Staff Paper

Financial and Risk Analysis of Maize Technology in Ethiopia, Based on CERES-Maize Model Results

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Staff Paper No. 00-47 **December 2000**

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Abstract

This paper presents a financial and risk analysis of improved versus traditional maize production technology in Ethiopia, based on yields simulated with the CERES-Maize crop growth model (Schulthess and Ward, 2000). The purpose is to analyze the potential performance of the SG2000/Ministry of Agriculture program technology under less favorable meterological conditions (rainfall level and distribution), and in areas with lower agroecological potential than those covered by the SG2000/MOA program through 1998. At the time of this study, expansion of the MOA program into lower potential zones seemed likely. Results show that use of fertilizer and improved seed is highly profitable under a variety of assumptions about crop growth conditions, maize prices, and fertilizer costs. Risk is examined using simple sensitivity and breakeven analysis, and stochastic dominance analysis.

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This Staff Paper may be found at http://www.aec.msu.edu/agecon/

The authors are Professor, Visiting Assistant Professor, and Visiting Associate Professor, Dept. of Agricultural Economics, Michigan State University. Funding for this research was provided by USAID/Ethiopia and the Food Security II Cooperative Agreement (AEP-5459-A-00-2041-00) between Michigan State University and the United States Agency for International Development, through Africa Bureau's Office of Sustainable Development, Agriculture, Natural Resources and Rural Enterprise Division (AFR/SD/ANRE). The views expressed in this document are exclusively those of the authors.

ACKNOWLEDGMENTS

The authors wish to thank Urs Schulthess who, together with Rick Ward, conducted the CERES-Maize modeling study on which this paper is based (Schulthess and Ward, 2000). Schulthess provided the raw modeling results from their study, responded to questions about the model, and conducted additional runs of the CERES-Maize model in response to comments and questions from the authors.

An earlier version of this paper was presented at the mini-symposium on “Risk and Agricultural Input Use,” XXIV International Conference of Agricultural Economists, Berlin, August 13-18, 2000.

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BACKGROUND

Intensive maize production has been promoted in Ethiopia since 1993 under a joint Sasakawa-Global 2000 and Ministry of Agriculture program. A 1997 study by the Department of Agricultural Economics, Michigan State University, in collaboration with SG2000/MOA, showed a very significant impact of improved seed and fertilizer on maize yields and net returns to farmers (Howard et al., 1999). These positive results, while gratifying, were not surprising given that the study zones (Jimma, Weliso) were very favorable for maize, and 1997 rainfall was very good. A key issue for the program, therefore, was: How well would the SG2000 technology perform in less favorable agroecological and rainfall conditions? Crop scientists at MSU were commissioned to study this question using the CERES-Maize crop growth model.[1] The results of this study are reported in Schulthess and Ward (2000).

The yields simulated for the Schulthess and Ward study regions were then used, along with other information, to conduct a financial and risk analysis of the likely performance of the SG2000 technology in less-favored agroecological zones. After giving a brief excerpt of the CERES-Maize model results, we summarize the methods used and the results obtained in the financial and risk analysis.

CERES-Maize Model

The CERES-Maize crop simulation model was used to test stability of the improved maize package over time under variable rainfall, and in three regions: Ambo (912 mm/year average rainfall, less than Weliso), Jimma (1,570 mm/yr), and Gore (1,930 mm/yr). In this discussion, we will focus mainly on the results for Jimma and Ambo, since our emphasis is on the less favorable

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[1]A similar study of dry zone maize in Kenya is reported in Wafula (1995). For other references to crop modeling studies in Africa, see Keating and Grace (1999).

zones. Using historical weather data (20 years in Jimma and 15 years in Ambo), yield scenarios were simulated for 2 x 3 = 6 treatments:

- Two levels of fertilizer and seed: fertilizer and improved seed versus local seed and no fertilizer
- Three levels of plant density: low, medium, and high (2, 4, and 6 plants/m^2)

The results showed the following (Tables 1 and 2):

1. Yields can be increased from 2 tons/hectare (t/ha) to 6-8 t/ha. In Jimma, yields were about 2 t/ha or higher except in one year of complete crop failure, and one other year for the nonfertilized treatments. Yields averaged 2.6-3.0 t/ha for nonfertilized and 4.7-7.6 t/ha for fertilized treatments. In Ambo, yields were below 1 t/ha in several years for nonfertilized treatments, but (with two exceptions) above 2 t/ha for fertilized treatments.
2. Increasing plant density has little effect on yield without fertilizer. In both zones, yields for the nonfertilized treatment with 6 plants/m^2 (NF6) were somewhat lower than for the NF4 treatment. With fertilizer, yield responds strongly to the increase in plant density.
3. Not surprisingly, yield variability is highest in the driest zone (Ambo; Table 2), for both fertilized and nonfertilized treatments.
4. Use of fertilizer and improved seed reduced yield variability (measured in terms of C.V.s) by more than 50 percent in Ambo and by more than 75 percent in Jimma, although it increased yield variability slightly in Gore.

Financial Analysis

Net returns were calculated using the time series of yields simulated by the CERES-Maize model, as described above, and costs and prices drawn from the SG/MSU/MOA crop budgets developed by Howard et al. (1999) and summarized here in Tables 3 and 4.[2] Figures are expressed in birr, where the exchange rate in 1999 was 6.70 birr/U.S.$.

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[2]Note that the yields shown in Tables 3 and 4 come from the SG/MSU/MOA survey. They are not the simulated CERES-Maize model yields used in this analysis. Therefore, while the prices and costs in Tables 3 and 4 are relevant to this paper, the net returns are not.

