REVIEW OF MARKETING AND AGRICULTURAL ECONOMICS
Vol. 45, No. 3 (*September*, 1977)

SPATIAL *v*. TIME-SERIES DATA FOR ASSESSING RESPONSE RISK

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A small case study of published data on response of dryland wheat to nitrogen fertilizer reveals that replication over space apparently substitutes rather poorly for replication over time, in estimating variance of yield conditional on level of fertilizer.

1 INTRODUCTION

Several alternative methodologies have been advanced and used for measuring various features (especially the mean and variance) of probability distributions of field crop yields. Attention has been concentrated on the effects induced by fertilizers (e.g., in the studies described in [1, 5, 6, 7, 8]) and this tradition is maintained in what follows.

Confronted by a scarcity of the multiseason (time-series) fertilizer experiments on which these studies are inevitably based, analysts may be tempted to follow the lead of plant breeders and to substitute replication over space (perhaps over just a year or two) for the intrinsically slow process of replication over time (e.g., [3, pp. 148–9]). There are several questions that obviously influence the feasibility and desirability of such substitution; for example, can an analytical approach be used wherein the effects of uncertain factors are explicitly modelled? Is year-to-year variation analogous to site-to-site variation across some defined region?

While the answers to these and the many related questions seem presently indeterminate or at least very uncertain, it might be helpful to have some indication of the possibilities for spatial (cross-sectional) data substitution of time series data in risky response analysis. Accordingly, a small case study was addressed to the problem.

2 DATA AND METHODOLOGY

A selection of data involving wheat yields measured at four levels of nitrogen fertilizer was made from those reported in [12]. The main comparison was between a time series of five trials (over 1956–61 excluding 1959) at Roseworthy Agricultural College (RAC) and a spatial series of

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trials at nine locations[1] in 1960. Choice of this particular comparison was based first on the homogeneity of the nine spatial locations. All nine sites occur on solonized brown sandy loam soils and receive a similar average rainfall. RAC is also one of the spatial sites. Choice of RAC as the time-series site was arbitrary. Subsequently, time-series and cross-sectional estimations are denoted by *T* and *C* respectively.

Differing methodologies have been used for estimating moments of yield distributions and so it was judged to be appropriate to superimpose a methodological comparison on the comparison of data sources. Several moments were estimated but for brevity attention is focused on variance of yield with only minor mention of mean yields. Variance is but one (albeit most imperfect [4, 11]) measure of risk.

The traditional method of estimating population means and variances is through the unbiased classical sample estimators, $\bar{Y} = \Sigma Y_i/n$ and $\sigma^2 = \Sigma[Y_i - \bar{Y}]^2/n - 1$ when $Y_1, Y_2, \ldots, Y_n$ are here observations at some specified level of nitrogen at, for example, either n sites in one year or n years at one site. Such estimators are subsequently denoted by *U* (for unbiased).

An alternative method, advocated for data situations described as sparse [3], is to smooth the data by ranking the Y_is into ascending order and plotting them with the k-th as an estimate of the $k/(n + 1)$ fractile. A smooth distribution function can then be sketched through these points. Mean and variance can then be estimated in several ways of which the simplest is to read specified fractiles, denoted by f and compute [9, 10] as $\bar{Y}_f = f_{\cdot 5} + 0.185[f_{\cdot 05} + f_{\cdot 95} - 2f_{\cdot 5}]$, $\hat{\sigma}_f^2 = [(f_{\cdot 95} - f_{\cdot 05})/3.25]^2$. Estimations of this type are denoted by *S* (for smoothed).

In his exemplification of the above smoothing procedure, Anderson [1] found it necessary to use predicted responses based on response functions fitted to data for each year of a trial because different fertilizer levels had been used from year to year. This can be thought of as involving an additional smoothing of the data. Estimations of this type are subsequently denoted by *P* (for smoothed predicted).

3 RESULTS AND DISCUSSION

A difficulty in using real-world data is that the true population parameters are unknown and there is no ultimate reference against which alternatives can be judged. This difficulty is not met in Monte Carlo studies with sampling from populations with specified known parameters [2].

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[1] The locations were Wanbi, Minnipa, Turretfield, RAC, Gulnare, Parafield, Taragoro, Gladstone and Ungerra (Maitland excluded). The 1959 year and the Maitland site were excluded to maintain homogeneity. Rainfall in that year was much the lowest recorded from 1956 to 1973 (134.1 mm compared with a mean of 300 mm). Maitland, situated on York Peninsula with a maritime influence, receives a rather higher average rainfall compared with the sites included in the spatial set. Additional results and economic analysis of the risky response are provided in [13].

