution of confidence intervals within partitioned groups helps in selecting superior treatments. Data from unreplicated trials on 14 farms in two villages in Malawi were analyzed. The design was a 2 × 2 factorial with two maize (*Zea mays* L.) cultivars and two fertilizer treatments (0 and 30 kg N/ha). Results show that in poorer maize environments, local flint cultivars were superior to an improved semi-flint composite, with or without fertilizer. The composite yielded more than local material with or without fertilizer in better environments. In all cases there was a marked and significant response to fertilizer.

Additional index words: Farming systems, Limited resource farmers, Maize, Malawi, Environmental index, Recommendation domains, Small-scale farms.

In recent years, there has been increasing concern that agricultural technology has not been adequately benefiting the world's small-scale farmers. One argument is that extension has been ineffective in reaching the millions of people involved. Another argument is that small-scale farmers are so traditional they do not want to change their habits, thus they reject most attempts to change their technology. Another concern has been that research and extension institutions are producing technology not appropriate to the conditions of small-scale farmers.

In partial response to this last argument, a new approach to research and extension has been developing (Whyte, 1981). Although several terms are used to describe the approach, perhaps the most descriptive, and one which is becoming more generalized, is known as Farming Systems Research and Extension (FSR/E). The approach includes, as part of the methodology, evaluation of technological alternatives on farms, under farm conditions (Byerlee et al., 1982).

The purpose and strength of on-farm testing is to assess the effect of clientele management and their resource quantities and qualities on the technology. This provides an opportunity, when appropriate analytical procedures are used, to partition the clientele into more homogeneous groups for purposes of making recommendations. In FSR/E, these homogeneous groups are called Recommendation Domains (Byerlee et al., 1980). The topic of this article is the researcher's use of data from a number of farms to understand the response of different materials or technologies under both good and poor farmer management.

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MATERIALS AND METHODS

Modified Stability Analysis of Farmer Managed Trials

"An index independent of the experimental varieties and obtained from environmental factors such as rainfall, temperature, and soil fertility would be desirable. Our present knowledge of the relationship of these factors and yield does not permit the computation of such an index. Until we can measure such factors in order to formulate a mathematical relation with yield, the average yield of the varieties in a particular environment must suffice. However, the varieties must be grown in an adequate number of environments covering the full range of possible environmental conditions if the stability parameters are to provide useful information." (Eberhart and Russell, 1966, p.37).

Eberhart and Russell utilized mean varietal yields at each location in a multi-location trial to define stability parameters to be used to describe the performance of a variety over a series of environments. MacKenzie et al. (1976) used location means of both potato (*Solanum tuberosum* L.) processing quality characteristics and yield for predictive purposes. Expanding on this concept by including farmer management as one of the sources of variation in results (as did MacKenzie et al., 1976), farmer managed tests can be analyzed without expanding data processing requirements beyond the capabilities of institutions in developing countries. The explicit incorporation of different environments, while not negating year to year variation, should reduce concern with that variation so that needed recommendations can be delivered to the farmers in as short a time as possible. By including a wide range of farm environments, the risk of extrapolation is minimized.

To understand the concept, consider farmer-managed trials conducted over a large number of farms within one preliminary recommendation domain and utilizing two types of materials. One is an improved cultivar and the other, a local variety. No other changes are made from the farmer's usual practices. The only constant at each location (farm) is the cultivars. Each farmer will subject them to different soil conditions, planting dates, pest control, fertilizer, and management in general. A farm for which the average yields of the two cultivars is high for whatever reason is considered to be a "good" environment for the crop as measured by the average yield. A farm for which yields are low for whatever reason is considered to be a poor environment. Environment, then becomes a continuous, quantifiable variable whose range is the range of average yields. Yield for each of the varieties can be related to environment by simple linear regression:

$$Y_i = a + be, \qquad [1]$$

where Y_i = yield of variety i, and
e = environmental index equal to the average yield of all treatments at each location.

By fitting Eq. [1] independently for each variety, then plotting the yield response to environment for each variety on the same graph, it is possible to visually compare varieties. Using the same procedure it is easy to generalize these equation sets to any number and kind of treatments.

A Farmer-Managed, On-farm Trial in Malawi

The Phalombe Project is located in southeastern Malawi between Mount Mulanje to the south and Lake Chilwa to

the north (Hansen et al., 1982). Much of the area is a colluvial plain at an altitude of 600 to 700 m. More fertile and well-drained piedmont soils surround the mountains and hills, while the plain is variable in drainage and soil texture (course sands to heavy clays). To the north and northwest the plain slopes down to Lake Chilwa and the Phalombe River which drains into the lake. Heavy clay soils in these lower areas are seasonably or permanently waterlogged. Unreliable rainfall is a major constraint to agricultural production and stability. Rainfall varies from place to place within the project with higher levels (1000 to 1300 mm annually) east of Mount Mulanje where agriculture is more secure and lower levels in the central section and along the western and northern sections.

