Agricultural Economics, 7 (1992) 289–299
Elsevier Science Publishers B.V., Amsterdam

Application of stochastic dominance criteria to evaluate bean production strategies in Central Province, Zambia

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(Accepted 26 November 1991)

ABSTRACT

Bezuneh, M., 1992. Application of stochastic dominance criteria to evaluate bean production strategies in Central Province, Zambia. *Agric. Econ.*, 7: 289–299.

Beans are the most important relish crop in the farming systems of Serenje District in Central Province, Zambia. Both leaves and dried beans are major food sources for home consumption, and dried beans have a commercial value in the system. Given this dual role, increasing bean yields would improve family nutrition as well as economic returns to capital and labor invested. However, low levels of production have been recorded over the years due to the use of local bean varieties, low fertility, and inadequate pest control. As a result, on-farm research on beans was carried out for four years to identify bean varieties and management strategies that would result in higher yields and economic returns.

In this paper, the results of the four years on-farm research were analyzed using stochastic dominance efficiency criteria in order to determine the most risk-efficient production management strategies. The result indicated that the Brazilian bean variety Carioca, when used in combination with fertilizer and insecticide, performed best for the traditional and small-scale farmers in Serenje District who are usually highly averse to risk.

INTRODUCTION

Beans are the most important relish crop in the farming systems of Serenje District in Central Province, Zambia (Fig. 1). Both leaves and dried

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The on-farm research of this study was funded jointly by USAID and Government of Zambia under the Zambia Agricultural Research and Extension Project (ZAMARE) of Univ. Illinois, under agreement number 611-0201.

0169-5150/92/$05.00

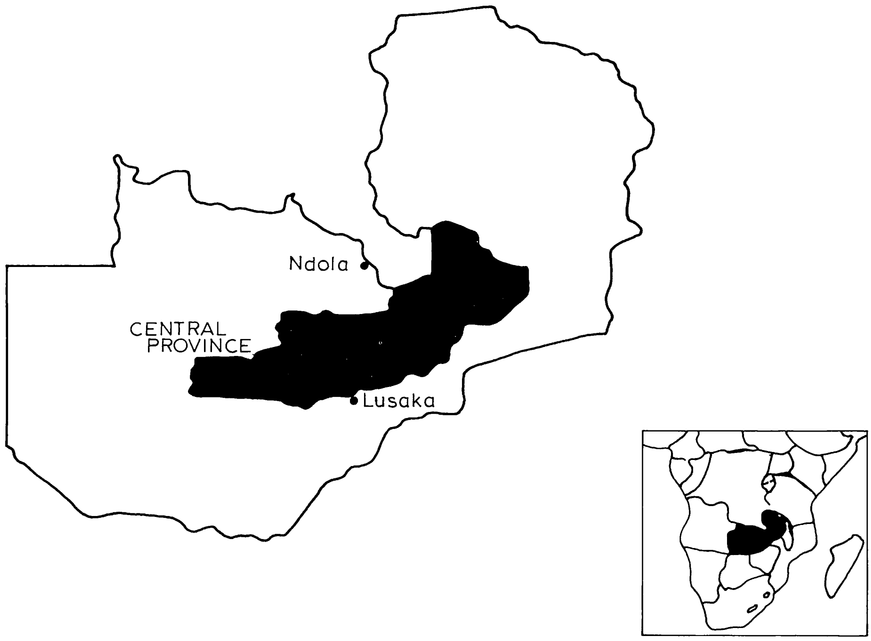

Fig. 1. Location of central Province, Zambia.

beans are major food sources for home consumption, and dried beans have a commercial value in the system (Bezuneh and Olsen, 1990a). Given this dual role, increasing bean yields would improve family nutrition as well as economic returns to capital and labor invested. However, in this system, the level of production is very low and is not even sufficient to meet home consumption. The low yield local bean varieties and pest infestation (bean stemfly) are major contributing factors to low yields realized by farmers (CIMMYT, 1978; ARPT-CP, 1982, 1986).

