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The University of Arkansas, Fayetteville
(International Agricultural Programs)

and

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Rwandan Institute for Agricultural Sciences (ISAR)

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An Economic Analysis of Traditional Bean Production in the Highlands of Rwanda

Malcolm Mayfield

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AN ECONOMIC ANALYSIS OF TRADITIONAL BEAN PRODUCTION IN THE HIGHLANDS OF RWANDA

EXECUTIVE SUMMARY OF A MASTERS THESIS, DEPARTMENT OF AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY, UNIVERSITY OF ARKANSAS, 1988

Malcolm Mayfield

INTRODUCTION

This report presents the results of an econometric analysis of bean production in the Rwandan Highlands.[1] The study described is significant because systematic, quantitative studies of the traditional bean production system have not been available previously, despite the fact that beans (*Phaseolus vulgaris*) have long been a crop of preeminent importance in Rwanda. The principle findings of this study are: a) labor is used efficiently but returns at the margin are now critically low; b) opportunities exist for major gains in productivity from soil amendments, especially phosphorous and lime; c) bush beans can be preferable to higher-yielding pole beans in some circumstances, even when staking materials are plentiful; d) management practices and economic performance are associated with altitude, distance of the farm plot from the *rugo* (main dwelling) and the type of bean field (i.e., pole bean or bush, intercropped or pure).

Overview of The Agricultural Economy of Rwanda.

Rwanda is a small (26,388 km^2), landlocked country in east-central Africa. Its population in 1989 was estimated to be over seven million, making it the most densely populated country on the continent (Population Reference Bureau, 1989). Population density on arable land is currently estimated to be 400 persons/km^2 (USAID, 1987). The Rwandan population is overwhelmingly rural (95%) and employed in agriculture (91%), which in turn contributes around 42% of gross domestic product (USAID, 1987).

Rwanda is surrounded by low-income countries, and its prospects for developing export industries are limited by its remote location. Goods must travel 1800 km to reach the nearest port at Mombasa. High transport costs raise the price of imported chemical fertilizers to 2.5 times their world market prices (Neumann, 1983).

Despite geographical isolation and the high concentration of people in farming, the performance of the agricultural sector since independence from Belgium in 1962 has been good relative to the rest of sub-Saharan Africa, which has suffered declines in per capita food production. Output in the sector grew slightly faster than population and contributed to GDP growth of 6%/year from 1974 to 1981, raising Rwanda's per capita income from the lowest in the world in 1972 to the seventeenth lowest in 1981. GNP per capita was estimated to be $290 in 1986 (USAID, 1987; World Bank, 1988). Food crop production increased by an average of 4.3%/year between 1966 and 1983, attributable mainly to an expansion of the harvested area averaging 3.7%/year (USAID, 1987).

Recent trends in population growth and food output are not encouraging, however. The annual rate of population growth has accelerated from 2.6% in 1960-70 to 3.4% in 1970-80 and 3.8% in 1988 (May, 1988; World Bank, 1983). In contrast, the growth of agricultural output slowed to 2.6% in 1980-85 since, by the end of that

[1]The research was conducted during 1987-88 for the Farming Systems Research Program, a USAID farming systems research project based at Rwerere, Rwanda. The study area covers four of the 16 communes in Ruhengeri prefecture.

period, virtually no suitable land remained to be brought under cultivation. The response of farmers to the shortage of new land has been to shorten or eliminate fallow periods and adopt double and even triple cropping in some areas. Most of the recent growth has probably come from increases in cropping intensity. Accurate information on crop yields is not available for Rwanda as a whole, but most indications are that yields have declined along with soil fertility.

Rapid population growth and the traditional practice of dividing the land among sons have led to fragmentation and very small holdings. The average farm was just 1.2 ha in 1986 and supported about six persons. Only 20% of farms are larger than 2 ha (MINIPLAN, 1988).

Farmers produce primarily, but not entirely, for their own subsistence. A 1984 survey revealed that 80% of rural households produce over 52% of the food they consume.[2] For staples such as beans, over 90% of total output is consumed directly by the farm family (i.e is not sold or traded), while only 23% of all food consumed (by value) is purchased (MINIPLAN, 1988).

Food imports from neighboring countries represent a substantial part of the commercial market for some products, primarily beans and sorghum. Imports of these commodities provided over half of the amounts purchased in 1986 (Loveridge, 1988).

For Rwanda to avoid rapid declines in per capita food production, sustainable increases in the productivity of small farmers are essential. To achieve this requires a concentrated effort by agricultural researchers to adapt suitable yield-increasing technologies to the conditions of the subsistence farms that predominate in Rwanda. In the past, however, agricultural researchers have lacked adequate information on the characteristics (e.g cultural practices, input and output levels, production constraints) of these farms. This is in part due to the extremely limited capacity of Rwanda's agricultural research system (as recently as 1982, Rwanda had only one PhD-level agricultural scientist), but it is also due to a previous emphasis on export crops (coffee, tea, cinchona and pyrethrum).

Initiation of the Study.

Diagnostic surveys undertaken in the study area in 1985 as part of the Farming Systems Research Project (FSRP) indicated that beans are a critically important component of local farming systems in terms of cropped area and as the principal source of protein in the diet (Franzel et al., 1985). Bean production problems thus became an important focus of research efforts.

At the inception of the FSRP, information on current (i.e., traditional) production practices was virtually nonexistent. To formulate a sensible research program, the FSRP required an empirically based description of bean production. The need for an adequate knowledge base led to the initiation, in 1986, of a study of traditional bean production. One of the goals of the study was to identify variables that can be used to organize farms or fields in ways that can improve further research.

One limitation of the above study was that data were not collected on soil and other physical factors likely to have important effects on bean yield. This led to generally inconclusive, if not misleading, results. Large differences between locations, for instance, could not be explained. Regressions on yield, moreover, had limited explanatory power, and little confidence could be placed in the estimated coefficients, many of which were not significant.

In order to resolve some of these problems, a second study of the traditional bean production system was initiated in July 1988. This paper reports the results of that study. Since this research is essentially a refinement and extension of the previous work, it may be viewed as the second phase of a single study of bean production. Hereafter, the previous study and the current study will be referred to as Phase I and Phase II, respectively.

Although they relate to a single food crop, these studies are intended to serve as prototypes for expanded analyses of farming systems in Rwanda.

Research Goals and Objectives.

The general goal of the study was to provide the detailed, quantitative information on the existing bean production system that can serve as the framework for designing a research (and extension) program for beans in the project area.

The specific objectives of this study are:

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[2]Production of most crops was unusually low in 1984 due to drought. It is likely that food purchases were higher than normal in that year, with much of the purchased food coming from outside Rwanda.

1. Identify socio-economic and agro-ecological variables that act as constraints in bean production.
2. Evaluate the economics of input use in bean production under prevailing prices and rates of use in the traditional system.
3. Use the variables identified as significant in bean production (and others) to examine the usefulness of some proposed classification schemes.

The first objective is accomplished by performing regression analyses of yield and variable inputs found to significantly affect yield. The second is achieved primarily by examining the coefficients derived from regressions of yield and interpreting these in terms of marginal value products and marginal factor cost. The third is accomplished using analysis of variance to test for significant differences between groups of fields and farms. The results are used to make some general comparisons of proposed classification schemes. The practical use of these as classification schemes is left to researchers to determine according to the specific issues raised in their applied research.

DATA AND METHODS

Effective agricultural research begins with the identification and ranking of the problems faced by the intended beneficiaries of the research effort. To varying degrees, however, newly initiated agricultural research projects lack sufficient information to perform this task with precision.

In Rwanda, the FSRP project combined second-hand sources of information with its own formal and informal surveys to develop a physical and socio-economic profile of the project area. Considerable effort was made toward identifying distinctly different groups of farmers.

The diagnostic survey confirmed that beans are a particularly important component of farming systems in both medium- and high-altitude zones, occupying a large percentage of the cropped area. They are grown on at least 95% of the farms in the project area. Rainfall in both zones is bimodal, allowing two growing seasons (season A, September to January; and season B, March to July). Beans are grown in both seasons.

The Phase I Study of Bean Production.

The Phase I study, reported by Brewster (1988), explored alternative ways of classifying farms and fields for research purposes.[3] Major emphasis in the study was placed on describing the prevailing patterns of ownership and use of land, animals and labor. This examination of resource endowments found that no clear pattern of stratification existed in a sample of 223 farms from the Buberuka Highlands. Similarly, for a sample of 45 farms with a total of 81 bean fields, most bean production variables did not vary significantly by the same set of resource variables.

The production variables examined are listed in Table 1 with their means and standard deviations. Judging from the magnitude of the standard deviations relative to the means, it is clear that farms (or at least fields) are far from uniform.

Some of the variation in these production variables was found to be associated with three "agro-ecological" variables: location (a dummy variable for commune), the degree to which beans are intercropped (mainly with maize or sorghum) and the type of bean grown (Table 2).[4]

The extension of the socio-economic analysis of bean production (Phase II) was initiated in July 1988 by collecting additional data to supplement the data collected by Brewster during Phase I.

In Phase I, data were collected from a sample of 81 fields on labor inputs, seed and organic fertilizer inputs, field sizes, plant density counts and yields of beans in the 1987 A season. At the farm level, data were collected from 45 farms on the composition of the household, animal ownership, past use of non-family labor and farm size (ha). A list of Phase I variables is given in Table 3.

Data Collected for Phase II.

Analysis of agro-ecological variables was not a major aspect of the previous research. Indeed, location (identified as one of four communes) was the only variable examined, reflecting physical differences between sites. Data on the topographical position of the field (i.e, peak, plateau, etc.) were collected but not analyzed.

[3]Four variables related to resource endowment were examined: Farm size (ha), number of economically active household members (i.e, persons age 15 to 64), total animals owned, and total days of labor hired, for all crops, in the previous season.

[4]There are two main types of beans: pole beans (or climbing beans) and bush beans (semi-climbing or dwarf). Pole beans normally require stakes for support.

Although degree of intercropping and type of bean (bush or pole) were formerly included as agro-ecological variables, these are correctly viewed as management variables.

For Phase II, supplementary data were gathered between July and October 1988 from the same sample of 81 fields followed in Phase I. The additional data reflect greater emphasis on physical factors (Table 4).

Key Hypotheses:

1. Regression (OLS).

Since the principle objective of the regression analyses was to identify important explanatory variables, rather than to test a narrowly defined model or hypothesis, a variable selection technique was employed throughout to eliminate insignificant variables. Specifically, a backward selection algorithm was used to eliminate variables whose coefficients were not significant at the 90% confidence level. Backward selection begins with all of the available variables in the model and then omits the variable with the smallest t-ratio. This procedure continues until all of the variables remaining in the model have significant coefficients (SPSS, 1988).

Two main series of relationships were examined using multiple regression. Major emphasis was placed on the first of these, the estimation of yield response surfaces. The other series examined land preparation and weeding labor inputs.

Yield.

Given the possibility that pole beans and bush beans respond differently to labor inputs, plant nutrients and other factors, yield equations were estimated separately for each bean type. Brewster (1988) suggested that higher observed labor and organic fertilizer rates for pole beans may be due to greater marginal returns to these inputs compared to bush beans. That is, at a given level of input, the marginal return to the input may be higher for pole beans. Thus, separate equations were compared to determine differences between bean types in terms of significant variables and the magnitude of estimated coefficients.