Prices are averages of the prices for white maize that prevailed during the immediate post-harvest period (January) of 1998**.** Costs were total package costs (item 4 in Tables 3 and 4) plus the costs of interest payments, wage labor, animal traction, and hand tools and sacks (items 5, 6B, 7, and 8). Costs for the with-fertilizer and no-fertilizer treatments were based respectively on the "SG Mean"[3] and "Local Seed, No Fertilizer" figures in Tables 3 and 4.[4] Prices and costs were held constant for the period analyzed. Note:

1. In Ambo, the SG mean costs are somewhat higher than in Jimma, where urea costs were lower. The local/no fertilizer costs are somewhat lower in Ambo than in Jimma, where for reasons we do not know animal traction costs are significantly higher for the local/no fertilizer technology than the SG mean technology.
2. Prices in Ambo are somewhat higher than in Jimma, since Ambo is closer to the major market center of Addis Ababa.

Table 5 and Figure 1 show the net returns associated with the yields simulated by the CERES-Maize model for Jimma, sorted from lowest to highest.[5] Points to note include:

1. Even the nonfertilized treatments gave good results, with mean net returns of 1,000-2,000 birr/ha (about $150-300/ha, or two to five times the total cost), and losses occurring in only 1-2 out of 20 years.
2. The nonfertilized plus 4 plants/ha treatment (NF4) outperformed the NF6 treatment (higher mean net return and equal or higher net returns in all but one year).
3. The fertilized treatments had 50-300% higher mean net returns, losses in only 1 year (where a 100% crop failure was simulated), and showed a strong effect of increased plant density, as illustrated in Figure 1.

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[3]Mean values for the SG technology plots surveyed.

[4]To simplify the calculation of net returns for the six treatments simulated by the CERES-Maize model, seed costs, which are minor, were not adjusted to reflect the differences in plant density.

[5]Net returns were sorted partly in preparation for the stochastic dominance analysis, and partly as a way of showing, in Figures 1 and 2, the extent of variability of simulated net returns.

Table 6 and Figure 2 show the results for Ambo:

1. Lower yields in (drier) Ambo were offset by the higher maize price, so that except for NF2 and NF4 mean net returns in Ambo are higher than for Jimma, even though about half of the nonfertilized treatments gave net returns below 1,000 birr/ha.
2. Mean net returns were 12% lower for nonfertilized treatments in Ambo than in Jimma, but 16.5% higher for fertilized treatments.
3. With fertilizer, increased crop density showed the same strong effect as in Jimma.
4. Losses occurred in only 0-2 of the 15 years (no complete crop failure was simulated).

Risk Analysis

The variability of net returns was examined first by looking at the C.V.s (see Table 7, "base scenario" sections). The C.V.s of net returns were lower for the fertilized treatments than for the nonfertilized treatments, by 25-30% in Jimma and by 50-60% in Ambo. Looking across zones, the C.V.s of net returns were substantially lower (40-50%, using Ambo as the base) for nonfertilized (NF) treatments in Jimma compared to Ambo, but only slightly lower (10-20%) for fertilized (F) treatments. So, fertilizer reduced C.V.s more significantly in Ambo than in Jimma.

Three types of sensitivity analysis were then conducted. The results are summarized in Table 7 (values) and Table 8 (percentage changes). Not surprisingly, net returns were more sensitive to alternative assumptions about yield or price than about cost, but overall there was little difference between the two zones in the impact on net returns of the three alternative assumptions:

1. <u>50% reduction in the maize price</u>.
   a. Jimma: mean net returns fell by 66-69% for NF and F treatments, respectively.
   b. Ambo: mean net returns fell by 63-68% for NF and F treatments, respectively.
2. <u>50% increase in the total package (fertilizer+seed) cost</u>.
   a. Jimma: mean net returns fell by 16-19%.
   b. Ambo: mean net returns fell by 13-18%.

3. Farmer yields assumed to be 75% of yields simulated by the model.[6]
    a. Jimma: mean net returns fell by 33-34%.
    b. Ambo: mean net returns fell by 31-34%.

Breakeven and switching values were then calculated (Table 9). The results show:

1. Maize yields and prices would have to decline by 75-80% in order to make the no-fertilizer technology just break even (drive net returns down to zero). For the SG technology package, yields and prices would have to decline by 66-80% in order to break even.
2. In order for the profitability of the with-fertilizer technology to decline to the point where it no more than equals that of the no-fertilizer technology, fertilizer costs for the SG package (total, not per kg) would have to rise by 2-5 times.

Stochastic dominance analysis was then conducted on the base scenario net returns. The two stochastic dominance criteria used were:

1. First-degree stochastic dominance (FSD). Given two actions (or projects) A and B, each with a probability distribution of outcomes $\boldsymbol{x}$ defined by CDFs $F_A(x)$ and $F_B(x)$:

    A dominates B in the first-degree sense if $F_A(x) \leq F_B(x)$ for all x, with at least one strong inequality. The cumulative distribution function (CDF) of A must always lie below and to the right of the CDF of B. This is a strong requirement that is rarely satisfied.
2. Second-degree stochastic dominance (SSD). This criterion assumes the decision maker is risk averse for all x. With SSD, A is preferred to B if:

[6]This accounts for the difference between actual yield levels observed on-farm in the 1997 GMRP/MSU/AAU/MOA/SG2000 survey, and those simulated in the CERES-Maize model. We (Howard) estimate that farmers using local seed and no fertilizer obtained yields that averaged about 76% of the simulated yields. Farmers who used improved seed and fertilizer obtained yields averaging about 87% of simulated yields.

$$\int_{-\infty}^{x^*} F_A(x)dx \leq \int_{-\infty}^{x^*} F_B(x)dx$$

SSD is used when CDFs cross. Alternatives are compared based on areas under their CDFs. A will dominate B if the area where A is preferred to B is greater than the area where B is preferred to A. However, if B is preferred to A at the outset, A cannot dominate B. SSD is not satisfied much more often than FSD.