The Adaptive Research Planning Team of Central Province (ARPT-CP), using the farming systems research and extension methodology, identified bean on-farm research as an important 'leverage' area in the Serenje farming systems, Traditional Recommendation Domain #2 (Fig. 2). As a result, ARPT-CP carried out on-farm research on beans for four years (1984/85–1987/88) to identify bean varieties and management strategies that would result in higher yields and economic returns with relatively less variation.

This paper analyzes the four years on-farm research in order to determine the most risk efficient management strategies in the bean enterprise for farmer's adoption. More specifically, the objective of this study is to investigate and compare the variability in net returns due to different bean

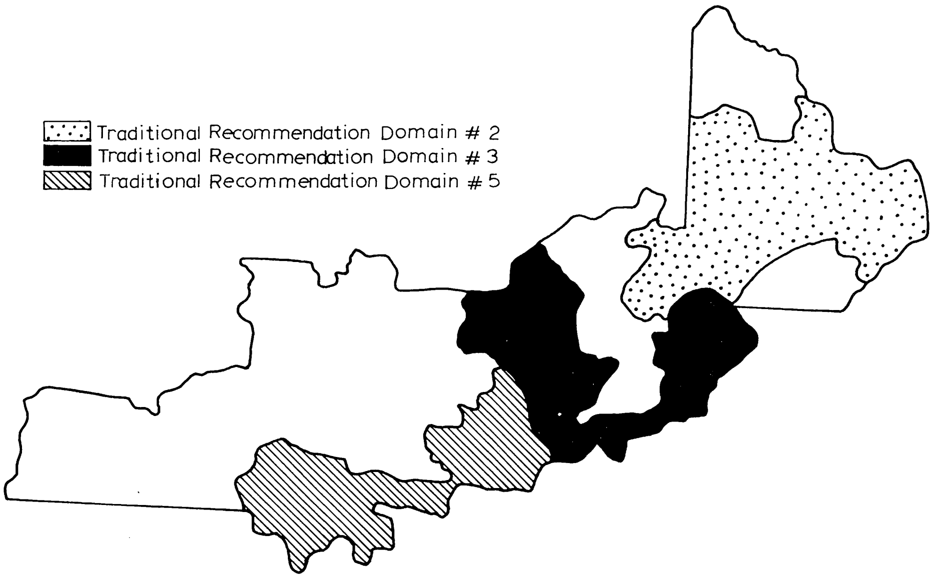

Fig. 2. Location of target farmers in Serenje District (TRD #2), Central Province.

varieties, and other management strategies, such as with and without fertilizer and insecticide.

The results of the analysis should be applicable to traditional and small scale farmers in other Eastern and Southern African countries with similar farming systems environment, and ought to serve as a lesson for those countries/or regions in Africa that are currently utilizing farming systems methodology for the purpose of developing crop technology for resource poor farmers.

STUDY AREA AND THE ON-FARM RESEARCH

In common with all other small-traditional farmers, two important objectives guide farmers' management behavior in bean production in Serenje District. First is procuring an adequate supply of beans for home consumption as a relish. Second, having met this objective, is maximizing cash-income from their bean farming operation.

The Serenje farming system is best characterized by:

(1) traditional small-scale farm households with hand hoe and family labor as the dominant source of power for cultivation;
(2) production for home consumption is the primary objective;
(3) despite unlimited cultivable land, only less than 5 ha per farm household are under cultivation;

(4) limited cash capital with minimum participation in both product and input markets; and
(5) limited family labor during the peak period of November through December.

The latter two features of this farming system make beans an attractive alternative. Most bean growers practice multiple bean plantings extending from early November to March. Beans, therefore, are an ideal short-term crop for planting (during January-March) after the critical labor period has been devoted to maize establishment.