Independent (explanatory) variables tested in the yield equations include the following: seeding rate (or plant density), planting month, altitude (a proxy for temperature and rainfall), compass orientation of the field, banana trees/ha, the dominant variety intercropped with beans, land preparation and weeding labor rates and soil properties (N, P and pH). These variables are listed in Table 5 with the hypothesized signs of their respective coefficients.

Planting Month. The categorical variables in Table 5 were all converted into binary variables. For planting month, fields planted in September were compared with those planted earlier (i.e, September vs. non-September; no fields were planted after September). The only hypothesis made regarding the sign of this variable was the null hypothesis that the coefficient is equal to zero.

Orientation. For the compass orientation of the field, fields facing northeast or southeast (0 to 180 degrees from true north) were expected to yield higher than those facing northwest or southwest because of exposure to morning sunlight (cloudiness tends to increase during the day).

Variety. Fields planted to a single, named variety were expected to yield more than fields planted to a mixture ("melange") of unnamed varieties. The assumption is that planting mixtures of varieties is a risk-averse strategy that accepts a lower mean yield in return for less risk (yield variability).

Intercrop Species. It was hypothesized that peas reduce bean yields more than other intercropped species due primarily to their ability to compete very strongly for space--a consequence of the spreading, climbing growth habit that peas exhibit. Other intercrop species included maize and sorghum. Bananas were not counted as an intercrop but were analyzed separately for their effect on yield.

Altitude. Altitude is inversely related to both temperature and rainfall in the region. Higher temperatures may have had a positive effect on yields in the lower altitudes, but in the season studied, excessive rainfall was the most frequently cited explanation for reduced yields. This hypothesis is thus unique to the season studied. In "normal" years, one might hypothesize a negative relationship between altitude and yield.

Labor, Seed and Soil Chemical Properties. The coefficients associated with labor, seed and nutrient input levels are of particular interest for their economic implications. For example, given local bean prices and wages, the coefficient of preparation labor (when other factors are held constant) can be used to evaluate the efficiency of the market for this input. Assuming that producers are rational and have sufficient information about the responses to alternative inputs and input and output prices, one can expect that the marginal product of an input will be worth at least as much as the marginal cost of the input over the range of input levels represented in the sample. Given the very low resource levels at which most farmers in the region operate, however, it was expected that farmers may be constrained in their access to some inputs, such that the value of the marginal

product of these inputs is higher than marginal factor cost. This was particularly expected in the case of seed since farmers must frequently purchase seed, and cash is said to be extremely limited for most farmers (Franzel et al., 1985).

Labor Inputs.

Labor was separated by production tasks, of which land preparation and weeding were examined separately in regression analyses.

A previous report (Franzel et al., 1985) suggested that labor availability may be constraining during the land preparation and weeding periods in the crop calendar (i.e. August/September and October/November, respectively). Assuming that land preparation and weeding labor input rates are significantly related to yield, it is important to identify factors explaining differences in these rates between fields.

The independent variables assumed to affect labor inputs are listed in Table 6 with the expected signs of their coefficients for each category of labor.

A key assumption underlying the labor input models was that farmers may be partially constrained in their ability to procure labor from outside of the family. Labor inputs are, therefore, a function of the supply of family labor (per ha of farm land) as well as factors that tend to detract from the availability of that labor for bean production, such as the distance family members must walk from the *rugo* to the nearest market or source of drinking water and alternative tasks such as tending animals. In this respect, animals per family laborer was hypothesized to be negatively related to labor inputs. Presumably, the greater the number of animals per person, the more that tending animals will compete with bean production tasks as a use of family labor.

The distance from the *rugo* to the bean field, on the other hand, can be viewed as affecting the cost of labor inputs since the time required to go to and from the bean field was not included in estimates of labor inputs.

Similarly, if weeding and tilling the soil are more difficult on steeper slopes, it should take longer to achieve the same result. This suggests that the marginal value product (MVP) of labor is lower on steep slopes at any given level of labor inputs. Assuming that farmers equate the MVP of an input with its marginal factor cost (MFC; i.e, the wage rate), labor rates will fall as slope increases. This also assumes that labor is non-limiting and that the MVP is decreasing over the range in which MVP equates with MFC.

An alternative hypothesis is that farmers attempt to reduce the erosion risks of steeply sloped fields by leaving the soil in a rougher state of preparation and allowing larger weed populations.

The size of the bean field was included as an explanatory variable to test the hypothesis that there are economies of scale with regard to tilling and weeding fields.

The density of bean plants (plants per unit of land) was hypothesized to be negatively associated with weeding labor since denser stands of beans would tend to suppress weeds and reduce weeding requirements. This variable was applied to all fields whether intercropped or not.

Since labor inputs were anticipated to be partly dependent on bean type, this variable was included as a dummy variable. Pole beans were hypothesized to receive greater labor inputs than bush beans.

2. Analysis of Variance.

Socio-Economic Variables. In Phase I, farm size, family labor, outside labor use and animal ownership were analyzed using cross-tabulation and correlation matrices (to determine the degree of intercorrelation) in addition to bivariate ANOVAs to determine their "effects" on bean production variables. In Phase II, the above variables were redefined as three "rate" variables: family labor, outside labor use and animal ownership were expressed in terms of units/ha of farm land. These variables were examined for inter-correlations and their impact on production variables as before, except that Duncan Multiple Range Tests were added in Phase II.

Farm Size. Some researchers have suggested that relatively large farms differ from smaller farms in many significant ways (Zalla, 1988). Zalla suggested "a classification based primarily on farm size," with "low-resource systems" having under 0.5 ha of cultivable land, and "high-resource systems" having more than 1.5 ha. In the following passage, Zalla explains the rationale for basing farm classification on farm size:

> The diagnostic work indicates that various problems relating to soil fertility top farmers' concerns by a factor of three to one. Under current circumstances, the potential for increasing fertility is a function of the amount of manure and compost that the system can generate and the fallow cycle. These, in turn, are related to farm size and the availability of labor for feeding, watering and caring for animals and distributing the manure. Thus, we would hypothesize that larger farms and/or farms with more active workers tend to have more fertile soils and higher crop yields than the average farm. (Zalla, 1988, pp. 6-7)

With the additional observations on farm size collected for Phase II, the hypotheses alluded to above were tested using similar break-points to define large, medium and small farms. Break-points were modified slightly to reflect the actual separation in the sample distribution.

Altitude. FSRP researchers have in the past used altitude to define different research zones and as a criterion for selecting sites for on-farm trials (Franzel et al., 1985; Yamoah and Mayfield, 1988). Much of the effect of altitude on farming systems is believed to come indirectly through the relationship between altitude and temperature. Some crops (e.g, peas and wheat) perform well at high altitudes and relatively low temperatures, while others (e.g, bananas and cassava) perform poorly in the same environment. In general, however, relationships between altitude and other factors important in the production of beans and other crops are not well understood. In Phase II, therefore, an attempt was made to evaluate how such factors vary by altitude.

Distance From the *Rugo*. The distance to the field from the *rugo* is widely believed to be of primary importance in determining how the field is managed. Intensively managed, high-value crops such as fruit, vegetables and tobacco are commonly grown near the *rugo* where they can be guarded against theft and bird damage. Proximity to the *rugo* also reduces the "cost" of applying labor and fertilizer, in terms of time spent going to and from the field, thus tending to increase the use of these inputs. Despite the potential importance of this variable, however, no attempt has yet been made to quantify its effects. The question investigated in Phase II was thus: Are "close" fields sufficiently different from "far" ones to justify using this variable to classify fields into different groups for analysis?

RESULTS AND DISCUSSION

Yield.

Initially, the sample was divided into two groups according to bean type: bush and pole beans. Regressions for both groups generally resulted in low adjusted R^2's, with few coefficients significantly different from zero.

One concern was that highly intercropped fields might be substantially different from relatively pure stand fields, therefore making the underlying relationships more difficult to detect. This issue was addressed by separating fields that were highly intercropped from those that were not by creating a third category of fields defined according to the percentage of total plants in the field that were beans: category 1 = moderately intercropped and pure bush bean fields (percentage bean $\geq$ 88); category 2 = moderately intercropped and pure pole bean fields (percentage bean $\geq$ 88); and category 3 = heavily intercropped bush bean fields (percentage bean < 88). Four pole bean fields were found by this definition to be heavily intercropped and were subsequently excluded from the analysis of yield.

Linear Yield Model.

The model in Table 7 combines the results of the separate yield equations for each bean field category by introducing slope and intercept dummies, the former only for seed rate, phosphorous, pH and labor variables. It excludes orientation, culture (dominant intercrop species) and nitrogen, which were not helpful in explaining yield for any category. The coefficients are in units of kg/ha of dry beans. Variables followed by 1 and 2 refer to category 1 and 2, respectively. Category 3 (intercropped bush beans) was the reference category. This model assumes linear relationships, at least as local approximations.

With the exception of category 2 ("pure" pole beans), the signs of the variables in the model are consistent with the hypotheses made earlier.

Variety. Several aspects of this model are worth noting. Consider, for example, the intercept dummy for variety. It appears that fields planted to a single variety do yield more than mixed fields. This difference, equivalent to 3,392 Rwandan francs (FRw)[5]/ha, might be viewed as a premium paid by farmers who choose to grow mixtures of varieties, presumably as a risk-reducing strategy. The coefficient is not highly significant, however.

Planting Month. The coefficient of the dummy variable for planting month ("SEPTEMBER," where September = 1, July or August = 0) is more difficult to interpret. It is possible that the yield of late-planted beans was higher because they were less affected by adverse rainfall conditions; heavy rainfall was cited by many farmers as the primary cause of poor harvests in the 1987 A season (Brewster, 1988). However, rainfall data from a site near the center of the project area indicate that rainfall was abnormally low from July to

[5]At the 1986 average official exchange rate, 80 FRw = $1.00. The 1986 average price was reported to be approximately 25 FRw/kg of dry beans (Brewster, 1988).

September. This suggests that the positive coefficient is due to drought stress reducing yield of earlier-planted fields. Whether the observed yield advantage is consistent over time is not known.

On the other hand, there is often a price advantage associated with harvesting earlier. Market prices for beans at the nearby prefectural capital tend to fall about 5 FRw/kg between December and January. In the same period of the previous year, the price fell 14 FRw/kg (MINAGRI, 1986).

Intercepts. The intercepts for category 1 and 2 are significantly lower than that for category 3. It is interesting to note that these intercepts ascend in the order category 2, 1, 3, although this is opposite to the order for yield: type 3 = 505.4 (kg/ha); type 1 = 639.3; type 2 = 1083.2. This confirms that pole beans are more responsive to inputs than are bush beans. At low input (and pH) levels, pole beans yield less than bush beans. Thus, unavailability of stakes may not be the only important reason why more farmers do not grow pole beans. In this sample, only 23 of the 81 fields (28%) were planted to pole beans.

Banana Trees. The positive coefficient for banana trees/ha suggests that the benefits from banana plants outweigh any negative shading effects they may have on beans.[6] Casual observation of banana groves indicated apparently high levels of organic matter in the soil and a build-up of mulch on the surface. Possible benefits from organic matter and mulch include 1) faster formation and greater stability of soil aggregates for improved soil structure, 2) protection from the impact of raindrops, 3) greater infiltration of water--less surface run-off, 4) greater capacity to hold moisture, slower evaporation and less frequent occurrence of plant moisture stress, and 5) greater effective cation exchange capacity, or ECEC (i.e, greater nutrient holding capacity) (Hausenbuiller, 1985).