The results for Jimma were:

1. By first-degree stochastic dominance (FSD), NF4 dominates NF2 and F6 dominates F4 and F2 (Table 5). Neither NF4 nor NF6 dominates the other by FSD, as illustrated by the crossing of the cumulative distribution functions in Figure 3 (same page as Table 11). Also, F6 does not dominate NF4, since it has a greater loss in the worst year, when a 100% crop failure was simulated for all treatments.
2. By second-degree stochastic dominance (SSD), neither NF4 nor NF6 dominates the other (see Tables 10 and 11).[7] Treatment F6 does not dominate any of the nonfertilized treatments, because its worst-year loss is greater.
3. Indeed one can argue that the choice of preferred treatment can be made (in this particular case) without resorting to stochastic dominance analysis. The sorted net returns in Table 5 suggest that a decision maker willing to accept the 1 in 20 risk of a loss of 841 (vs. a loss of 355) would prefer F6 to any other treatment, since the net returns from F6 are 2-3 times higher in all years except the one year where a 100% crop failure occurs.[8]

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[7]The calculations in Table 10 follow a procedure presented in Worman and Schurle (1990). Table 11 shows the cumulative probability distribution of net returns for equal intervals between the approximate minimum and maximum values.

[8]A more formal way to model this would be to use the Generalized Stochastic Dominance approach described in Cochran and Raskin (1988). However, this approach, also known as "stochastic dominance with respect to a function," requires specification of bounds on the decision maker's absolute risk aversion coefficient. Since there was no basis for estimating such coefficients for Ethiopian farmers, this approach was not used.

The results for Ambo were:

1. Worst-case net returns are better for fertilized than for nonfertilized treatments; the model does not simulate a complete crop failure for Ambo as it did for Jimma.
2. F4 dominates F2 and all NF treatments by FSD.
3. F6 would dominate all other treatments except that its lowest net return is 392 vs. 453 for F4. (For this reason, it cannot dominate F4 by SSD.)

Lastly, as an alternative approach to the stochastic dominance analysis of the NF4 and NF6 treatments for Jimma (Tables 10 and 11), the @Risk program (see www.palisade.com) was used to do a Monte Carlo analysis of the yield and net returns scenarios for those two treatments. To smooth out the 20-year discrete yield distributions simulated by CERES-Maize for NF4 and NF6, the @Risk model used triangular probability distributions for yield that were fitted roughly to the discrete distributions. The triangular distributions {min, mode, max} were {0, 3316, 4053} and {0, 3034, 3632} for NF4 and NF6, respectively.

Not surprisingly, since NF4 has a higher mode and maximum value, its simulated distribution of net returns dominates NF6 by the first-degree SD criterion. It might be useful to repeat this exercise using probability distributions that match the simulated discrete distributions more closely than the triangular distribution.

Conclusions:

1. Crop simulation models can be useful, but they depend on good soils and weather variability data. Here, the variability in yields across years was lower than we expected; the time series of weather data may have been too short to include a representative number of drought years. Simulated yields in this study seemed to be 15-25% higher than typical farmer yields.

2. The SG technology appeared to be stable under different weather conditions. Net returns remained quite positive, with a low incidence of losses. This is partly because the driest zone for which yields were simulated still had relatively good rainfall (912 mm/yr).
3. Although Ambo is drier than Jimma, mean net returns for fertilized treatments were actually better in Ambo than in Jimma due to the higher maize price in Ambo.
4. Simply comparing the sorted net returns for the different treatments gave as many if not more insights than application of formal stochastic dominance criteria.

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Table 1. CERES-Maize: Simulated Yields for Jimma and Ambo, by Year

	YIELDS (kg/ha)--Jimma					
Year	No Fert. 2 plants/m2	No Fert. 4 plants/m2	No Fert. 6 plants/m2	Fertilized 2 plants/m2	Fertilized 4 plants/m2	Fertilized 6 plants/m2
1978	3430	3310	2935	5333	6964	8126
1979	0	0	0	0	0	0
1980	2250	2380	2285	5044	6777	8084
1981	3243	3794	3309	5189	6682	8164
1982	2644	3218	3042	4934	6761	8148
1983	2392	2803	2643	4910	6686	8049
1984	3366	3444	3034	5593	6667	7926
1985	2882	3471	3135	5003	6622	8175
1986	3031	3713	3393	4980	6519	8131
1987	498	819	1021	4104	5997	7184
1988	3379	4045	3624	5438	7083	8445
1989	2566	3316	3034	5013	6657	8003
1990	3263	4053	3632	4937	6557	8196
1991	3262	3910	3278	5255	6724	8185
1992	3272	3992	3520	5366	6949	8461
1993	1933	2248	2210	4436	6331	7527
1994	2986	3239	2836	4516	6447	7938
1995	2419	2811	2577	5210	6885	8143
1996	1957	2384	2365	5059	6797	8139
1997	3515	3625	2708	5520	6871	7835
Mean	2614	3029	2729	4792	6349	7643

	YIELDS (kg/ha)--Ambo					
Year	No Fert. 2 plants/m2	No Fert. 4 plants/m2	No Fert. 6 plants/m2	Fertilized 2 plants/m2	Fertilized 4 plants/m2	Fertilized 6 plants/m2
1956	1076	1290	1378	4600	6784	8227
1957	516	822	1008	5042	7056	8126
1958	1437	2011	2161	5014	6788	7930
1959	157	318	475	3501	5202	6345
1960	54	103	145	1285	2041	1950
1967	2874	3207	2940	4469	6783	8273
1968	3466	3877	3334	5224	7443	7983
1969	485	822	1005	4550	6642	7926
1970	660	985	1169	3894	6069	7512
1971	960	1210	1279	2247	3652	4554
1972	1574	2187	2087	2098	3398	4211
1973	3459	4511	3813	4113	6704	8361
1981 a/	1546	1708	1734	4927	6869	7920
1982	3772	3188	2218	5398	5834	6106
1983	3077	3025	2557	4325	6458	7853
Mean	1674	1951	1820	4046	5848	6885

a/ No yields for 1974-80 were simulated, since weather data were not available for that period.