The first result was rather null and for brevity is not elaborated. This was the finding that mean yield response did not vary markedly with respect to estimation method and varied only in level and not in curvature with respect to data source. An alternative expression of this result is that marginal expected product can be estimated equivalently (at least in this case) from either time-series or cross-sectional data and by any of the estimational approaches used here.

The second set of results concerns variance response and is reported in a summary/graphical form in figure 1.

If we take the view (expressed in [1]) that the measure of variance most appropriate to individual decision makers is that faced from year to year, then the time-series (*T*) results serve as the better reference type. Thus the results in figure 1 suggest to us that, in our very restricted case study, the cross-sectional or spatially replicated data in just one (typical) year overestimate the risk involved in wheat growing and in use of nitrogenous fertilizer. They also tend to estimate somewhat different patterns of marginal risk (rate of change of variance with respect to changing nitrogen level) although this tendency is not at all well established because all the marginal risks in figure 1 are rather low cf [1, 5, 6].

The results concerning methodology are less clear-cut but fortunately do not influence crucially the above results on sources of data. The unbiased (*U*) and smoothed (*S*) estimations are somewhat different (within and between data-source groups) in estimating the level of yield variance. However, within each data-source group, the marginal risk effects appear similar (it is the marginal risk effects that will most influence risk-averse producers' use of fertilizer [1, 4]). The pattern of results for the smoothed predictions (*P*) is a less reassuring finding. This method has produced variance response curves that are more irregular than those from the other methods and thus it seems that it should be resorted to only when it cannot be avoided.

4 CONCLUSION

As it must, risk analysis remains an intrinsically risky business. This is especially so when empirical data are used to seek enlightenment. Many problems can be avoided by taking the more purely subjective approach of eliciting decision-makers' personal probability distributions [4]. However, when analysts seek experimental or other observational data on yield variances, we suggest that they may do best to concentrate their efforts on time-series data for narrowly defined regions rather than to take the seemingly easier way out of short-period data from widely dispersed locations.

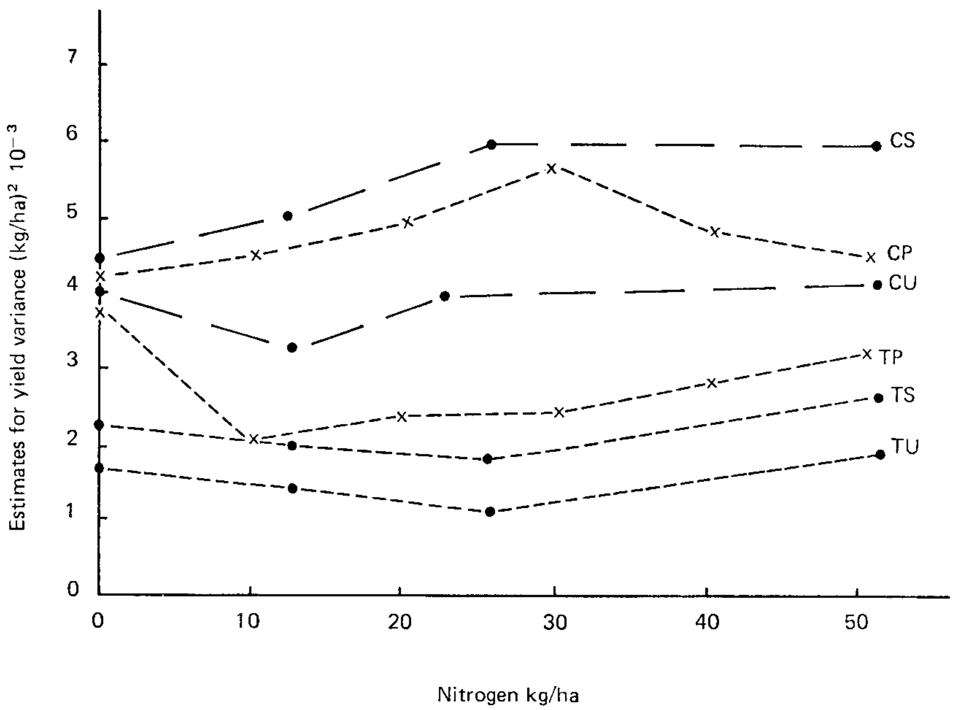

Figure 1: *Alternative estimates of yield variance related to level of nitrogen fertilizer. (T = time-series data, C = cross-sectional data, U = unbiased estimate, S = smoothed estimate, P = smoothed estimate of predictions from individual year response functions).*

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