To some extent, it is possible that the positive effect of banana trees seen here is in fact related to additional factors not directly related to the banana trees themselves. In this regard, it is noted that farmers prefer to plant bananas close to the *rugo* (e.g., see Appendix Table A.6.1), in part to protect the crop from theft, and that fields closest to the *rugo* tend to receive the greatest applications of manure and compost. Given the importance of both bananas and beans in the rural economy, additional research on this association seems justified.

Four slope dummies were found to be significant for pole beans: seed rate, land preparation labor, pH and phosphorous. Only two slope dummies, weeding labor and phosphorous, were significant for category 1.

Seed Rate. The coefficient for the interactive seed rate variable suggests that the MVP of pole bean seed is quite high. Brewster (1988) used values of 25 FRw/kg for yield and 30 FRw/kg for seed. These values give a marginal value product of 58.6 FRw/kg[7] and a marginal factor cost of 30 FRw/kg, for a benefit/cost ratio of 1.95. It is possible that this reflects the cash constraints of farmers.

Another possible explanation is that, lacking sufficient stakes, farmers plant fields more sparsely than if stakes were abundant at low cost. Such a practice might lead to sub-optimal returns to land but higher returns to other inputs (seed, stakes) if the yield per plant is greater at lower densities. This second explanation is perhaps preferable as it applies more to pole beans than to bush beans, for which the interactive seed rate variable was not significant.

Preparation Labor. Land preparation labor does not appear to be limiting for bean production in the project area. Evidence of this comes from the coefficient of the interactive preparation labor variable for pole beans (and for intercropped bush beans in a quadratic functional form, discussed below). The coefficient, equal to the marginal physical product (MPP) in a linear model, is 0.31 kg/hour of labor. This is equivalent to 7.8 FRw/hour, valuing yield at the 1986 average price of 25 FRw/kg.[8] This is not significantly different from the observed, simple average wage for preparation labor during the 1987 A season, 8.95 FRw/hour.

Weeding Labor. In the above linear model, weeding labor for category 1 was the only labor variable found to be significant for bush beans. The MVP of weeding labor, again at a price of 25 FRw/kg for dry beans, is 19 FRw/hour and more than twice that found for preparation labor applied to pole beans. Conclusions regarding the allocation of labor between these two uses cannot be made, however, since they occur at different periods in the season.

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[6]Among the 31 fields with banana trees, the mean density was 424 banana plants/ha.

[7]The MVP is calculated by multiplying the marginal physical product (MPP) (i.e, for a linear function, the estimated coefficient) times the product price. For seed rate: 2.344 (kg/ha) x 25 (FRw/kg) = 58.6 (FRw/ha).

[8]According to price data presented in Appendix B of the thesis, however, the average price per kg from December to January over the five years prior to the year studied was 31.9 FRw (29.6 in January and 34.2 in December). Farmers' actual price expectations are thus likely to fall between this value and the 1986 average price of 25 FRw/kg.

In considering the relatively high MVP of weeding labor applied to category 1 fields, it is worth noting that this category received the least weeding labor per hectare (significantly less than pole beans). The results suggest that farmers may underestimate the marginal value of weeding labor applied to pure and moderately intercropped bush beans.

Soil Acidity: pH. In a recent report, Yamoah et al. (1990) report that mean pH levels for three zones within the project area (northern, middle and southern) fell between 5.01 and 5.39. For the 81 fields in the present study, mean pH was 5.5, and there were no significant differences between field categories[9]. From the coefficient of pH for pole beans, however, it is clear that pole beans are likely to benefit substantially from liming when pH is low (e.g, below 5.5). There is no similar evidence that bush beans would benefit.

The coefficient of pH for category 2 suggests a benefit of 638 kg/ha, approximately valued at 16,000 FRw/ha, for each unit increase in pH. This value, suitably discounted for labor costs and risk, can be compared with estimated lime requirements to calculate a plausible break-even cost of lime.[10]

Available Soil Phosphorous. The phosphorous x pole bean interactive variable has a coefficient of 65.6, which represents, at 25 FRw/kg of beans, an MVP of 1,640 FRw for each part-per-million increment in available P in the soil. This is similar to the corresponding value for category 1 at 1,365 FRw/PPM soil P. The significance of P in this sample corroborates the findings of FSRP scientists who found that pole beans respond significantly to applications of 60 kg/ha of P_2O_5 fertilizer[11] (Yamoah and Burleigh, 1989).

Yield Model Allowing Non-linear Relationships.

In the preliminary regressions performed for category 3, analysis of residuals and partial regression plots suggested that some modifications in the assumed functional form were warranted. These modifications involved the addition of squared terms for preparation and weeding labor to give quadratic functions. The model presented in Table 8 incorporates these changes into the previous, linear model.

In this model the dummies for category 1 and variety were not significant, and these were excluded. The coefficients are again in units of kg/ha.

Although the changes in the model affect the values of some coefficients more than others, most of the changes are modest. The exception is the coefficient of planting month ("SEPTEMBER"), which increases by over 50%.[12] R^2 increases slightly compared to the previous model, but the real gain comes from now being able to compute two additional MVPs from a single category.

Marginal Product of Labor (MPP). Evaluated at their means, the MPPs of preparation and weeding labor for category 3 are 0.328 and 0.288, respectively.[13] At 25 FRw/kg of beans, the MVP of preparation labor is 8.20 FRw/hour, or just 0.75 FRw/hour less than the observed average rate of 8.95. The MVP of weeding labor is calculated to be 7.20 FRw/hour compared to an observed average wage for weeding labor of 8.13 FRw/hour. For both weeding and preparation labor, the estimated MVPs are not significantly different from the mean wage (falling within the 95% confidence intervals of mean wages paid for weeding and preparation labor)[14].

The purpose of this study is not to test the validity of the neo-classical model, but these results do provide incidental evidence that the behavior of Rwandan farmers may agree closely with the predictions derived from that model. Researchers are well advised to assume that farmers perceive accurately the productive value (at the margin) of traditional inputs. This view is further supported by the results of an analysis of labor inputs as dependent variables (see below)

An important implication of the yield models' results is that the marginal product of labor is already low in terms of both nutritional and monetary value. With the possible exception of weeding labor for category 1, and

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[9]See the appendix at the end of the paper.

[10]Agronomic research on liming is proceeding in the study area.

[11]This yield difference refers to that between plots with prunings of *Sesbania sesban* only and those with prunings plus 60 kg/ha of fertilizer added.

[12]The larger value is closer to the values obtained for the two bush bean categories in separate equations (both about 400 kg).

[13]Two outlying observations on weeding labor shift the mean upward by 184 hours/ha. The mean excluding these observations (587.7) is close to the median with them included (568), either of which appears to be a better indicator of the central tendency in the sub-sample. It was also discovered that both observations come from a single farm that paid an unusually low wage for weeding labor (5.8 FRw/hour). The MVP of weeding labor is evaluated at the mean excluding the two observations.

The mean of preparation labor for category 3 is 760 hours/ha.

The reported MPPs were calculated prior to rounding the coefficients in the table.

[14]The 95% confidence intervals for the means of category 3 weeding and preparation labor wages were 6.23 - 9.78 FRw/hour and 7.87 - 10.5 FRw/hour, respectively.

barring any increase in planted areas, there appears to be little scope for absorbing additional labor in the production of beans with traditional methods.

This fact is particularly clear when one examines the nutritional value of the roughly 0.3 kg of beans that an hour of labor produces at the margin. According to Government of Rwanda (GOR) data, a kilogram of dry beans provides 323 kilocalories (Kcal) and 21.7 g of protein (MINIPLAN, 1988). These values times 0.3 give 97 Kcal and 6.5 g of protein.

Alternatively, one can examine the number of calories that can be purchased with the hourly wage. The average wage for all hired labor was found to be 8.55 FRw, whereas the 1986 price of maize, a starchy staple, was approximately 16 FRw/kg (MINIPLAN, 1988). According to GOR data, maize kernels contain 360 Kcal/kg (MINIPLAN, 1988). For an eight-hour day, these figures suggest that labor is valued at only 1,540 Kcal/day. This is compared to the estimated 2,100 Kcal/day required by adults for maintenance of good health (Loveridge et al., 1988).

Although some labor, particularly weeding labor, is provided by children with lower caloric requirements, the marginal products and wages observed imply that average labor utilization rates are already approaching the point at which marginal value equals marginal cost in terms of calories. Beyond this point, additional labor inputs result in a net loss of calories.

Summary of Yield Model Results.

The results of the yield response models demonstrate clear differences between bush and pole beans. In particular, pole beans are more responsive to pH, phosphorous and seeding rate. These differences are important since they imply that the availability of staking material may not be the only factor limiting the more widespread adoption of pole bean varieties. The results are encouraging, however, since they imply that applications of lime and/or phosphate may increase yields enough to be economically beneficial.

In terms of seed rate for pole beans, it was suggested that the seemingly high return to seed at the margin is probably a function of the scarcity of stakes rather than of seed per se. Successful efforts by FSRP researchers to popularize the practice of planting leguminous shrubs along the contours and terraces of fields should significantly increase the availability of stakes, reduce their cost and encourage farmers to expand the area planted to pole beans (Yamoah and Getahun, 1989).

The models also provide important information about the use of labor in the production of a basic food crop. It was found that while farmers do not appear to allocate labor inefficiently, the value of labor at the margin is generally very low, equivalent to only a third of a kilogram of beans per hour. When considering a proposed intervention involving additional labor requirements, researchers should bear in mind that an output-increasing technology is not likely to be adopted if it does not also increase the productivity of labor. Interventions need to be examined carefully for their effect on labor productivity.

Labor Input Models.

This section discusses the results of regression models for weeding and land preparation labor. These models combine log-log and log-linear functional forms that were found to fit the data considerably better than linear, linear-log or quadratic models.

The models presented in Tables 9 and 10 used as observations all 81 fields in the sample for which labor inputs were non-zero. The dependent variables are the natural logs of weeding and preparation labor inputs, expressed in units of hours of labor/ha.

In both models, field size and wages are significant, as is whether or not the farmer hired the respective type of labor ("PAYWEED" and "PAYPREP"). The signs of the coefficients of these variables are the same in both models. Also, some variables were not found to be significant in either model and were excluded. These were family laborers/ha, distance from the *rugo* to the nearest market and source of drinking water, the slope of the field and the type of bean.

Notice that bean plant density ("LN_DENS") was included only in the weeding labor model. Consistent with the original hypothesis, denser stands of beans apparently do reduce weeding requirements.

Hirers vs. Non-Hirers.[15] The results indicate that, ceteris paribus, farmers who hire labor tend to use labor at higher rates than those who do not hire labor. In a separate analysis, it was found that 84% of large farms (greater than 1.3 ha) hired labor for bean production, compared to 36% of small farms (less than 0.6 ha).

[15]Weeding and land preparation labor was hired for 26 and 38 fields, respectively.

It was also found that large farms are able to realize pecuniary economies in their ability to procure labor on favorable terms[16]. Although the average wage paid by the larger farms was significantly less than that paid by smaller farms, this fact does not explain the observed differences between hirers and non-hirers, however, since the effect of wages on labor use is included in the models explicitly.