Table 2. Summary Statistics of Simulated Maize Yield Data for Three Locations in Ethiopia as Affected by Plant Density and Fertilization

Location	Treatment a/	Mean (kg/ha)	Std Dev.	C.V.	Minimum	Maximum
Ambo	NF plants/m^2	1674	1306	78.0	54	3772
	NF 4 plants/m^2	1951	1379	70.7	103	4511
	NF 6 plants/m^2	1820	1091	60.0	145	3813
	F 2 plants/m^2	4046	1313	32.4	1285	5398
	F 4 plants/m^2	5848	1761	30.1	2041	7443
	F 6 plants/m^2	6885	1551	22.5	1950	8361
Gore	NF 2 plants/m^2	3134	391	12.5	2387	3650
	NF 4 plants/m^2	3355	537	16.0	2525	4163
	NF 6 plants/m^2	3051	574	18.8	2027	3919
	F 2 plants/m^2	4791	875	18.3	2606	5560
	F 4 plants/m^2	6454	1322	20.5	3162	7309
	F 6 plants/m^2	7504	1601	21.3	3446	8267
Jimma	NF 2 plants/m^2	2614	949	36.3	0	3515
	NF 4 plants/m^2	3029	1059	35.0	0	4053
	NF 6 plants/m^2	2729	623	22.8	0	3632
	F 2 plants/m^2	4792	384	8.0	0	5593
	F 4 plants/m^2	6349	263	4.1	0	7083
	F 6 plants/m^2	7643	329	4.3	0	8461

Source: Schulthess and Ward (2000), Table 3.
a/ NF = nonfertilized, local seed; F = fertilized, improved seed.

Table 3. Budget Used for Jimma Net Returns Calculations

JIMMA -- JANUARY SALES

Budget Item	SG mean	Local Seed No fertilizer
n used in calculations	69	4
1. GRAIN YIELD (kg/ha) 1/	5508	1835
1.A. Adjusted grain yield (kg/ha) 1/	5293	1763
2. FARMGATE PRICE (birr/kg) 2/	0.54	0.54
3. GROSS REVENUE (1 x 2)	2883.2	952.2
4. TOTAL PACKAGE COSTS 3/	641.99	49
4.A. Treated seed (birr/ha)	129	49
4.B. DAP	263	0
4.C. Urea	248	0
4.D. Herbicide	0.39	0
4.E. Insecticide	0	0
4.F. Fungicide	1.6	0
5. INTEREST 4/	0	0
6. LABOR 5/		
6.A. Total family/mutual labor days 6/	135	78
6.B. Total wage labor (birr/ha) 7/	62	36
7. ANIMAL TRACTION COST (birr/ha) 8/	98	261
8. HAND TOOLS AND SACKS (birr/ha)	39.2	8.9
8.A. Hand tools (birr) 9/	2.8	3.1
8.B. Sacks (birr) 10/	36.3	5.8
9. TOTAL COST (4+5+6.B+7+8)	841.2	354.9
10. NET INCOME/HA (3 - 9)	2042.0	597.3
11. NET INCOME/FAMILY-MUTUAL LABOR DAY (10/6.A)	15.1	7.7

Source: Howard, et al., *Green Revolution Technology Takes Root in Africa*, IDWP 76, Dept. of Ag. Econ., Michigan State University, 1999.

1/ Source: crop cut estimates, GMRP/ MSU/ AAU/ MOA/ SG2000 Survey. Assumes no grain lost during shelling. Assumes maize harvested in November and storage losses of 1.98% per month, the average of various estimates from Tolessa and Ransom 1993.

2/ Source: EGTE price monitoring unit and GMRP/ MSU/ AAU/ MOA/ SG2000 Survey. Local market prices collected by EGTE are adjusted to farmgate prices using survey data on prices reported by farmers. Prices are average prices for white maize during January 1998.

3/ 4.A.+4.B.+4.C.+4.D.+4.E.+4.F. MOA/ SG2000 maize package consists of 25 kg seed, 100 kg DAP, 100 kg urea.

4/ Source: GMRP/ MSU/ AAU/ MOA/ SG2000 Survey and rate information from MOA/ SG2000. SG2000 participants pay no interest; MOA program participants pay 10% interest annually. Assumes that period of loan is 10 months.

5/ Source: GMRP/ MSU/ AAU/ MOA/ SG2000 Survey.

6/ Includes shelling labor.

7/ Valued at cash/ in-kind payment rates provided by survey participants.

8/ Sum of (a) rental costs reported by survey respondents and (b) for owned/ borrowed oxen, maintenance + depreciated value of animals and animal traction equipment multiplied by percentage of total farm represented by the MOA-SG, traditional or graduate plot. (see spreadsheet f). Purchase price, life and salvage value of equipment based on field reports by survey supervisors.

9/ Depreciated value of 2 hoes, 2 axes, 2 cutting knives. Purchase price, life and salvage value of equipment based on field reports by survey supervisors.

10/ Depreciated value of sacks needed to transport maize marketed in 1996-97 season. Since sacks are retained by farmer and used for other purposes, cost is apportioned by multiplying depreciated sack value by percentage of total farm represented by MOA-SG or graduate plot. Purchase price, life and salvage value based on field reports by survey supervisors.