Climatic stress is compounded by erratic distribution during the rainy season, especially by the prevalence of February dry spells when the maize (*Zea mays* L.) ears are forming (Hansen et al., p.6).

Fourteen farmers from two villages participated in trials which were conducted on their respective farms. A simple, non-replicated 2 × 2 factorial arrangement with two maize varieties and two levels of fertilizer (0 and 30 kg N/ha) was used. All maize was intercropped with cowpeas (*Vigna unguiculata*) and sunflowers (*Helianthus annus* L.), a common practice in the area. Maize varieties tested were the "local" flint variety and CCA, an improved semi-flint composite. Plot size was eight rows (90 cm apart) by 10 hills (90 cm apart). Maize was planted at the rate of three seeds per hill and the cowpea was widely dispersed. Sunflower was planted after maize was established (Hansen et al., 1982 p.14–15).

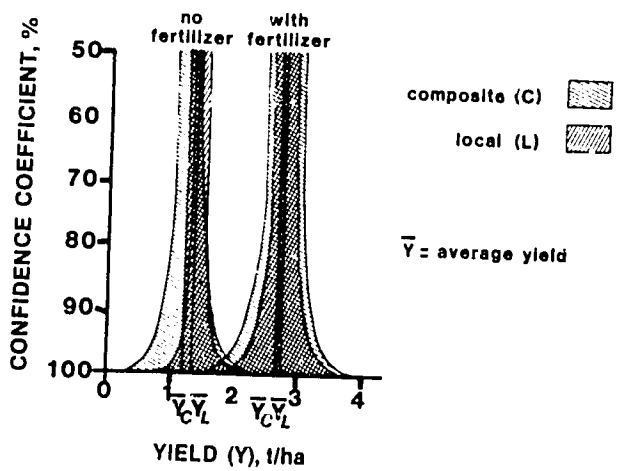

Fig. 1 Distribution of confidence intervals for grain yield of local and CCA composite maize.

Only maize yields are reported in this paper. Weekly visits were made to each farm to record dates of planting, weeding, fertilizer application, rainfall, pests, etc. An early drought forced replanting after 1 month in one village. Insecticide was applied once even though insecticide use is not a common practice in the area.

RESULTS

The data for the Phalombe Project area, Table 1, were analyzed by Hansen et al. (1982). Analysis of variance showed significant differences among farmers and between villages, but no differences were detected for variety. A graphed distribution of confidence intervals ($\bar{x} \pm t_a s_{\bar{x}}$) of the combined results of the 14 trials (Fig. 1) shows that the local variety had a higher average yield and more stability (narrower confidence intervals) for both fertilizer situations. Conclusions based on this evidence would indicate no advantage for the improved composite in this area, but a distinct response to fertilizer. These are similar to the conclusions from the analysis of variance.

In the present analysis, the data for each fertilizer level and for each variety were fit to Eq. [1] by simple linear regression. This can be accomplished easily, on simple, pre-programmed electronic calculators. The equations and the data points can be displayed graphically for visual comparisons. The results from the Phalombe Project are shown in Fig. 2 and 3. In each

Table 1. Maize yield from farmer-managed, on-farm trials, Phalombe, Malawi, 1981/1982.

Treatments	Farmers, first village 1	2	3	4	5	6	7	8	Treatment mean for village
	t/ha								
Local maize (LM)	2.2	2.2	1.9	1.2	1.3	0.9	1.0	0.5	1.4
Fertilizer local (LM-F)	3.6	3.7	4.3	3.2	2.3	2.3	3.1	2.8	3.2
CCA Maize (CCA)	3.5	2.0	2.9	0.4	0.6	0.5	0.6	0.3	1.3
Fertilizer CCA (CCA-F)	5.0	4.7	4.3	3.5	2.4	1.7	3.0	2.8	3.4
Mean for farmer	3.6	3.2	3.3	2.1	1.7	1.3	1.9	1.6	2.3
	Farmers, second village 1	2	3	4	5	6			
Local maize (LM)	1.8	1.1	1.6	1.0	1.6	0.6			1.3
Fertilizer local (LM-F)	3.2	2.5	2.9	1.2	1.9	0.8			2.1
CCA Maize	2.2	0.7	0.9	0.3	1.1	0.3			0.9
Fertilizer CCA (CCA-F)	2.9	2.5	2.1	1.1	0.8	0.4			1.6
Mean for farmer	2.5	1.7	1.9	0.9	1.4	0.5			1.5