Demand for Labor and Elasticities. In both models, the sign of the coefficient for wages is negative, indicating downward-sloping demand curves, as one might expect. The two types of labor appear to differ, however, in terms of their elasticity of demand with respect to wages. With a log-log functional form, the coefficient is equivalent to the elasticity. Thus, the elasticity of demand for weeding labor is -1.62, compared to an elasticity of -0.71 for preparation labor. In other words, relative to preparation labor demand, weeding labor demand is more than twice as responsive to wages. In a technical sense as well, weeding labor demand is elastic (less than -1), and preparation labor demand is inelastic (greater than -1).

An explanation for the difference in elasticities between the two types of labor may be found by considering that weeding and land preparation labor are, in fact, different types of activities with different requirements and physical effects. On the one hand, land normally must be prepared, and this must be done within a matter of days or weeks before rains become too heavy. Weeding, on the other hand, is never "completed" in the sense of making fields weed-free, and the task takes place over several months. This leads to greater elasticity of demand for weeding labor relative to preparation labor.

These differences are reflected in the coefficients of weeding and preparation labor for category 3 in the previous analysis of yield (Table 8). The quadratic production functions described by these coefficients also differ in a similar fashion--the slope of the yield response curve for preparation labor decreases much more rapidly than the curve for weeding labor. That is, the marginal value of preparation labor, in terms of increased yield, falls at a faster rate as more labor is used.

In a partial equilibrium framework in which farmers are assumed to equate marginal value products with marginal factor costs, one can derive a predicted input demand curve for labor by setting the MVP of labor equal to wages and solving for the latter (see Debertin, 1986, Chapter 13). Using the parameters for category 3 weeding and preparation labor to derive demand curves, one finds that these curves closely resemble the directly estimated demand curves implied by the results of the labor input models. Both pairs of demand curves are shown together in Fig. 1. Notice that for the "predicted" demand curves as well, weeding labor demand is more elastic than preparation labor demand.

Figure 1 shows graphically how production relationships can underlie market behavior. Moreover, it supports the conclusion that farmers producing primarily for their own subsistence are often well-informed about those relationships.

Animals per Laborer. The fact that demand for weeding labor appears to be more elastic than demand for preparation also suggests that alternative uses of laborers' time are more likely to compete with weeding inputs than with land preparation inputs. A case in point seems to be tending animals. "ANIMALS" was selected in the weeding labor model but not in the preparation labor model. This result agrees with the argument that tending animals is an activity that competes with weeding as a use of available labor.

Distance to Field from the *Rugo*. "D_RUGO" significantly reduces preparation labor inputs but not weeding labor inputs. Recalling the hypothesis made for this variable, it was suggested that increasing the time required to walk from the household to the field has the effect of increasing the cost of field tasks and decreasing labor input rates. The negative sign of the coefficient of "D_RUGO" supports this hypothesis.

Field Size. The finding that field size is negatively correlated with labor inputs suggests that farmers with large fields may not yet be fully utilizing land efficiently, assuming that larger fields are otherwise the same as smaller ones. Of course, this raises the possibility that fields of different sizes differ. Examining this question, it was found that smaller fields are more likely to be planted to pole beans than to bush beans. However, bean type was not significant in earlier models even when the field size variable was omitted.

Another possibility is that technical economies of size are realized with respect to labor inputs. The suggestion is that the same amount of work is achieved in less time on larger fields because of more efficient organization of some aspects of the work.

[16]See the appendix.

Results of Bi-Variate Analyses.

Duncan Multiple Range Tests (DMRT) were used in analyses of variance to test for significant differences in means for sets of agronomic, economic and other variables in several classification schemes. The independent variables used as classifiers were described earlier. Of the independent variables examined, the following six resulted in large numbers of significant differences: commune, altitude, farm size, family laborers per hectare of farm size, bean field category and the distance from the *rugo* to the field.[17] For each of these, a separate series of tables was constructed to summarize the results of the DMRTs.

The dependent variables are grouped under the following headings:

a. Socio-Economic Variables.

b. Field-Level Management Variables.

c. Field-Level Physical Variables.

d. Bean Production Inputs.

e. Yield, Costs and Returns.

f. Percentage of Total Fields in Different Field Categories.

Farm-level variables were not analyzed with respect to bean field categories or the distance of the field from the *rugo*.

Comparison of Classification Schemes

The appendix tables reveal the significant[18] associations found between independent and dependent variables. With few exceptions, at least one of the classifying variables listed across the top resulted in significant differences between the (sub-sample) means of the dependent variables.

Overall, grouping fields and farms according to commune produces the greatest number of significant differences between means. All of the field-level physical variables, for instance, differ by commune. This variable also appears to "capture" much of the observed variation in farm-level variables such as wages and family composition/size.

As opposed to commune, altitude can be used for classification analyses outside the project area. Although it varies significantly by commune, altitude showed no significant associations with the farm-level variables. At the field level, in contrast, most of the variables associated with commune are also associated with altitude. In terms of management variables, altitude is associated with planting month and the number of banana trees/ha.

It is interesting to note that the number of family laborers (persons age 15 to 64)/ha is associated with soil nitrogen, soil phosphorous and weeding labor rate while farm size is not, although farm size is somewhat negatively correlated with family laborers/ha.

Comparing bean field category with the distance of the field from the *rugo*, the most striking difference is in the production input variables. Seven out of 10 input variables, including seed rate and preparation labor, have significant differences by field categories. Only one input variable is associated with distance from the *rugo*. In contrast, the field categories variable is not associated with soil N and P, while distance from the *rugo* is.

An Example of Using Classification Results

The classification results can be used at different stages of the research and extension process. At early stages, they can help to guide the selection of sites and cooperating farmers for on-farm trials. At later stages, the results may be used to adjust recommendations to farmers to improve the appropriateness of an intervention.

As an illustration of how these results may be used, consider again the issue of soil acidity's effect on yield and the potential for liming acid soils. In the analysis of yield it was found that the problem seems confined to

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[17]The four communes in the project area and the three bean field categories were the basis on which sub-samples were formed for these two variables. For the continuous independent variables, break-points defining three sub-samples were as follows:

Altitude:	2,000 m and 2,200 m
Farm size:	0.6 ha and 1.3 ha
Family Laborers/ha:	2.27 and 5.00
Distance from field to rugo:	1.0 min and 10.0 min

In selecting break-points, three factors were considered: The hypotheses suggested in the literature, the actual separation found to occur in the sample and a desire to avoid small sample sizes.

[18]That is, significant at the 90% confidence level.

pole beans. As a first step, a researcher might wish to test this assumption under the more controlled environment of researcher-managed trials, either to make sure that an opportunity to increase the yield of bush bean fields is not missed or to further assess the potential benefits and costs of liming. Whatever the trial's purpose, however, a critical consideration will be whether the location, the soil and perhaps the cooperating farmers selected for the trial are representative.

At this stage, the researcher views the relevant distinction to be between the two types of bean fields, bush and pole. The classification results contain information that can be used to help assure that the conditions of the trials are representative of these two populations. Mean pH is 5.53 and does not differ across bean field categories, but there are significant pH differences by commune and altitude. These differences ought to be considered when selecting locations for the trials.

Liming material is bulky, and applying it will require substantial additional labor inputs as well as cash costs. The total amount of additional labor and cash required will depend not only on the rate of application but also on the size of the bean field. Since "pure" bush bean fields (category 1) are almost twice as large, on the average, as "pure" pole bean fields (category 2), one issue to consider is whether farmers growing only bush beans will be willing or able to adopt liming given their limited resources. With regard to cash costs, for example, one notes that on the larger farms (i.e, those greater than 1.3 ha), cash costs/ha are significantly more than on smaller farms (Table A.3.5). Assuming that smaller farms have less available cash than larger farms, even on a per-hectare basis, acceptance of liming recommendations may be largely a function of farm size. This might warrant some alteration in recommendations to bring the intervention within reach of the majority of small farms. Extension personnel might investigate the feasibility of organizing smaller farmers into cooperatives to handle purchase, delivery and application of lime.

Note that by the time extension recommendations are made, the relevant classification may have shifted from bean field categories to farm size. Of course, classification variables can be combined to make the research as specific as necessary. For example, large farms growing both pole and bush beans could be viewed as one population, small farms growing only bush beans another, and so on.

This example is hypothetical and only begins to touch upon the large number of issues and considerations that would likely affect the success of the intervention--lime x fertilizer interactions, for example. The intent is merely to suggest some of the ways the data in the appendix might be used.

Summary

OLS regression models were used to analyze yield and labor inputs. These models helped identify a set of variables which, with others, were analyzed in analyses of variance for six major classification parameters. The explanatory power of the yield models was considerable. The variables selected explain two thirds of the observed differences in yield between fields. Given the complex nature of agriculture in Rwanda, these results are useful if they allow researchers to focus their efforts on important topics and avoid potential dead-ends.

A comparison of coefficients for pole beans with those for bush beans makes it clear that pole beans are generally more responsive than bush beans to variable inputs and soil chemical conditions. The only exception found was for weeding labor. Weeding labor was not significant for pole beans, perhaps because pole beans can literally climb above the competition.

An analysis of the labor variables, both in the yield response models and in separate regressions, found that farmers generally allocate labor efficiently in bean production, but that low returns put them at the margin of subsistence. The results indicate that farmers are well-informed as to the value of labor at the margin. A possible exception is that of weeding labor applied to "pure" bush bean fields. The results suggest that additional weeding of these fields would be profitable.

In the analyses of variance (classification results), six independent variables were compared. This discussion was kept brief and somewhat general; however, since applied researchers inevitably have specific issues in mind. They are encouraged to examine the results in more detail and, one hopes, extract the desired information.

SUMMARY AND CONCLUSIONS

This study sought to identify determinants of yield in bean production in the Rwandan highlands. Significant variables in yield response equations were discussed in terms of the economic implications of their respective coefficients. For labor inputs, the analysis was extended to include models with these inputs as dependent variables. As a step toward developing appropriate classifications of farms or fields, the study succeeds in that a limited set of variables was identified that explained two thirds of the variation in yield. This success should be viewed in light of the extremely complex, heterogeneous environment of the study area and the large number of potentially important variables for which data were unavailable.[19]

The study also examined different methods of classifying farms and fields. Six out of the eight classification schemes examined were selected as the most useful. Duncan Multiple Range Tests were performed for each of the independent variables on a range of dependent variables including, but not limited to, the factors found to be significant in regression models. The six classification variables selected were:

1. Commune
2. Altitude
3. Farm Size
4. Family Laborer/Hectare
5. Bean Field Categories
6. Distance to Field from *Rugo*

The classification schemes based on these variables all resulted in significant differences across many dependent variables.

Yield Response and Labor Models

The yield response models clearly demonstrate the need to differentiate between bush and pole beans. Most importantly, it was found that the greater sensitivity of pole beans, particularly to pH, could be a major factor limiting the adoption of pole bean varieties. The results indicate that significant gains in yield might be realized through application of lime to pole bean fields: 628-638 kg/ha for each unit increase in pH. No evidence was found that the yield of bush beans would be significantly improved by raising soil pH. Clearly, the magnitude of the potential gains in pole bean yield suggests that further agronomic and economic research could lead to a major improvement in bean yield if economically viable recommendations can be developed and sources of lime can be identified and exploited. Alternatively, varietal selection efforts could focus on identifying acid-tolerant cultivars.