Despite unlimited local markets and attractive prices offered by the local market agencies for dry beans, farmers are unable to produce surplus for cash. Thus, both the leaves and seeds are generally used for home consumption. Maize is the major source of cash-income in the system (ARPT-CP, 1982, 1986).

DATA AND METHOD

ARPT-CP carried out on-farm bean research with various bean varieties, fertilizer levels and seed treatments (with insecticide). Eight different management strategies comparing a new bean variety called Carioca from Brazil, which had performed well on a research station in Zambia, with the farmers own local variety (retained seed) were tested on farmers' fields for four years (1984/85–1987/88) (Table 1). The study was carried out for two years as research managed and research implemented on-farm trials and two years as extension managed and farmer implemented on-farm test demonstrations within the Serenje farming systems.

TABLE 1

Management strategies tested

Strategies	Code
Farmers' own practice (i.e., local variety without fertilizer and insecticide)	L_{00}
Local variety with fertilizer	L_{+0}
Local variety with insecticide	L_{0+}
Local variety with fertilizer and insecticide	L_{++}
Carioca variety without fertilizer and insecticide	C_{00}
Carioca variety with fertilizer	C_{+0}
Carioca variety with insecticide	C_{0+}
Carioca variety with fertilizer and insecticide	C_{++}

Levels of fertilizer used were 0 and 200 kg/ha of compound 'D' (20 N, 40 P_2O, 20 K_2O, 20 S per ha). Seed treatment (insecticide) levels were 0 and 10 grams of 50% WP endosulfan per kg of beans.

TABLE 2

Cumulative probability distributions for first-degree stochastic dominance

Outcome of strategies (net income)								Cumulative probability
L_{00}	L_{0+}	L_{+0}	L_{++}	C_{00}	C_{0+}	C_{+0}	C_{++}	
157	150	117	146	304	343	429	806	0.06
190	180	186	164	347	398	559	874	0.12
190	198	195	222	494	422	621	984	0.18
240	233	210	302	534	474	644	1027	0.24
246	240	285	415	600	570	745	1072	0.30
258	269	301	481	611	785	755	1115	0.36
300	332	213	498	618	943	859	1431	0.42
465	387	312	590	727	1051	998	1473	0.48
478	683	336	590	790	1082	1220	1484	0.54
712	792	467	651	1116	1115	1267	1908	0.60
760	834	557	730	1118	1210	1406	1908	0.66
769	968	614	984	1188	1646	1524	1960	0.72
957	982	633	1040	1434	1646	1690	2076	0.78
1435	1355	928	1099	2138	1882	1901	2575	0.84
1914	1549	1114	1574	3326	2587	2746	4452	0.90
2120	2323	2413	1845	3564	3528	4224	4664	0.96
2392	2323	2784	1968	5465	5880	5914	4664	1.00
Mean: 799	732	692	782	1434	1504	1618	2028	

Net income is measured in Zambian Kwacha (Kwacha per ha), and is obtained from partial budget analysis carried out by the author. US\$1 = 8 Kwacha.

The data used in this study were first collected from the on-farm trials and test demonstrations that were carried out testing each strategy (shown on Table 1) on 17 farms over the four years. Secondly, partial budget analysis was carried out in order to obtain the net return of each strategy (Table 2). The guidelines and procedures of partial budget analysis for on-farm experiments used are given in Perr et al. (1976) and CIMMYT (1988).

Traditional (subsistence) and small-scale farmers are resource poor, and highly risk averse (Binswanger, 1980; Dillan and Scandizzo, 1978). Thus, certainty of outcome is an important consideration in their decision-making process. The dominant question in this regard is: How risky is the new alternative or strategy in relation to farmers' current practice? Risk (or variation) in agricultural production, and hence in net income, is now widely recognized as the most important factor in the adoption process of new production technology by tranditional and small-scale farmers such as those in Serenje District (Anderson, 1974; Anderson, Dillon and Hardaker, 1977; King and Robison, 1984; Ames, Reid and Lukusa, 1989). In this paper, the stochastic dominance (SD) criteria are utilized to select the most risk efficient technologies for bean production.