Table 4. Budget Used for Ambo Net Returns Calculations

WELISO -- JANUARY SALES

Budget Item	SG mean	Local Seed No fertilizer
n used in calculations	92	33
1. GRAIN YIELD (kg/ha) 1/	5554	3858
1.A. Adjusted grain yield (kg/ha) 1/	5337	3707
2. FARMGATE PRICE (birr/kg) 2/	0.69	0.69
3. GROSS REVENUE (1 x 2)	3682.8	2558.2
4. TOTAL PACKAGE COSTS 3/	657	71
4.A. Treated seed (birr/ha)	136	71
4.B. DAP	260	0
4.C. Urea	260	0
4.D. Herbicide	1	0
4.E. Insecticide	0	0
4.F. Fungicide	0	0
5. INTEREST 4/	0.0	0.0
6. LABOR 5/		
6.A. Total family/mutual labor days 6/	158	204
6.B. Total wage labor (birr/ha) 7/	123	92
7. ANIMAL TRACTION COST (birr/ha) 8/	93	63
8. HAND TOOLS AND SACKS (birr/ha)	28.7	16.1
8.A. Hand tools (birr) 9/	1.6	1.3
8.B. Sacks (birr) 10/	27.1	14.8
9. TOTAL COST (4+5+6.B+7+8)	901.7	242.1
10. NET INCOME/HA (3 - 9)	2781.0	2316.1
11. NET INCOME/FAMILY-MUTUAL LABOR DAY (10/6.A)	17.6	11.4

Source: Howard, et al., *Green Revolution Technology Takes Root in Africa*, IDWP 76, Dept. of Ag. Econ., Michigan State University, 1999.

1/ Source: crop cut estimates, GMRP/ MSU/ AAU/ MOA/ SG2000 Survey. Assumes no grain lost during shelling. Assumes maize harvested in November and storage losses of 1.98% per month, the average of various estimates from Tolessa and Ransom 1993.

2/ Source: EGTE price monitoring unit and GMRP/ MSU/ AAU/ MOA/ SG2000 Survey. Local market prices collected by EGTE are adjusted to farmgate prices using survey data on prices reported by farmers. Prices are average prices for white maize during January 1998.

3/ 4.A.+4.B.+4.C.+4.D.+4.E.+4.F. MOA/ SG2000 maize package consists of 25 kg seed, 100 kg DAP, 100 kg urea.

4/ Source: GMRP/ MSU/ AAU/ MOA/ SG2000 Survey and rate information from MOA/ SG2000. SG2000 participants pay no interest; MOA program participants pay 10% interest annually. Assumes that period of loan is 10 months.

5/ Source: GMRP/ MSU/ AAU/ MOA/ SG2000 Survey.

6/ Includes shelling labor.

7/ Valued at cash/ in-kind payment rates provided by survey participants.

8/ Sum of (a) rental costs reported by survey respondents and (b) for owned/ borrowed oxen, maintenance + depreciated value of animals and animal traction equipment multiplied by percentage of total farm represented by the MOA-SG, traditional or graduate plot. (see spreadsheet f). Purchase price, life and salvage value of equipment based on field reports by survey supervisors.

9/ Depreciated value of 2 hoes, 2 axes, 2 cutting knives. Purchase price, life and salvage value of equipment based on field reports by survey supervisors.

10/ Depreciated value of sacks needed to transport maize marketed in 1996-97 season. Since sacks are retained by farmer and used for other purposes, cost is apportioned by multiplying depreciated sack value by percentage of total farm represented by MOA-SG or graduate plot. Purchase price, life and salvage value based on field reports by survey supervisors.

Table 5. Net Returns for Jimma by Treatment, Sorted

	NET RETURNS (Birr/ha)--Sorted from lowest to highest					
	Not fertilized 2 plants/m2	**Not fertilized 4 plants/m2**	**Not fertilized 6 plants/m2**	**Fertilized 2 plants/m2**	**Fertilized 4 plants/m2**	**Fertilized 6 plants/m2**
	-355.0	-355.0	-355.0	-841.0	-841.0	-841.0
	-96.3	70.5	175.4	1290.9	2274.3	2890.9
	649.2	812.8	793.1	1463.4	2447.8	3069.1
	661.6	881.4	832.0	1505.0	2508.1	3229.1
	813.8	883.4	873.6	1709.6	2545.5	3276.4
	887.6	1101.1	983.7	1722.1	2565.2	3282.6
	901.6	1105.3	1018.0	1723.7	2599.0	3316.4
	978.0	1316.7	1051.8	1746.0	2617.2	3340.3
	1018.5	1327.6	1118.2	1758.0	2622.4	3358.5
	1142.1	1364.5	1169.7	1763.2	2630.2	3380.3
	1196.2	1367.6	1221.1	1779.3	2632.2	3382.9
	1219.5	1434.1	1221.1	1787.0	2652.0	3387.0
	1329.7	1448.1	1225.3	1854.6	2671.2	3389.1
	1339.5	1528.1	1273.6	1865.5	2679.5	3391.7
	1340.1	1573.8	1347.9	1888.9	2689.9	3400.0
	1344.7	1615.9	1364.0	1929.4	2728.3	3405.7
	1393.6	1676.2	1407.6	1946.5	2735.6	3410.9
	1400.3	1718.8	1473.6	1983.9	2768.9	3416.7
	1426.8	1746.3	1527.6	2026.5	2776.7	3546.0
	1471.0	1750.5	1531.8	2064.5	2838.5	3554.3
Mean	1003.1	1218.4	1062.7	1648.3	2457.1	3129.4

Note: Cells in boxes contain values that are lower than those in the cells directly to the left.