Seed rate was found to be positively correlated with yield for pole beans but not for bush beans. The MVP of seed for pole beans was found to be almost twice the price of seed. These results may be due to the persistent difficulty many farmers have in obtaining staking materials at affordable prices. In 1986, stakes could be purchased for 1 FRw each, but at that price pole beans lose their economic advantage over bush beans (Mayfield et al., 1989). A reasonable assumption is that farmers plant pole beans at lesser densities in order to maximize returns to stakes.

In Rwanda, published economic analyses of labor in traditional agriculture--agriculture as currently practiced by nearly all of the country's farmers--are rare.[20] The yield and labor models presented in this thesis contribute significantly to what is known about the use of labor in the production of a basic food crop. These models show the following:

1. Three out of four significant labor coefficients support the conclusion that farmers allocate labor efficiently.
2. Demand for weeding labor is more elastic than that for weeding labor. This difference corresponds to predictions based on the production function in a partial equilibrium framework.
3. The value of labor at the margin is generally very low, equivalent to only a third of a kilogram of beans per hour in three cases and three-quarters of a kilogram per hour in one case. The low marginal value

[19]These include plant diseases and damage due to birds, rodents and insects; soil chemical properties such as micronutrient levels, aluminum content and cation exchange capacity; and soil physical properties such as texture, bulk density and depth of topsoil.

[20]There are only a few working economists in Rwanda, mostly expatriates. This author was not aware of any published econometric studies of input use in traditional Rwandan agriculture.

product of labor found in this study is consistent, moreover, with current wage levels. In terms of calories, these values were found to be at or near what is required to sustain human health. Therefore, if these results apply to other crops, it is unlikely that additional labor can be absorbed in agricultural production with traditional technologies. Interventions are needed to boost both yield and the productivity of labor. This fact should be borne in mind when considering proposed interventions that require additional labor inputs.

Classification Results

The results of the analysis of farm- and field-level classification schemes were summarized in terms of the significant associations found between independent and dependent variables. With few exceptions, at least one of the classifying variables resulted in significant differences between the (sub-sample) means of the dependent variables. For most variables of interest, therefore, a classification scheme exists that distinguishes significantly different groups of farms or fields.

Comparing different classification schemes, the study found that grouping fields and farms by commune produces the greatest number of significant differences between means.

Altitude showed no significant associations with farm-level variables, while at the field level, most of the variables associated with commune are also associated with altitude.

Surprisingly, the resource variables (animals, family laborers and outside labor use, per hectare of farm size) generally resulted in few significant differences. Only family laborers/ha was included for discussion. This variable was associated with soil nitrogen, soil phosphorous and weeding labor rates.

The study results represent a detailed, quantitative description of important aspects of farming systems in the Rwandan highlands. That description is far from complete.

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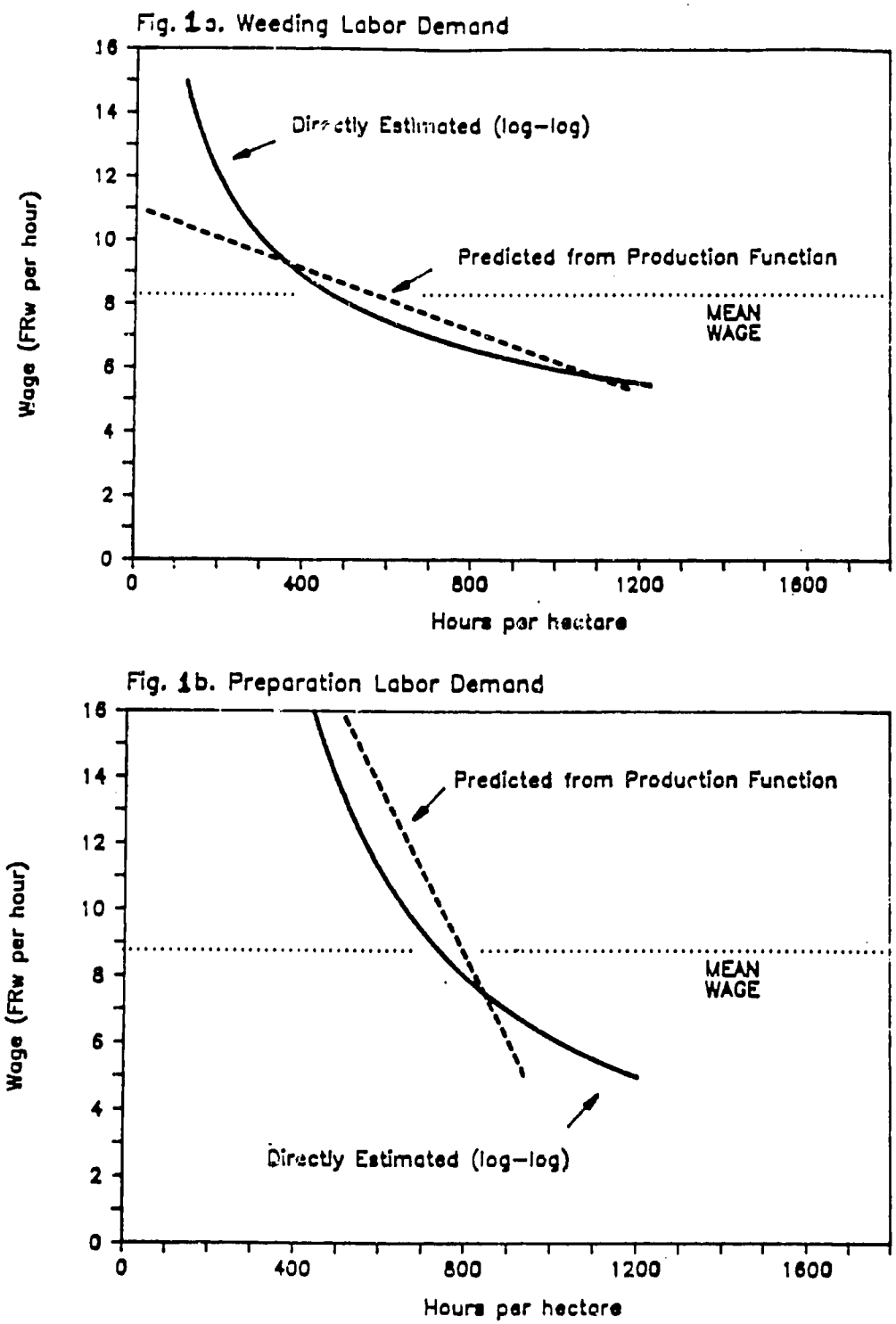

Fig. 1. Predicted vs. estimated demand for labor.

Table 1. Means and standard deviations of production variables.

Production Variable	Units	Mean	Std. Dev.	n
Yield	kg/ha[1]	738.8	559.0	81
Seed	kg/ha	189.7	184.2	79
Compost	tons/ha	5.1	10.9	79
Land Prep. Labor	hours/ha	1106.2	1057.8	81
Weeding Labor	hours/ha	681.2	573.5	81
Harvest Labor	hours/ha	295.5	316.4	81
Total Labor[2]	hours/ha	2435.5	1692.0	81
Return to Labor[3]	FRw/hr[4]	5.8	6.5	79
Accounting Profit[5]	FRw/ha	13,264.9	14,149.3	81
Economic Profit	FRw/ha	-11,658.5	15,543.2	79

Source: Brewster, 1988.

[1]Field areas were adjusted to account for the presence of other, intercropped plants. The methods used for determining areas are described in Appendix 3 of Brewster, 1988.

[2]Includes land clearing, planting, staking, manuring and post-harvest labor.

[3]Equals gross returns, less seed and equipment costs, divided by total hours of labor used over the season.

[4]Rwandan francs. One U.S. dollar was equal to about 80 FRw in 1987.

[5]These were hypothetical profits based on valuing yields and inputs at estimated average prices. The bulk of the harvest is kept for consumption.

Table 2. Significant differences between means of production variables by location, bean type and degree of intercropping.

Production variable	Location	Type	Intercropping
Yield	-	x	x
Seed	x	x	-
Compost	x	x	-
Land Prep. Labor	x	x	x
Weeding Labor	x	-	x
Harvest Labor	x	-	-
Total Labor	-	x	-
Returns to Factors	x	-	x
Accounting Profit	-	x	x
Economic Profit	x	-	-

Source: Brewster, 1988. An x indicates that the F test is significant at the 90 % level.

Table 3. Variables from Phase I.

VARIABLE	Units	Definition
Farm Level Variables		
AGE	Years	Age of family members, re-coded into age categories.[1]
OUTSIDE LABOR	Days	Paid and exchange labor used for all crops in the previous season.
ANIMALS	Head	Includes only cows, goats and sheep
FARM SIZE	Hectares	Area of all cultivated fields.
LOCATION		The commune, sector and cellule in which the farm is primarily located.
Field-Level Variables		
FIELD SIZE	Hectares	Area of bean field
LABOR	Hours	Labor used, broken down by sex, task and type (family, paid or exchange).
WAGES	FRw	Amount paid for a given quantity of labor.
SEED	Kilograms	Bean seed planted in an individual field.
SEED COST	FRw	Amount paid for seed.
PLANT DENSITIES	Plants/m^2	Plant densities of beans and other species.
COMPOST	Kilograms	Organic fertilizer applied during in the season.[2]
PLANTING MONTH		Month in which beans were planted.
BEAN TYPE		Type of bean planted, bush or pole.
BEAN VARIETY		The (named) variety of bean if a single variety.
BANANAS	Trees/field	Number of banana trees in the bean field.
PLACEMENT		Topographical position of the field: peak, valley, etc.
CULTURE		Main crop planted with beans in intercropped fields.

[1]Age categories are: 10-15, under 10 and over 65, and 16-65.
[2]Fertilizer types are:composted manure, rugo manure, composted vegetable matter, fresh stable manure and chemical fertilizer. Organic fertilizers were first measured in baskets, chemical fertilizer in kilograms. Only one field received any chemical fertilizer.

Table 4. Variables from Phase II.

VARIABLE	Units	Definition
ALTITUDE	meters	Altitude above sea-level of the field.
SLOPE	degrees	Slope of the field at its center.
FIELD HEIGHT	meters	Average height, top to bottom of the field.
TERRACES	number	Number of terraces in the field.
ORIENTATION	degrees	Direction, from true north, faced by the field.
SOIL pH		pH of topsoil in water (1 : 1 soil-to-water ratio).
SOIL N	percent	Percentage nitrogen content of topsoil.
SOIL P	parts per million	Phosphorous content of topsoil.
Distances from *Rugo* to:		Time required to walk from the main dwelling to the:
FIELD	hr/min/sec	Bean field.
ROAD	hr/min/sec	Nearest 4-wheel vehicle road.
WATER	hr/min/sec	Nearest source of drinking water.
MARKET	hr/min/sec	Nearest market town.
FIELD SIZE	hectares	Area of bean field.
FARM SIZE	hectares	Area of all cultivated fields.
LAND TRANSACTIONS	hectares	Sales, purchases and gifts of land made over the past year.

Table 5. Variables included in yield response equations and the expected signs of their coefficients.

Variable	Expected Sign of Coefficient
Continuous Variables	
Seeding Rate	+
Altitude (m)	+
Banana Trees/ha.[1]	+
Land Preparation Labor	+
Weeding Labor	+
Nitrogen[2]	+
Phosphorous	+
pH	+
Dummy Variables	
Planting Month (September)	?
Orientation (East)	+
Variety (Single)	+
Intercrop Species (Peas)	-

[1]This variable was rejected in Phase I. However, the number of banana trees per field was inappropriately divided by "adjusted field size" in Phase I (i.e. adjusted to account for the area taken by other plants intercropped with beans) instead of actual field size. Although a possible negative effect from shading was considered, the advantages of soil protection and organic matter buildup beneath the banana tress were assumed to be dominant.