The principles and procedures for application of stochastic dominance criteria, both first degree (FSD) and second degree (SSD), are elaborately discussed in Anderson (1974), Anderson, Dillon and Hardaker (1977), King and Robison (1984) and Boehlje and Eidman (1984). Briefly, the decision rule for FSD rests on the assumption that all decision makers prefer more to less, and have positive marginal utility over all outcomes considered. Under the FSD rule, an alternative with cumulative distribution function $F(Y)$ dominates a second alternative with cumulative distribution function $G(Y)$ by FSD if:

$$F(Y) \leq G(Y)$$

for all outcomes of Y, with inequality holding for at least one value of Y. If depicted graphically, this means that $F(Y)$ must lie below $G(Y)$. This condition is transitive, meaning that if $G(Y)$ dominates a third alternative with $H(Y)$, $F(Y)$ will also dominate $H(Y)$. The selection rule under SSD requires an assumption, in addition to preferring more to less, that the decision maker is risk averse. Thus, SSD is more discriminating than FSD, and is appropriate for eliminating inefficient (risky) alternatives considered efficient under the FSD. Under SSD, $F(Y)$ is preferred to $G(Y)$ by all risk averse decision makers if:

$$\int_{-\infty}^{Y} F(Y)\,\mathrm{d}y \leq \int_{-\infty}^{Y} G(Y)\,\mathrm{d}y$$

for all possible outcomes of y, with inequality holding for at least one value of Y. Hence, for $F(Y)$ to dominate $G(Y)$ by SSD, the area under the cumulative distribution function of F must be less than or equal to the area under the cumulative distribution function of G, and must be less than for at least one value of Y.

Although the risk aversion assumption seems to exclude those decision-makers who are risk-neutral or risk-takers, as pointed out by King and Robison (1984), it is a reasonable assumption to make for our target farmers in Serenje District because of their low level of endowments, i.e. wealth (ARPT-CP, 1986; CIMMYT, 1978).

RESULTS

Carioca with fertilizer and insecticide (C_{++}) generated significantly higher bean yields than the farmer's local variety with or without fertilizer and seed treatment. As a result, over the four years, C_{++} gave the highest mean net return (Kwacha 2028 per ha), 61% higher than the highest net

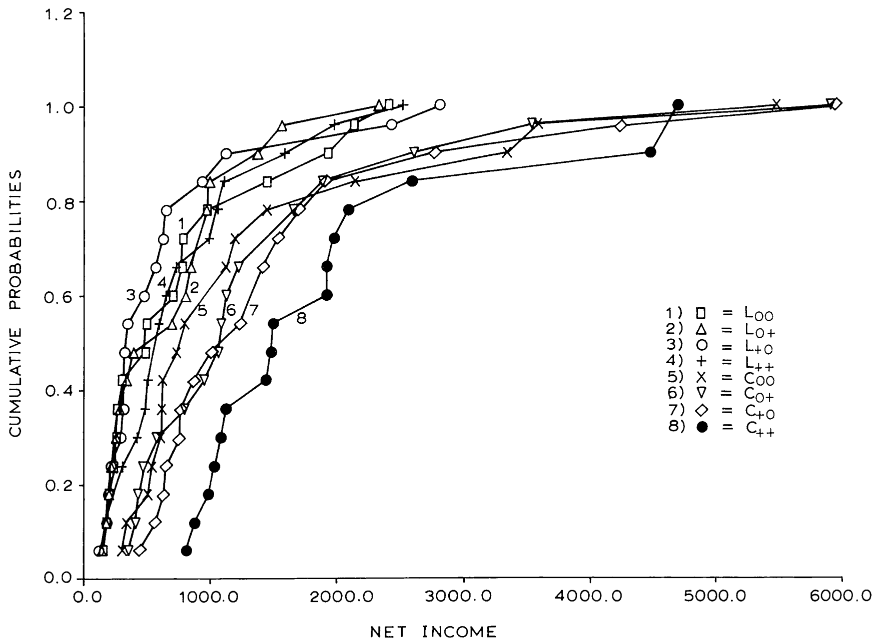

Fig. 3. Cumulative distribution function of net income (illustrates first-degree stochastic dominance).

return treatment with the local variety (L_{++}). In fact, each treatment with carioca generated more net returns than any treatment with the local variety (Table 2).