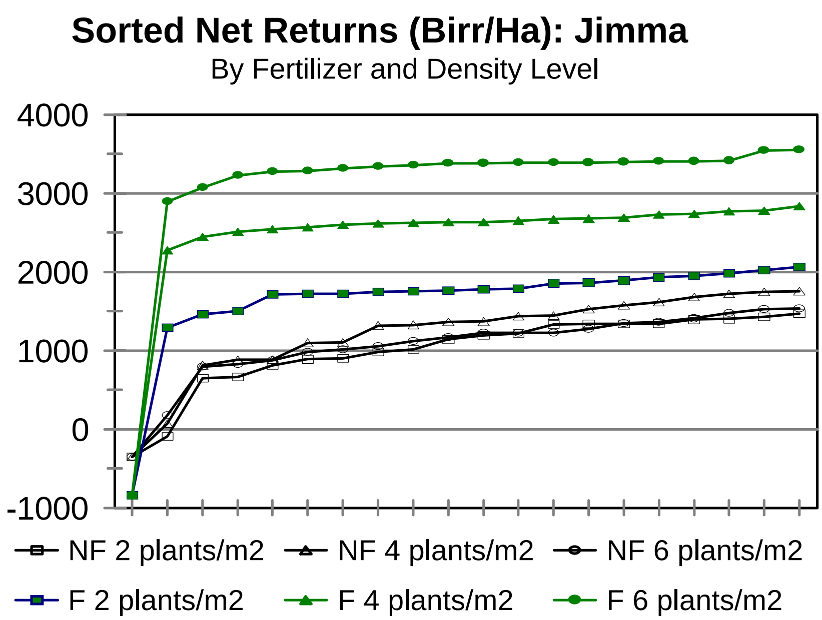

Figure 1. **Sorted Net Returns: Jimma.**

Table 6. Net Returns for Ambo by Treatment, Sorted

	NET RETURNS (Birr/ha)--Sorted from lowest to highest					
	Not fertilized 2 plants/m2	Not fertilized 4 plants/m2	Not fertilized 6 plants/m2	Fertilized 2 plants/m2	Fertilized 4 plants/m2	Fertilized 6 plants/m2
	-206.2	-173.6	-145.8	-49.0	452.8	392.4
	-137.8	-30.9	73.3	490.6	1353.5	1893.2
	79.9	303.6	425.1	589.5	1522.1	2120.9
	100.5	303.6	427.1	1421.9	2551.0	3151.0
	196.1	411.8	534.0	1682.8	2970.5	3309.7
	395.2	561.2	607.0	1828.1	3126.5	4084.3
	472.2	614.3	672.7	1968.8	3384.7	4310.7
	711.9	891.7	909.0	2064.4	3506.8	4355.1
	784.2	1092.9	1143.3	2118.2	3548.0	4359.1
	802.8	1209.7	1192.4	2151.4	3600.4	4361.8
	1665.7	1765.9	1230.3	2368.4	3601.1	4397.0
	1800.5	1874.1	1455.3	2426.2	3603.7	4491.9
	2054.0	1886.7	1709.5	2444.8	3657.5	4558.9
	2058.7	2331.5	1971.0	2565.6	3781.6	4589.5
	2261.8	2752.3	2289.0	2681.1	4038.5	4647.9
Mean	869.3	1053.0	966.2	1783.5	2979.9	3668.2

Note: Cells in boxes contain values that are lower than those in the cells directly to the left.

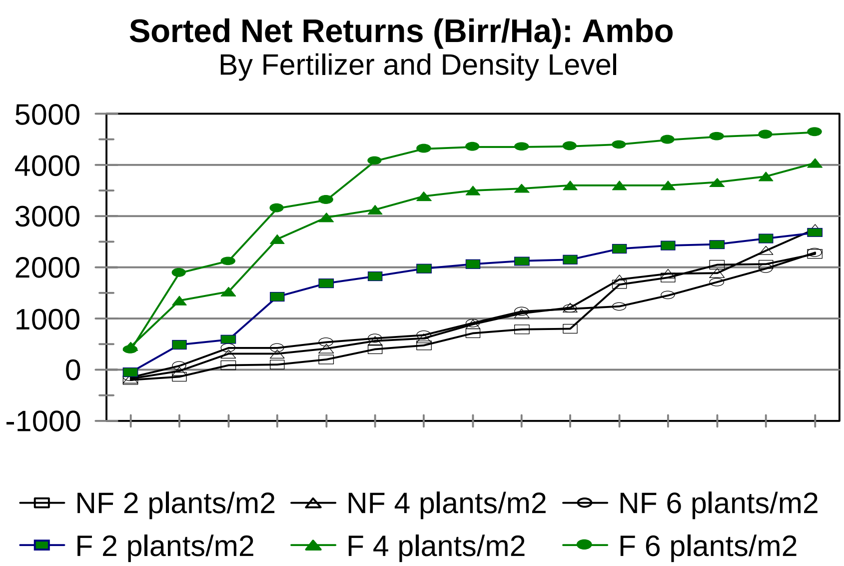

Figure 2. Sorted Net Returns: Ambo.