[2]Soil N and P were included instead of compost manure although soil samples were taken two years after the season followed. The interest was in identifying significant physical factors. Since the nutrient content of compost/manure differs greatly, and given that measurements of compost/manure inputs were approximate at best, this variable is not necessarily superior to the N and P variables in yield equations.

Table 6. Variables included in labor input equations and the expected signs of their coefficients.

Variable	Land Preparation	Weeding
	(Expected Sign of Coefficient)	
Wages[1]	-	-
Family Laborers		
(10 - 65)/ha	+	+
Animals/Laborer	-	-
Distance from *Rugo* to:		
Market	-	-
Water Source	-	-
Bean Field	-	-
Slope of Field	-	-
Field Size	-	-
Bean Plant Density	N.A.	-
Bean Type (pole)	+	+

[1]Wages were defined as the actual hourly wage paid for hired labor or, if none was hired, the commune average wage.

Table 7. Combined yield response model with linear functional forms.

VARIABLE	Definition	Coefficient	t-ratio
INTERCEPT	Reference intercept	-1254.3	-2.512 *
CATEGORY1	Dummy for pure bush bean fields	-757.1	-3.721 **
CATEGORY2	Dummy for pure pole bean fields	-4582.6	-5.588 **
ALTITUDE	Elevation above sea level (m)	0.787	3.363 **
BANANAS	Banana trees/ha in field	0.450	3.251 **
VARIETY	Dummy for fields planted with a single, named bean variety (named variety = 1, melange = 0)	135.7	1.711 *
SEPTEMBER	Dummy for planting month (September = 1, July or August = 0)	199.1	2.134 *
WEEDING1	Weeding labor on pure bush bean fields (hours/ha)	0.760	4.672 **
PHOSPHOR1	Soil phosphorous in pure bush bean fields (parts per million)	54.61	3.257 **
SEEDRATE2	Seed used (kg/ha) in pure pole bean fields	2.344	4.261 **
PREPLABOR2	Preparation labor on pure pole bean fields (hours/ha)	0.311	3.611 **
PHOSPHOR2	Soil phosphorous in pure pole bean fields (parts per million)	65.65	2.170 *
pH2	Soil pH in pure pole bean fields	638.06	5.193 **

Adj. R^2: .662 df (residual): 64 F = 13.387 Sig. F = 0.0000

*Significant at the 0.1 level.
**Significant at the 0.01 level.

Table 8. Yield response model with linear and quadratic functional forms.

VARIABLE	Definition	Coefficient	t-ratio
INTERCEPT	Reference intercept	-1260	-2.624 *
CATEGORY2	Dummy for pure pole beans	-3923	-4.924 **
SEPTEMBER	Dummy for planting month (September = 1, July, August = 0)	338.4	3.824 **
ALTITUDE	Elevation above sea level (m)	0.531	2.372 *
BANANAS	Banana trees/ha in field	0.356	2.736 **
WEEDING1	Weeding labor on pure bush bean fields (hours/ha)	0.729	5.312 **
PHOSPHOR1	Soil phosphorous in pure bush bean fields (parts per million)	35.91	3.070 **
SEEDRATE2	Seed (kg/ha) used in pure pole bean fields	2.231	4.218 **
PREPLABOR2	Preparation labor in pure pole bean fields (hours/ha)	0.308	3.712 **
PHOSPHOR2	Soil phosphorous in pure pole bean fields (parts per million)	71.91	2.482 *
pH2	Soil pH, pure pole bean fields	627.81	5.311 **
WEEDING3	Weeding labor on intercropped bush bean fields (hours/ha)	0.386	2.115 *
WEED3SQ	Square of WEEDING3	-0.00008	1.863 *
PREPLABOR3	Preparation labor on intercropped bush bean fields (hours/ha)	0.994	3.351 **
PREP3SQ	Square of PREPLABOR3	-0.00044	-3.516 **

Adj. R^2 = .687 df (residual) = 62 F = 12.905 Sig. F = 0.0000

*Significant at the 0.1 level.
** Significant at the 0.01 level.

Table 9. Regression model of weeding labor (log).

VARIABLE	Definition	Coefficient	t-ratio
INTERCEPT	Reference intercept for fields with no hired labor	11.22	11.02 **
PAYWEED	Dummy for hiring some weeding labor (some = 1, none = 0)	0.278	2.010 *
ANIMALS	Number of animal units[1]/adult (age 15 to 64)	-0.047	-2.182 *
FIELDSIZE	Size of bean field (ha, adjusted for intercropping)	-4.272	-5.452 **
LN_DENS	Natural log of bean plant density (no. of bean plants/m^2)	-0.368	-1.951 *
LN_WAGE	Natural log of wage paid (or, if none was hired, the commune avg. wage for weeding labor) (FRw/hour)	-1.618	-4.624 **

Adj. R^2: .456 df (residual) = 73 F = 14.077 Sig. F = 0.0000

[1]Goats and Sheep = one unit each; Cattle = 8 units each.
*Significant at the 0.1 level.
**Significant at the 0.01 level.

Table 10. Regression model of preparation labor (log).

VARIABLE	Definition	Coefficient	t-ratio
INTERCEPT	Reference intercept for fields with no hired labor	8.316	10.70 **
PAYPREP	Dummy for hiring some preparation labor (some = 1, none = 0)	0.383	2.69 **
D_RUGO	Walking distance from dwelling to the field (minutes)	-0.007	-2.55 *
FIELDSIZE	Size of bean field (ha, adjusted for intercropping)	-2.755	-3.33 **
LN_WAGE	Natural log of wage paid (or, if (none was hired, the commune avg. wage for prep. labor (FRw/hr)	-0.710	-1.89 *

Adj. R^2: .224 df (residual) = 76 F = 6.762 Sig. F = 0.0000

*Significant at the 0.1 level.
**Significant at the 0.01 level.

APPENDIX

FARM AND FIELD CLASSIFICATION TABLES

The tables in this appendix present means of dependent variables related to bean production or to food production generally. The means in the tables are broken down by the following six classification variables: commune, farm size, altitude, family laborers/ha of farm size, bean field categories and the walking distance to the field from the *rugo*.

The six classification variables are evaluated in terms of their correlation with the following sets of variables of interest.

a. Selected Socio-Economic Variables

b. Field-Level Management Variables

c. Field-Level Physical Variables

d. Bean Production Inputs

e. Yield, Costs and Returns

f. Percentage of Total Fields in Different Field Categories

Duncan Multiple Range Tests: In cases where significant differences were found between at least one pair of means, all of the group means in that row are followed by one or more letters (a, b, c..., etc.) to indicate those differences. Letters are assigned in ascending order: Thus, within a given row, a mean followed by "a" is significantly smaller (at the 90% confidence level) compared to another mean followed by "b," and so on. A mean followed by "ab," on the other hand, is not significantly different from another followed by either "a" or "b." If no significant differences were found, no letters are given.

Caveat. For consistency and simplicity, the DMRT is also applied to "percentage of total" variables, even though these non-normal distributions, violating the normality assumption made for ordinary analysis of variance. This assumption must be approximately satisfied in order for the range test to be valid. However, the primary objective here is to compare the usefulness of different classification schemes, and this method still allows the researcher to make such comparisons as long as it is applied consistently. Nevertheless, the reader is advised that the significant differences indicated by the DMRT results are valid only for normally distributed dependent variables.

Table A.1.1. Selected socioeconomic variables, by commune.

Variable	Commune					
	Nyarutovu	Nyamugali	Cyeru	Butaro	Tot.	Std Dev
(N =)	15	15	10	5	45	
Farm Size (ha)	1.05	1.02	0.82	1.14	1.00	0.53
Adults/ha (15-64)	3.01	3.88	3.43	2.09	3.29	1.97
Dependents/ha:						
Ages 10-14	0.57 a	0.79 ab	0.39 a	1.73 b	0.73	1.17
< 10, > 64	2.97 b	1.76 b	0.00 a	2.69 b	1.87	2.14
Total/ha	6.55 b	6.43 ab	3.82 a	6.51 b	5.90	3.30
Avg. Wage (FRw/hr)	8.64 b	7.70 ab	6.72 a	11.52 c	8.52	2.16
Animals/ha						
Cows	0.36 a	0.62 a	1.76 b	1.21 ab	0.85	1.48
Goats & Sheep	2.57	2.14	3.11	4.75	2.79	2.91
Distance (minutes)						
from *Rugo* to: Road	9.7 b	8.7 b	7.4 b	2.4 a	8.3	5.6
Market	42.7	46.1	43.6	30.7	42.0	24.4
Water	7.4 a	20.5 b	9.0 a	9.4 a	12.0	9.7

Table A.1.2. Field-level management variables, by commune.

Variable	Commune					
	Nyarutovu	Nyamugali	Cyeru	Butaro	Tot.	Std Dev
(N =)	27	26	19	9	81	
Field Size (m^2) (adjusted)	837	1,021	611	1,159	879	872
Distance to Field from *Rugo* (min)	6.1 a	24.8 b	5.6 a	19.9 ab	13.5	26.2
Planting Month[1]	7.22 a	8.08 b	8.21 b	8.78 c	7.90	0.68
Banana Trees/ha	275 b	62 a	216 b	0 a	162	272
Terraces/Field	0.85	1.23	0.79	0.67	0.94	1.05
% of Fields with:						
Banana Trees[2]	63 b	19 a	47 b	0 a	38	
Terracing	56	65	47	44	56	
Hired Labor	44 a	58 a	47 a	100 b		

[1]July = 7, August = 8, September = 9
[2]See "caveat" at the beginning of the appendix tables.

Table A.1.3. Field-level physical variables, by commune.

Variable	Commune				Tot.	Std Dev
	Nyarutovu	Nyamugali	Cyeru	Butaro		
(N =)	27	26	19	9	81	
Nitrogen (%)	0.18 a	0.23 b	0.28 c	0.26 bc	0.23	0.08
Phos (PPM)	7.58 a	8.08 a	9.26 ab	10.85 b	8.50	3.75
pH	5.53 ab	5.31 a	5.68 b	5.81 b	5.53	0.52
Slope (degrees)	17.0 a	22.3 b	23.1 b	15.4 a	20.0	7.09
Altitude (m)	1,914 a	2,225 c	2,079 b	2,171 c	2,081	166

Table A.1.4. Bean production input variables, by commune.

Variable	Commune				Tot.	Std.Dev
	Nyarutovu	Nyamugali	Cyeru	Butaro		
(N =)	27	26	19	9	81	
Labor (hours/ha)						
Preparation	1,224 b	738 a	1,075 ab	842 ab	990	722
Weeding	570 a	892 b	673 ab	299 a	660	569
Other[1]	607	652	651	586	629	489
Total Labor	2,400	2,281	2,398	1,660	2,280	1,350
(of which)						
Family Labor	1,300 ab	1,500 b	1,608 b	867 a	1,389	911
Exchange Labor	760 b	222 a	262 a	7 a	387	627
Hired Labor	341	559	527	786	504	709
Seed, kg/ha	130 a	161 a	232 b	163 ab	167	121
Compost, tons/ha	3.96 ab	1.44 a	7.33 b	8.38 b	4.34	8.99
% of Fields w/ Compost Applied[2]	30 a	35 a	78 b	63 ab	46	

[1]Includes seeding, manuring, staking, harvest and post-harvest labor.
[2]See "caveat" at the beginning of the appendix tables.