On the basis of net returns, all the treatments with carioca would be recommended over the treatments with the local variety. However, when the risk aversion behavior of the traditional and small-scale farmers is incorporated into the process of deriving recommendations, one is able to narrow the choice of alternatives to be selected as the optimum-efficient strategies for farmers' adoption.

The cumulative probability distribution of the net income generated from each strategy is presented in Table 2, and plotted in Fig. 3 as discrete distributions for easy inspection. Comparing any two cumulative functions of those strategies with the local variety (i.e., L_{00} with L_{+0}, L_{00} with L_{0+}, and L_{00} with L_{++}, or any other combination) indicates that no one alternative dominates the other in terms of first degree stochastic dominance (FSD). The second degree stochastic dominance (SSD) analysis also indicated that none of the three strategies with the local variety (i.e., L_{+0}, L_{0+}, and L_{++}) dominates the farmers' own practice (L_{00}). As a result, distributions of the four strategies with the local variety can be ranked by neither first degree nor second degree stochastic dominance. Thus, farmer's own practice (L_{00}) could not be eliminated from these set of choices. However, all the strategies with the local variety were dominated by all strategies with the Carioca variety (C_{00}, C_{+00}, C_{0+} and C_{++}) using the FSD criterion (Table 2 and Fig. 3).

TABLE 3

Calculation of area under the cumulative distribution functions for second-degree stochastic dominance analysis

Net income	Cumulative probabilities		Change in net income	Area under the cumulative curve	
	C_{+0}	C_{++}		C_{+0}	C_{++}
429	0.06	0.00	–	0.00	0.00
559	0.12	0.00	130	7.80	0.00
621	0.18	0.00	62	15.24	0.00
644	0.24	0.00	23	19.38	0.00
745	0.30	0.00	101	43.62	0.00
755	0.36	0.00	10	46.62	0.00
806	0.36	0.06	51	64.98	0.00
859	0.42	0.06	53	84.06	3.18
874	0.42	0.12	15	90.36	4.08
984	0.42	0.18	110	136.56	17.28
998	0.48	0.18	14	142.44	19.80
1027	0.48	0.24	29	156.36	25.02
1072	0.48	0.30	45	177.96	35.82
1115	0.48	0.36	43	198.60	48.72
1220	0.54	0.36	105	249.00	86.52
1267	0.60	0.36	47	274.38	103.44
1406	0.66	0.36	139	357.78	153.48
1431	0.66	0.42	25	374.28	162.48
1473	0.66	0.48	42	402.00	180.12
1484	0.66	0.54	11	409.26	185.40
1524	0.72	0.54	40	435.66	207.00
1690	0.78	0.54	166	555.18	296.64
1901	0.84	0.54	211	719.76	410.58
1908	0.84	0.66	7	725.64	414.36
1960	0.84	0.72	52	769.32	448.68
2076	0.84	0.78	116	866.76	532.20
2575	0.84	0.84	499	1285.92	921.42
2746	0.90	0.84	171	1429.56	1065.06
4224	0.96	0.84	1478	2759.76	2306.58
4452	0.96	0.90	228	2978.64	2498.10
4664	0.96	1.00	212	3182.16	2688.90
5914	1.00	1.00	1250	4382.16	3938.90