Table 7. Sensitivity and Risk Analysis of Net Returns for Jimma and Ambo

Jimma	NF2 a/	NF4	NF6	F2	F4	F6
Base Scenario	(Values = Birr/ha)					
Mean	1003.1	1218.4	1062.7	1648.3	2457.1	3129.4
Minimum	-355.0	-355.0	-355.0	-841.0	-841.0	-841.0
Maximum	1471.0	1750.5	1531.8	2064.5	2838.5	3554.3
No. < 0	2	1	1	1	1	1
C.V.	0.49	0.45	0.43	0.37	0.32	0.30
50% Reduction in Maize Price						
Mean	324.1	431.7	353.8	403.7	808.0	1144.2
Minimum	-355.0	-355.0	-355.0	-841.0	-841.0	-841.0
Maximum	558.0	697.7	588.4	611.7	998.7	1356.7
No. < 0	2	2	2	1	1	1
C.V.	0.76	0.64	0.65	0.76	0.49	0.41
50% Increase in Package Cost						
Mean	825.6	1040.9	885.2	1227.8	2036.6	2708.9
Minimum	-532.5	-532.5	-532.5	-1261.5	-1261.5	-1261.5
Maximum	1293.5	1573.0	1354.3	1644.0	2418.0	3133.8
No. < 0	2	2	2	1	1	1
C.V.	0.60	0.53	0.52	0.50	0.39	0.35
Farmer Yields Assumed 75% of Model Yields						
Mean	663.6	825	708.3	1026	1632.6	2136.8

Ambo	NF2	NF4	NF6	F2	F4	F6
Base Scenario	(Values =					
Mean	869.3	1053.0	966.2	1783.5	2979.9	3668.2
Minimum	-206.2	-173.6	-145.8	-49.0	452.8	392.4
Maximum	2261.8	2752.3	2289.0	2681.1	4038.5	4647.9
No. < 0	2	2	1	1	0	0
C.V.	1.00	0.85	0.72	0.46	0.35	0.35
50% Reduction in Maize Price						
Mean	313.7	405.5	362.1	440.8	1039.0	1383.1
Minimum	-224.1	-207.8	-193.9	-475.5	-224.6	-254.8
Maximum	1009.9	1255.2	1023.5	889.5	1568.3	1872.9
No. < 0	5	2	2	3	1	1
C.V.	1.38	1.10	0.96	0.94	0.51	0.46
50% Increase in Package Cost						
Mean	748.3	932.0	845.2	1332.5	2528.9	3217.2
Minimum	-327.2	-294.6	-266.8	-500.0	1.8	-58.6
Maximum	2140.8	2631.3	2168.0	2230.1	3587.5	4196.9
No. < 0	4	2	2	1	0	1
C.V.	1.16	0.96	0.82	0.62	0.42	0.39
Farmer Yields Assumed 75% of Model Yields						
Mean	591.5	729.2	664.2	1112.1	2009.4	2525.7

a/ Column headings: NF=nonfertilized; F=fertilized; 2, 4, 6 = number of plants per m2

Table 8. Percentage Reductions from Base Scenario Net Returns

	NF2 a/	NF4	NF6	F2	F4	F6
50% Reduction in Maize Price						
Jimma b/	67.7%	64.6%	66.7%	75.5%	67.1%	63.4%
	Ave. NF	66.3%		Ave. F	68.7%	
Ambo	63.9%	61.5%	62.5%	75.3%	65.1%	62.3%
	Ave. NF	62.6%		Ave. F	67.6%	
50% Increase in Package Cost						
Jimma c/	17.7%	14.6%	16.7%	25.5%		
	Ave. NF	16.3%		Ave. F	18.7%	
Ambo	13.9%	11.5%	12.5%	25.3%	15.1%	12.3%
	Ave. NF	12.6%		Ave. F	17.6%	
Farmer Yields Assumed 75% of Model Yields						
Jimma d/	33.8%	32.3%	33.3%	37.8%	33.6%	31.7%
	Ave. NF	33.2%		Ave. F	34.3%	
Ambo	32.0%	30.7%	31.3%	37.6%	32.6%	31.1%
	Ave. NF	31.3%		Ave. F	33.8%	

a/ Column headings: NF=nonfertilized; F=fertilized; 2, 4, 6 = number of plants per m^2.
b/ I.e., for NF2 a 50% lower maize price causes net returns to fall by 67.7%.
c/ I.e., for NF2 a 50% higher package cost causes net returns to fall by 17.7%.
d/ I.e., for NF2 reducing model yields by 25% causes net returns to fall by 33.8%.

Table 9. Breakeven and Switching Values

Breakeven Calculations	No Fert. 2 plants/m2	No Fert. 4 plants/m2	No Fert. 6 plants/m2	Fertilized 2 plants/m2	Fertilized 4 plants/m2	Fertilized 6 plants/m2
Jimma						
Maize price	0.14	0.12	0.14	0.18	0.14	0.11
Maize yield	683	683	683	1619	1619	1619
Fert cost	1309	1524	1369	2358	3249	3921
F = NF fert cost				1049	1643	2471
Ambo						
Maize price	0.15	0.13	0.14	0.23	0.16	0.14
Maize yield	365	365	365	1358	1358	1358
Fert cost	1040	1224	1137	2549	3745	4433
F = NF fert cost				1508	2521	3296

Switching Values a/	No Fert. 2 plants/m2	No Fert. 4 plants/m2	No Fert. 6 plants/m2	Fertilized 2 plants/m2	Fertilized 4 plants/m2	Fertilized 6 plants/m2
Jimma						
Maize price	-74%	-77%	-75%	-66%	-75%	-79%
Maize yield	-74%	-77%	-75%	-66%	-75%	-79%
Fert cost	N/A	N/A	N/A	362%	536%	667%
F = NF fert cost b/				105%	221%	383%
Ambo						
Maize price	-78%	-81%	-80%	-66%	-77%	-80%
Maize yield	-78%	-81%	-80%	-66%	-77%	-80%
Fert cost	N/A	N/A	N/A	399%	633%	768%
F = NF fert cost b/				195%	393%	545%

a/ Percentage change in the variable that makes net returns equal to zero.

b/ Percentage change in SG package fertilizer cost at which SG and local/no fertilizer net returns are equal.