Table A.1.5. Yield, costs and returns, by commune.

Variable	Commune					
	Nyarutovu	Nyamugali	Cyeru	Butaro	Tot.	Std Dev
(N =)	27	26	19	9	81	
YIELD: kg/						
ha	571 a	624 a	947 b	787 ab	699	491
hr of Labor	0.29 a	0.31 ab	0.43 bc	0.52 c	0.35	0.25
Gross Returns (FRw)						
/ha	14,235 a	15,600 a	23,675 b	19,677 ab	17,483	12,266
/hr of Labor	5.95 a	6.84 ab	9.87 bc	11.85 c	8.79	6.17
Cash Costs/ha	3,440 a	5,382 a	3,882 a	9,109 b	4,680	5,820
Labor Costs (FRw/ha)	20,411	17,019	15,757	19,162	18,091	10,197
Returns/ha Less						
Cash Costs	10,795 a	10,218 a	19,793 b	10,568 a	12,803	13,481
Total Costs[1]	-10,029	-6,242	877	-4,379	-5,628	12,766

[1]Cash costs plus economic (opportunity) cost of labor, seed and equipment (excluding stakes).

Table A.1.6. Percentage of total fields in different field categories, by commune.[1]

Variable	Commune				
	Nyarutovu	Nyamugali	Cyeru	Butaro	Tot.
(N =)	27	26	19	9	81
Category 1	44 b	23 a	21 ab	44 ab	32
Category 2	22 a	08 a	47 b	22 ab	23
Category 3	30 a	62 b	26 a	33 ab	40
Bush	74 b	85 b	47 a	78 ab	72
Pure (> 88% bean)	67 b	31 a	68 b	67 b	56

[1]See "caveat" at the beginning of the appendix tables.

Table A.2.1. Selected socioeconomic variables, by average altitude of fields.

Variable	Altitude (m) < 2000	2000-2200	> 2200	Tot.	Std Dev
(N =)	16	19	10	45	
Farm Size (ha)	1.11	0.94	0.93	1.00	0.53
Adults/ha (15-64)	3.21	2.95	4.08	3.29	1.97
Dependents/ha					
Ages 10-14	0.61	0.97	0.47	0.73	1.17
< 10, > 64	2.25	1.42	2.14	1.87	2.14
Total/ha	6.07	5.34	6.69	5.90	3.30
Avg. Wage (FRw/hr)	8.07	8.87	8.39	8.52	2.16
Animals/ha					
Cows	0.88	0.81	0.88	0.85	1.48
Goats & Sheep	3.38	2.45	2.47	2.79	2.91
Distance (min) from					
Rugo to: Road	8.2	9.0	7.1	8.3	5.6
Market	42.8	42.4	40.1	42.0	24.4
Water	7.9 a	9.7 a	23.0 b	12.0	9.7

Table A.2.2. Field-level management variables, by altitude of field.

Variable	Altitude (m) < 2000	2000-2200	> 2200	Tot.	Std Dev
(N =)	28	34	19	81	
Avg. Field Size (adjusted) (m^2)	940	699	1,110	879	872
Distance to Field from *Rugo* (min)	6.1 a	10.2 a	30.3 b	13.5	26.2
Planting Month[1]	7.46 a	8.06 b	8.26 b	7.90	0.68
Banana Trees/ha	226 b	184 b	31 a	162	272
Terraces/Field	0.86	0.88	1.16	0.94	1.05
% of Fields with:					
Banana Trees[2]	57.1 b	35.3 b	15.8 a	38.3	
Terracing	50.0	52.9	68.4	55.6	
Hired Labor	42.9	58.8	68.4	55.6	

[1]July = 7, August = 8, September = 9
[2]See "caveat" at the beginning of the appendix.

Table A.2.3. Field-level physical variables, by altitude of field.

Variable	Altitude (m) < 2000	2000-2200	> 2200	Tot.	Std Dev
(N =)	28	34	19	81	
Nitrogen (%)	0.21	0.24	0.23	0.23	0.08
Phos. (PPM)	8.17	8.87	8.31	8.50	3.75
pH	5.55 ab	5.61 b	5.33 a	5.53	0.52
Slope (degrees)	17.00 a	20.95 b	21.85 b	19.96	7.09

Table A.2.4. Input variables, by altitude of field.

Variable	Altitude (m) < 2000	2000-2200	> 2200	Tot.	Std Dev
(N =)	28	34	19	81	
Labor (hours/ha)					
Preparation	1,147 b	1,012 ab	721 a	990	722
Weeding	558	684	766	660	569
Other[1]	540	715	608	629	490
Total Labor	2,246	2,410	2,095	2,279	1,350
(of which)					
Family Labor	1,375	1,493	1,183	1,389	911
Exchange Labor	908 b	303 a	227 a	387	627
Hired Labor	230	528	628	504	709
Seed, kg/ha	150 a	201 b	133 a	167	121
Compost, tons/ha	5.47	5.21	1.01	4.34	8.99
% of Fields with Compost Applied[2]	36 a	64 b	28 a	46	

[1]Includes seeding, manuring, staking, harvest and post-harvest labor.
[2]See "caveat" at the beginning of the appendix.

Table A.2.5. Yield, costs and returns, by altitude of field.

Variable	Altitude (m) < 2000	2000-2200	> 2200	Tot.	Std Dev
(N =)	28	34	19	81	
Yield: kg/					
ha	575 a	880 b	559 a	699	491
hr of labor	0.29 a	0.42 b	0.32 ab	0.35	0.25
Gross Returns (FRw)					
/ha	14,365 a	22,009 b	13,978 a	17,483	12,266
/hr of labor	7.15 a	10.60 b	7.96 ab	8.79	6.17
Cash Costs (FRw/ha)	2,478 a	5,742 b	6,025 b	4,680	5,820
Labor Costs (FRw/ha)	18,169	19,254	15,896	18,091	10,197
Returns/ha Less					
Cash Costs	11,888 ab	16,267 b	7,952 a	12,803	13,481
Total Costs[1]	-8,294	-3,271	-5,916	-5,628	12,766

[1]Cash costs plus economic (opportunity) cost of labor, seed and equipment (excluding stakes).

Table A.2.6. Percentage of total fields in different field categories, by altitude of field.[1]

Variable	Altitude (m) < 2000	2000-2200	> 2200	Tot.
(N =)	28	34	19	81
Category 1	43	27	26	32
Category 2	25	29	11	23
Category 3	32 a	32 a	63 b	40
Bush	75 ab	59 a	90 b	72
Pure (> 88% bean)	68 b	56 ab	37 a	56

[1]See "caveat" at the beginning of the appendix tables.

Table A.3.1. Selected socioeconomic variables, by farm size.

Variable	Farm Size (ha) < 0.60	0.60-1.30	> 1.30	Tot.	Std Dev
(N =)	13	18	14	45	
Adults/ha	5.39 c	2.89 b	1.86 a	3.29	1.97
Dependents/ha					
Ages 10-14	0.45	0.93	0.60	0.73	1.17
< 10, > 64	3.51 b	0.94 a	1.56 a	1.87	2.14
Total/ha	9.51 b	4.70 a	4.09 a	5.90	3.30
Avg. Wage (FRw/hr)	10.33 c	7.39 a	8.68 b	8.52	2.16
Animals/ha					
Cows	0.74	1.07	0.67	0.85	1.48
Goats & Sheep	3.25	2.82	2.31	2.79	2.91
Distance (min) from					
Rugo to: Road	7.7	9.6	7.3	8.3	5.6
Market	34.4 a	50.5 b	38.2 ab	42.0	24.4
Water	14.5	12.0	9.7	12.0	9.7

Table A.3.2. Field-level management variables, by farm size.

Variable	Farm Size (ha) < 0.60	0.60-1.30	> 1.30	Tot.	Std Dev
(N =)	32	34	25	81	
Avg. Field Size (adjusted) (m^2)	765	569	1,401	879	872
Distance to Field from *Rugo* (min)	15.6	13.9	11.2	13.5	26.2
Planting Month[1]	7.77	7.91	8.00	7.90	0.68
Banana Trees/ha	141	205	123	162	272
Terraces/Field	1.09	0.74	1.08	0.94	1.05
% of Fields with:					
Banana Trees[2]	22.7	44.1	44.0	38.3	
Terracing	63.6	47.1	60.0	55.6	
Hired Labor	36.4 a	47.1 a	84.0 b	55.6	

[1]July = 7, August = 8, September = 9
[2]See "caveat" at the beginning of the appendix.

Table A.3.3. Field-level physical variables, by farm size.

Variable	Farm Size (ha) < 0.60	0.60-1.30	> 1.30	Tot.	Std Dev
(N =)	32	34	25	81	
Nitrogen (%)	0.21	0.25	0.22	0.23	0.08
Phos (PPM)	8.10	8.38	9.02	8.50	3.75
pH	5.42	5.62	5.50	5.53	0.52
Slope (degrees)	19.95	21.18	18.32	19.96	7.09
Altitude (m)	2,071	2,101	2,063	2,081	166

Table A.3.4. Input variables, by farm size.

Variable	Farm Size (ha) < 0.60	0.60-1.30	> 1.30	Tot.	Std Dev
(N =)	32	34	25	81	
Labor (hours/ha)					
Preparation	1,093	1,003	884	990	722
Weeding	613	781	536	660	569
Other[1]	618	614	661	629	489
Total Labor	2,323	2,398	2,080	2,279	1,350
(of which)					
Family Labor	1,332 ab	1,591 b	1,163 a	1,389	911
Exchange Labor	729 b	358 a	126 a	387	627
Hired Labor	262 a	449 a	792 b	504	709
Seed, kg/ha	144	190	157	167	121
Compost, tons/ha	3.95	4.85	4.00	4.34	8.99
% of Fields with Compost Applied[2]	31.8	54.6	45.8	45.6	

[1]Includes seeding, manuring, staking, harvest and post-harvest labor.
[2]See "caveat" at the beginning of the appendix.

Table A.3.5. Yield, costs and returns, by farm size.

Variable	Farm Size (ha) < 0.60	0.60-1.30	> 1.30	Tot.	Std Dev
(N =)	32	34	25	81	
YIELD: kg/					
ha	798	677	643	699	491
hr of labor	0.39	0.32	0.36	0.35	0.25
Gross Returns (Frw)					
/ha	19,943	16,917	16,085	17,483	12,266
/hr of Labor	9.77	7.93	9.10	8.79	6.17
Cash Costs/ha	3,093 a	3,785 a	7,293 b	4,680	5,820
Labor Costs, FRw/ha	19,918	17,384	17,446	18,091	10,197
Returns/ha Less					
Cash Costs	16,851 b	13,132 ab	8,792 a	12,803	13,481
Total Costs[1]	-4,292	-6,170	-6,065	-5,628	12,766

[1]Cash costs plus economic (opportunity) cost of labor, seed and equipment (excluding stakes).