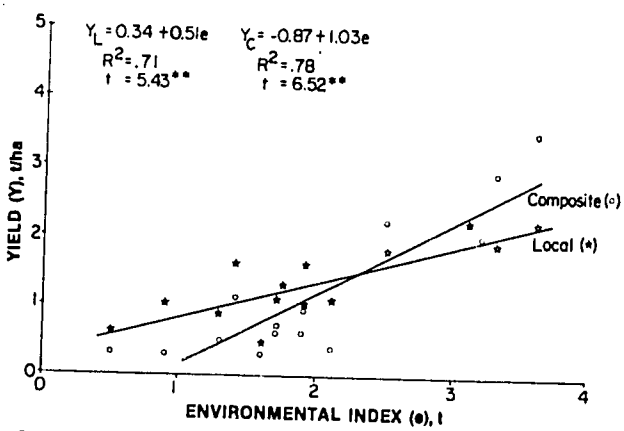

Fig. 2 Grain yield response for local maize (L) and CCA composite (C) to environment, without fertilizer, Phalombe Project, Malawi.

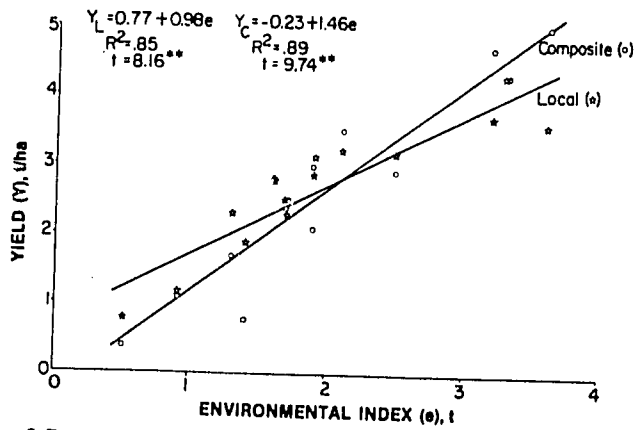

Fig. 3 Response of local maize (L) and CCA composite (C) to environment, with fertilizer, Phalombe Project, Malawi.

case, the R^2 value (the proportion of the variation in yield accounted for by regression) indicates a very good fit and the "t" and F values are highly significant, indicating positive responses to environment for each variety with and without fertilizer. It appears that the materials respond differently to environment and that the local material is superior in poor maize environments while the improved material is superior in good maize environments.

This analysis provides information for partitioning the farms into two recommendation domains and for making preliminary conclusions for each. In the poorer environments (e<2), those which normally do not produce more than 1.5 t/ha of local maize without fertilizer (the traditional technology), the local material is superior whether or not the farmer fertilized at the rate used in the trial. However, if local, unfertilized maize usually yields more than 1.5 t/ha on a particular field or for a particular farmer (the better maize environments with e>2), the new material is superior whether or not it is fertilized at the rate used in the trial.

Having partitioned the farms into two recommendation domains, Fig. 4 shows the frequency distribution of yields for the nine poorer environment farms (e<2). Here, it is clearly evident that with fertilizer, local maize is superior in yield, but the difference from composite is not so marked as without fertilizer. The case of the good environment farms (e>2) in the second recommendation domain is different (Fig. 5). Here, with or without fertilizer, the improved cultivar yields more than the local maize. The difference is greater with fertilizer than without. Results for the better environments, which indicate superiority for the composite material, probably reflect the superior environment found on the experiment station where the

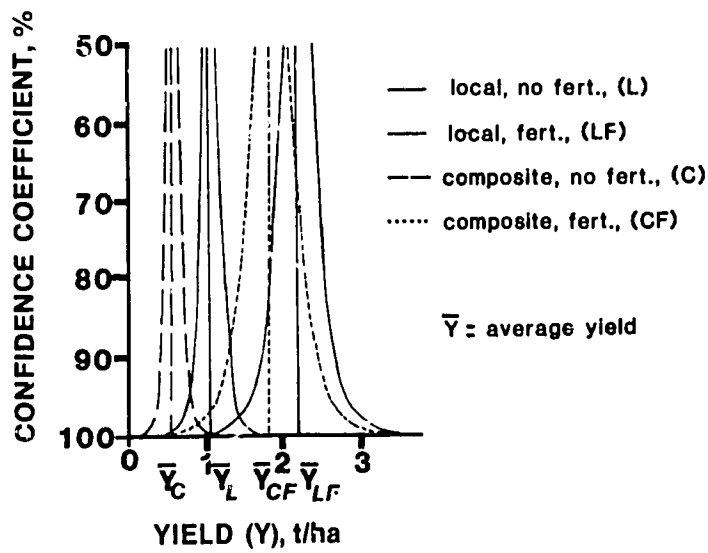

Fig. 4 Distribution of confidence intervals for grain yield of local and CCA composite maize, Phalombe Project, Malawi. Low environment—nine farms where average yield (Y) less than 2 t/ha.