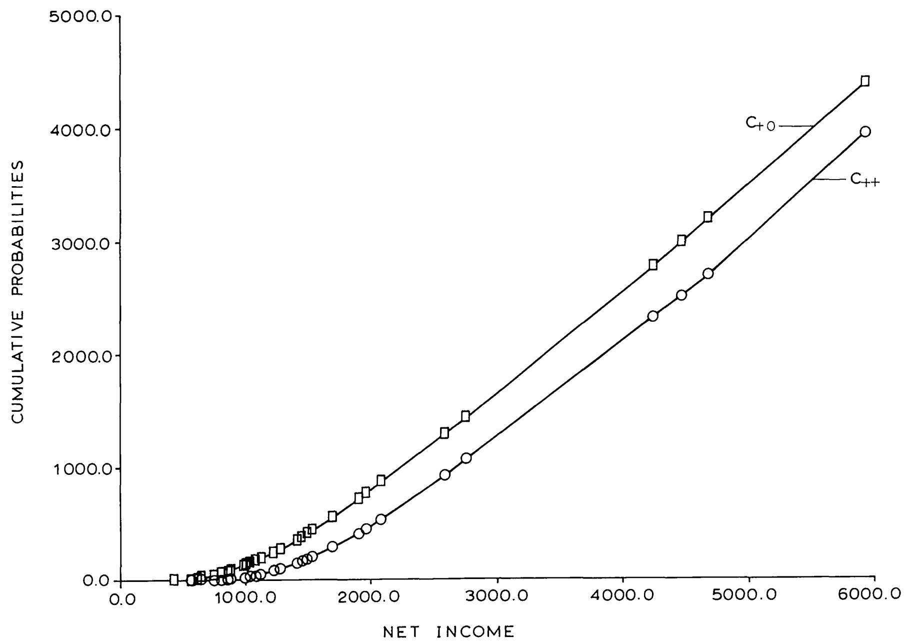

Fig. 4. Comparison of areas under cumulative curve (illustrates second-degree stochastic dominance).

As illustrated in Fig. 3, no one strategy with Carioca dominates any other strategy with Carioca by first degree stochastic dominance criteria. Therefore, these strategies were evaluated using SSD criterion in order to eliminate those strategies (or alternatives) which a risk averse decision maker would not consider. Alternative C_{+0} dominates both C_{00} and C_{0+} by second degree stochastic dominance. C_{++} is compared with C_{+0} in Table 3. The cumulative area under C_{++} is less than for C_{+0} at each net income level. This indicates that strategy C_{++} dominates by SSD all the other seven strategies considered (Fig. 4).

CONCLUSION AND IMPLICATIONS

Given the farming systems of the study area and farmers' objectives and priorities, the results of the four years on-farm research indicate that Carioca bean variety with fertilizer and insecticide is the most preferred alternative for the traditional and small-scale farmers who are usually highly risk averse. This strategy generated significantly higher yield and hence net income with the least variability.

Additionally, the Carioca variety should be preferred over any management strategy with the local variety both in terms of rate of return and stability. Hence, farmers in Serenje District would likely do better in bean production by planting Carioca variety, and even better, if this variety is accompanied by fertilizer and insecticide.

The next step in the sequence is to assess the Carioca bean acceptability potentials for adoption. Here, only implications for adoption are drawn. As argued in various socio-economic studies (Mann, 1978; Byerlee and Hesse de Polanco, 1986; Lang and Roth, 1984) farmers, particularly traditional and small scale, do not adopt technologies as a 'package' at once but rather sequentially based on availability of relevant inputs, own resource endowments, technical viability in the field, economic returns, and degree of risk averseness. Hence, technology or strategy that best fit farmers' circumstances will be selected first for adoption. In addition, one of the obstacles for adoption of high-yielded seed varieties with fertilizer and insecticide inputs has been the lack of well-organized input markets, adequate storage and transportation facilitate in most African countries (Ogutu, 1987).