Table 10. Second-degree Stochastic Dominance Analysis, Jimma, NF4 vs. NF6

Outcomes a/	1 if NF4	1 if NF6	NF4 area	NF6 area	NF4-NF6 b/
-355.0	1	0	0.0	0.0	0.0
-355.0	0	1	0.0	0.0	0.0
-347.2	1	0	0.4	0.4	0.0
-343.1	0	1	0.8	0.6	0.2
427.3	1	0	77.8	77.6	0.2
685.5	0	1	116.6	103.5	13.1
688.6	1	0	117.0	103.9	13.1
855.9	0	1	150.5	129.0	21.5
900.1	1	0	159.3	137.8	21.5
995.6	0	1	183.2	157.0	26.3
1007.1	0	1	186.1	159.8	26.3
1087.6	1	0	206.2	184.0	22.2
1098.0	0	1	209.3	187.1	22.2
1103.7	0	1	211.0	189.1	21.9
1138.0	0	1	221.3	202.8	18.5
1146.8	0	1	224.0	206.8	17.2
1260.1	0	1	257.9	263.4	-5.5
1293.3	0	1	267.9	281.7	-13.8
1321.9	1	0	276.5	298.8	-22.3
1322.9	1	0	276.9	299.5	-22.6
1361.9	1	0	292.4	322.8	-30.4
1380.1	1	0	300.6	333.7	-33.1
1409.7	0	1	315.4	351.5	-36.1
1411.2	0	1	316.2	352.5	-36.3
1468.4	1	0	344.8	392.5	-47.7
1610.7	1	0	423.1	492.2	-69.1
1612.8	0	1	424.3	493.6	-69.3
1613.3	0	1	424.6	494.0	-69.4
1621.6	1	0	429.6	500.6	-71.0
1641.4	1	0	442.4	516.4	-74.0
1684.5	0	1	472.6	550.9	-78.3
1720.8	1	0	498.1	581.8	-83.8
1745.3	0	1	516.4	602.6	-86.2
1761.4	1	0	528.5	617.1	-88.6
1779.0	1	0	542.6	633.0	-90.4
1804.0	0	1	563.8	655.4	-91.6
1807.6	1	0	566.9	658.9	-92.0
1886.0	0	1	637.5	733.4	-95.9
1974.9	1	0	717.4	822.2	-104.8
2099.0	1	0	835.4	946.4	-111.0

a/ Outcomes for both NF4 and NF6, sorted together from lowest to highest.

b/ If this col. contains both positive and negative values, neither technology dominates the other.

Source: Calculations based on procedure presented in Worman and Schurle, 1990.

Table 11. Cumulative Probability Distributions for NF4 vs. NF6, Jimma

	6 plants/m2 ('00 Birr/ha)	Prob of Value <= X-axis Value	4 plants/m2 ('00 Birr/ha)	Prob of Value <= X-axis Value
#1=	-3.60	0.00	-3.60	0.00
#2=	-2.54	0.05	-2.54	0.05
#3=	-1.48	0.05	-1.48	0.05
#4=	-0.42	0.05	-0.42	0.05
#5=	0.64	0.05	0.64	0.05
#6=	1.70	0.05	1.70	0.10
#7=	2.76	0.10	2.76	0.10
#8=	3.82	0.10	3.82	0.10
#9=	4.88	0.10	4.88	0.10
#10=	5.94	0.10	5.94	0.10
#11=	7.00	0.10	7.00	0.10
#12=	8.06	0.15	8.06	0.10
#13=	9.12	0.25	9.12	0.25
#14=	10.18	0.35	10.18	0.25
#15=	11.24	0.45	11.24	0.30
#16=	12.30	0.65	12.30	0.35
#17=	13.36	0.70	13.36	0.45
#18=	14.42	0.80	14.42	0.60
#19=	15.48	1.00	15.48	0.70
#20=	16.54	1.00	16.54	0.80
#21=	17.60	1.00	17.60	1.00

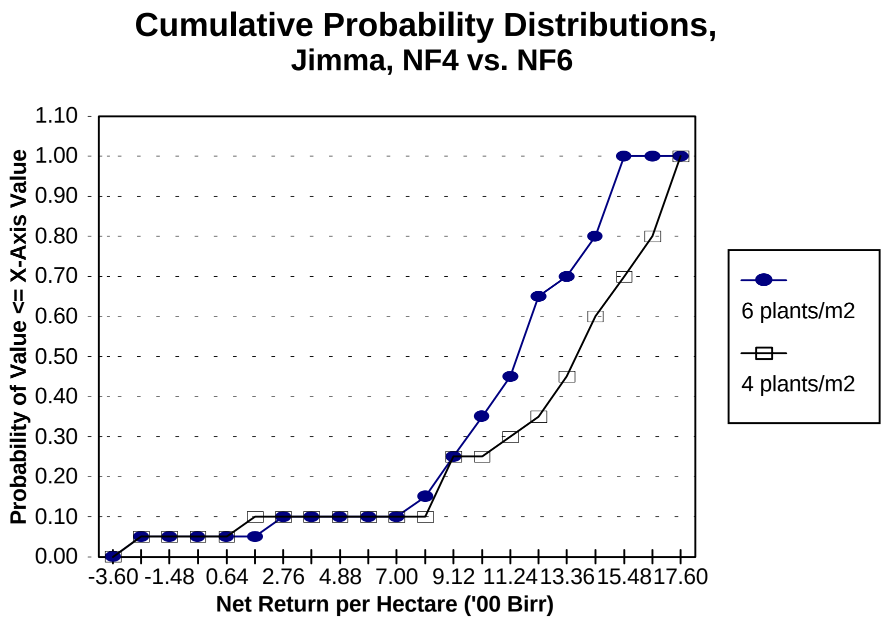

Figure 1. Cumulative Probability Distributions, Jimma, NF4 vs. NF6