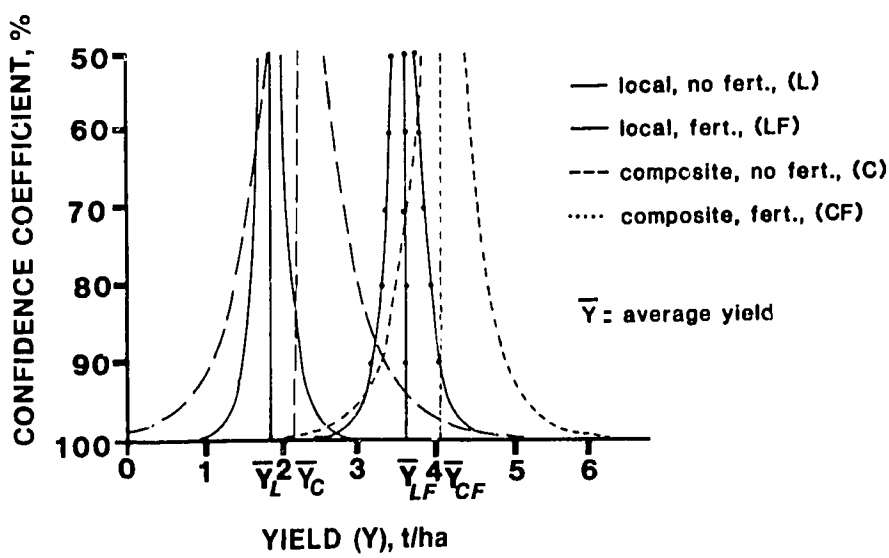

Fig. 5 Distribution of confidence intervals for grain yield of local and CCA composite maize, Phalombe Project, Malawi. High environments—five farms where average yield (Y) greater than 2 t/ha.

material was developed. The danger of extrapolating from the better environment of the experiment station to the poorer environments of the majority of farms is evident from the results of the analysis.

DISCUSSION

Although results from 2 or more years would be preferable, use of the environmental index negates many of the problems associated with only 1 year's data. It measures response to good or poor environments regardless of the reasons those environments are good or bad. Hence, if another year is better or worse for maize, the data points for an individual farm will shift to the right or left, but a "3" environment is still a "3" environment if the same treatments are used. Only if the usual environmental index range is much higher or lower or the range of the index very narrow so that extrapolation is extreme, should there be concern with the use of data from only 1 year.

In the Phalombe case, the local variety, unfertilized, could be compared with usual yields to determine how representative the environmental range was for that year. It is important to include low, as well as high yields in the data set to reduce extrapolation. When the data set represents only a particularly high yield situation (such as is frequently encountered on experiment stations) or when low yields are eliminated from the data (which frequently occurs) extrapolation to real farm conditions can be misleading. By including all the data from farmer-managed trials, affected by all the farmers good and bad practices, the data set does not need the usual yield adjustment from experimental to farm levels.

The use of 14 locations, as with the Phalombe data, is probably approaching the minimum number for accurate estimation of treatment differences over environments, and these should span a wide range of environments (L.A. Nelson, Division of Statistics, North Carolina State Univ., personal communication). Eight to 10 locations is probably too few. It is also better, although more costly, to have replicated trials because there is an internal check to see if there might be anything wrong with the data. Also, this gives more stability to the estimate of the treatment means (L.A. Nelson, personal communication). However, the method does work with unreplicated trials as is evidenced in the present case.

Research to evaluate technology conducted on farms and under farmer management provides a unique means of assessing the effect of farm differences which arise from social, cultural, and economic factors as well as from soils and climatic influences. Traditional research procedures lead to the control or minimization of such differences in order for effects of the technological variables to be more emphatic. But this control masks many of the real factors which affect the productivity of the technology being tested. Use of the average yield of all treatments on each farm as an environmental index, which reflects all the good and bad that will be found on the farms when the technology is adopted, is an efficient and simple means of assessing technology before it is incorporated in a massive extension effort. This process can help partition the clientele into recommendation domains, providing a more precise definition of potential adopters. Recommendation domains make extension efforts more effective and help guide researchers to provide improved technology, better adapted to specific agrosocioeconomic conditions.

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