The results of this study suggest that farmers who have limited ability to purchase and limited access to acquire the fertilizer and insecticide inputs (due to institutional constraints) should first adopt the new bean variety without fertilizer and insecticide, since this strategy would not involve a cash outlay. Once the Carioca variety is available, it can be retained and used as a seed. Other additional management strategies such as Carioca with fertilizer and insecticide (Table 1) should only be added as farmers become more confident in the technology and other institutional factors, such as input markets and agriculture policies are favorable towards such technology. Such a stepwise strategy for adoption was evidenced in the study area (Bezuneh and Olsen, 1990b).

ACKNOWLEDGEMENTS

The author would like to thank Darrell Bosch, Michael Collinson, Carl Mabbs-Zeno and Glen Ames for their helpful comments.

REFERENCES

Ames, G.C.W., Reid, D.W. and Lukusa, M. 1989. Introduction of new maize technology in Zaire's Kasai Oriental: application of risk analysis in farming systems research. Government Intervention in Agriculture. IAAE Occas. Pap. 5.

Anderson, J.R., 1974. Risk efficiency in the interpretation of agricultural production research. Rev. Market. Agric. Econ., 42: 131–184.

Anderson, J.R., Dillon, J.L. and Hardaker, B., 1977. Agricultural Decision Analysis. Iowa State University Press, Ames, IA.

ARPT-CP, 1982. Farm-Level Agronomic Survey in Serenje District Central Province. Adaptive Research Planning Team – Central Province, Ministry of Agriculture and Water Development, Zambia.

ARPT-CP, 1986. Informal Survey in Traditional Recommendation Domain No. 2 of Serenje District, Central Province. Pap. 2, Adaptive Research Planning Team – Central Province, Ministry of Agriculture and Water Development, Zambia.

Bezuneh, M. and Olsen, F., 1990a. Response of beans to fertilizer and seed treatment in Central Province, Zambia. Exp. Agric., 26: 381–385.

Bezuneh, M. and Olsen, F., 1990b. Bean technology under research and farmer management, and implications for adoption in Serenje District of Central Province, Zambia. Farm. Syst. Bull. 6, CIMMYT – Eastern and Southern Africa, Harare, Zimbabwe.

Binswanger, H.P., 1980. Attitudes toward risk: experimental measurement in rural India. Am. J. Agric. Econ., 56: 280–285.

Boehlje, M. and Eidman, R., 1984. Farm Management. Wiley, New York.

Byerlee, D. and Hesse de Polanco, E., 1986. Farmers stepwise adoption of technological packages: evidence from the Mexican Altiplano. Am. J. Agric. Econ., 68; 519–527.

CIMMYT, 1978. Demonstration of an Interdisciplinary Approach to Planning Adaptive Research Program in the Serenje District, Central Province, Zambia. Centro International de Mejoramiento de Maiz y Trigo, Nairobi, Kenya.

CIMMYT, 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual (revised edition). Centro International de Mejoramiento de Maiz y Trigo, Mexico, D.F.

Dillon, J.L. and Scandizzo, P., 1978. Risk attitudes of subsistence farmers in northeast Brazil: a sampling approach. Am. J. Agric. Econ., 60; 425–435.

King, R.P. and Robison, L.J., 1984. Risk efficiency models. In: P. Barry (Editor), Risk Management in Agriculture. Iowa State University Press, Ames, IA, pp. 68–81.

Lang, M.G. and Roth, M., 1984. Risk perceptions and risk management by farmers in Burkina Faso. paper presented Annu. Farming Systems Conf., Kansas State University.

Mann, C.K., 1978. Packages of practices: a step at a time with clusters. In: Studies in Development. Middle East Technical University, Ankara.

Ogutu, A.A.C., 1987. A new approach to fertilizer use and food production in less developed countries. In: M. Bellamy and B. Greenshields, B. (Editors). Agriculture and Economic Instability IAAE Occas. Pap. 4, pp. 17–20.

Perrin, R.K., Winkelmann, D.L., Moscardi, E.R. and Anderson, J.R., 1976. From agronomic data to farmer recommendations: an economics training manual. CIMMYT, Mexico, D.F.