Table A.3.6. Percentage of total fields in different field categories, by farm size.[1]

Variable	Farm Size (ha) < 0.60	0.60-1.30	> 1.30	Tot.
(N =)	32	34	25	81
Category 1	40.9	20.6	40.0	32.1
Category 2	13.6	32.4	20.0	23.5
Category 3	40.9	44.1	32.0	39.5
Bush	81.8	64.7	72.0	71.6
Pure (> 88% bean)	54.5	52.9	60.0	55.6

[1]See "caveat" at the beginning of the appendix.

Table A.4.1. Selected socioeconomic variables, by family laborers/ha.

Variable	Family Laborers/ha ≤ 2.3	2.3-4.9	≥ 5.0	Tot	Std Dev
(N =)	17	18	10	45	
Farm Size (ha)	9.92 b	12.48 b	7.01 a	1.00	0.53
Dependents/ha					
Ages 10-14	0.94	0.69	0.46	0.73	1.17
< 10, > 64	1.26 a	1.85 ab	2.96 b	1.87	2.14
Total/ha	3.65 a	5.96 b	9.61 c	5.90	3.30
Avg. Wage (FRw/hr)				8.52	2.16
Animals/ha					
Cows	0.37 a	1.25 b	0.97 ab	0.85	1.48
Goats & Sheep	2.89	3.36	1.58	2.79	2.91
Distance (min) from					
Rugo to: Road	7.6	9.8	6.8	8.3	5.6
Market	41.7	45.9	35.7	42.0	24.4
Water	10.5 a	10.5 a	17.3 b	12.0	9.7

Table A.4.2. Field-level management variables, by family laborers/ha.

Variable	Family Laborers/ha ≤ 2.3	2.3-5.0	≥ 5.0	Tot.	Std Dev
(N =)	31	33	17	81	
Avg. Field Size (adjusted) (m^2)	1,013	793	802	879	872
Distance to Field from *Rugo* (min)	20.3 b	7.2 a	13.3 ab	13.5	26.2
Planting Month[1]	7.94	7.88	7.88	7.90	0.68
Banana Trees/ha	113	192	195	162	272
Terraces/Field	1.10 b	0.64 a	1.24 b	0.94	1.05
% of Fields with:					
Banana Trees[2]	35.5	48.5	23.5	38.3	
Terracing	58.1	45.5	70.6	55.6	
Hired Labor	67.7 b	45.5 a	52.9 ab	55.6	

[1]July = 7, August = 8, September = 9
[2]See "caveat" at the beginning of the appendix.

Table A.4.3. Field-level physical variables, by family laborers/ha.

Variable	Family Laborers/ha ≤ 2.3	2.3-4.9	≥ 5.0	Tot.	Std Dev
(N =)	31	33	17	81	
Nitrogen (%)	0.26 b	0.22 a	0.20 a	0.23	0.08
Phos (PPM)	9.50 b	7.80 a	8.05 ab	8.50	3.75
pH	5.59	5.53	5.41	5.53	0.52
Slope (degrees)	17.97 a	21.94 b	19.76 ab	19.96	7.09
Altitude (m)	2,088	2,069	2,081	2,081	166

Table A.4.4. Input variables, by family laborers/ha.

Variable	Family Laborers/ha ≤ 2.3	2.3-5.0	≥ 5.0	Tot.	Std Dev
(N =)	31	33	17	81	
Labor (hours/ha)					
Preparation	888	965	1,226	990	722
Weeding	479 a	864 b	593 ab	660	569
Other[1]	559	668	682	629	490
Total	1,927	2,497	2,500	2,280	1,350
(of which)					
Family Labor	1,049 a	1,749 b	1,308 a	1,389	911
Exchange Labor	243 a	315 a	788 b	387	627
Hired labor	634	433	404	504	709
Seed, kg/ha	181	160	157	167	121
Compost, tons/ha	4.24	4.19	4.8	4.34	8.99
% of Fields with Compost Applied[2]	47	53	29	46	

[1]Includes seeding, manuring, staking, harvest and post-harvest labor.
[2]See "caveat" at the beginning of the appendix.

Table A.4.5. Yield, costs and returns, by family laborers/ha.

Variable	Family laborers/ha ≤ 2.3	2.3-4.9	≥ 5.0	Tot.	Std Dev
(N =)	31	33	17	81	
YIELD: kg/					
ha	643	707	787	699	491
hr of Labor	0.37	0.33	0.36	0.35	0.25
Gross Returns (FRw)					
/ha	16,085	17,668	19,670	17,483	12,266
/hr of Labor	9.25	8.24	9.03	8.79	6.17
Cash Costs/ha	6,053	3,536	4,398	4,680	5,820
Labor Costs, FRw/ha	16,043	18,388	21,252	18,091	10,197
Returns/ha Less					
Cash Costs	10,033	14,133	15,273	12,803	13,481
Total Costs[1]	-5,390	-5,514	-6,282	-5,628	12,766

[1]Cash costs plus economic (opportunity) cost of labor, seed and equipment (excluding stakes).

Table A.4.6. Percentage of fields in different field categories, by family laborers/ha.[1]

Variable	Family laborers/ha ≤ 2.3	2.3-4.9	≥ 5.0	Tot.
(N =)	31	33	17	81
Category 1	38.7	27.3	29.4	32.1
Category 2	22.6	24.2	23.5	23.5
Category 3	35.5	42.4	41.2	39.5
Bush	74.2	69.7	70.6	71.6
Pure (> 88% bean)	61.3	51.5	52.9	55.6

[1]See "caveat" at the beginning of the appendix.

Table A.5.1 Field-level management variables, by bean.

Variable	Pure Bush	Pure Pole	Intercropped Bush	Tot.[1]	Std Dev
(N =)	26	19	32	81	
Avg. Field Size (adjusted) (m^2)	1,127 b	590 a	915 ab	879	872
Distance to Field from Rugo (min)	11.0	8.2	19.7	13.5	26.2
Planting Month[2]	7.81	8.05	7.91	7.90	0.68
Banana Trees/ha	163 b	315 b	87 a	162	272
Terraces/Field	1.08	0.74	1.00	0.94	1.05
% of Fields with:					
Banana Trees[3]	46.2 b	57.9 b	21.9 a	38.3	
Terracing	57.7	47.4	59.4	55.6	
Hired Labor	57.7	57.9	56.3	57.1	

[1]Average of all 81 fields, including intercropped pole beans.
[2]July = 7, August = 8, September = 9
[3]See "caveat" at the beginning of the appendix.

Table A.5.2. Field-level physical variables, by bean field category.

Variable	Pure Bush	Pure Pole	Intercropped Bush	Tot.[1]	Std Dev
(N =)	26	19	32	81	
Nitrogen (%)	0.22	0.24	0.24	0.23	0.08
Phos (PPM)	8.95	7.89	8.63	8.50	3.75
pH	5.53	5.59	5.49	5.53	0.52
Slope (degrees)	18.77	21.53	19.81	19.96	7.09
Altitude (m)	2,046	2,058	2,122	2,081	166

[1]Average of all 81 fields, including intercropped pole beans.

Table A.5.3. Input variables, by bean field category.

Variable	Pure Bush	Pure Pole	Intercropped Bush	Tot.[1]	Std Dev
(N =)	26	19	32	81	
Labor (hours/ha)					
Preparation	924 a	1,333 b	760 a	990	722
Weeding	501	591	752	660	569
Other[2]	491 a	837 b	535 a	629	490
Total Labor	1,916 a	2,760 b	2,047 a	2,280	1,350
(of which)					
Family Labor	1,078 a	1,714 b	1,272 a	1,389	911
Exchange Labor	377	440	279	387	627
Hired labor	461	606	497	504	709
Seed, kg/ha	163 ab	216 b	139 a	167	121
Compost, tons/ha	2.27 a	8.98 b	2.96 a	4.34	8.99
% of Fields with Compost Applied[3]	36 a	67 b	38 a	46	

[1]Average of all 81 fields, including intercropped pole beans.
[2]Includes seeding, manuring, staking, harvest and post-harvest labor.
[3]See "caveat" at the beginning of the appendix.

Table A.5.4. Yield, costs and returns, by bean field category.

Variable	Pure Bush	Pure Pole	Intercropped Bush	Tot.[1]	Std Dev
(N =)	26	19	32	81	
YIELD: kg/					
ha	639 a	1,083 b	505 a	699	491
hr of Labor	0.37 ab	0.44 b	0.30 a	0.35	0.25
Gross Returns (FRw)					
/ha	15,982 a	27,080 b	12,635 a	17,483	12,266
/hr of Labor	9.27 ab	11.23 b	7.41 a	8.79	6.17
Cash Costs, FRw/ha	4,754	4,945	4,715	4,680	5,820
Labor Costs, FRw/ha	16,122 a	21,104 b	16,081 a	18,091	10,197
Returns/ha Less					
Cash Costs	11,228 a	22,135 b	7,920 a	12,803	13,481
Total Costs[2]	-5,469 ab	-1,090 b	-8,142 a	-5,628	12,805

[1]Average of all 81 fields, including intercropped pole beans.
[2]Cash costs plus economic (opportunity) cost of labor, seed and equipment (excluding stakes).

Table A.6.1. Field-level management variables, by walking distance from the *Rugo* to the bean field.

Variable	Distance from *Rugo* (minutes) ≤ 1.0	1.0-10.0	≥ 10.0	Tot.	Std Dev
(N =)	25	31	25	81	
Avg. Field Size (adjusted) (m^2)	883	772	1,008	879	872
Planting Month[1]	7.72	7.97	8.00	7.90	0.68
Banana Trees/ha	382 b	76 a	51 a	162	272
Terraces/Field	0.48 a	0.97 b	1.36 b	0.94	1.05
% of Fields with:					
Banana Trees[2]	64 c	39 b	12 a	38	
Terracing	32 a	61 b	72 b	56	
Hired Labor	56	52	60	56	

[1]July = 7, August = 8, September = 9
[2]See "caveat" at the beginning of the appendix.

Table A.6.2. Field-level physical variables, by walking distance from the *Rugo* to the bean field.

Variable	Distance from *Rugo* (minutes) ≤ 1.0	1.0-10.0	≥ 10.0	Tot.	Std Dev
(N =)	25	31	25	81	
Nitrogen (%)	0.21 a	0.26 b	0.22 ab	0.23	0.08
Phos. (PPM)	9.56 b	7.59 a	8.57 ab	8.55	3.79
pH	5.57	5.55	5.44	5.53	0.53
Slope (degrees)	19.44	19.84	20.64	19.88	7.17
Altitude (m)	2,037	2,070	2,139	2,081	167

Table A.6.3. Input variables, by walking distance from the *Rugo* to the bean field.

Variable	Distance from *Rugo* (minutes) ≤ 1.0	1.0-10.0	≥ 10.0	Tot.	Std Dev
(N =)	25	31	25	81	
Labor (hours/ha)					
Preparation	1,081	1,056	818	990	722
Weeding	779	611	600	660	569
Other[1]	730	624	536	629	490
Total Labor	2,589	2,292	1,954	2,279	1,350
(of which)					
Family Labor	1,573 b	1,479 ab	1,092 a	1,389	911
Exchange Labor	509	399	249	352	498
Hired labor	507	413	612	512	712
Seed, kg/ha	152	191	154	167	121
Compost, tons/ha	5.04	4.30	3.71	4.34	8.99
% of Fields with Compost Applied[2]	46	45	46	46	

[1]Includes seeding, manuring, staking, harvest and post-harvest labor.
[2]See "caveat" at the beginning of the appendix.

Table A.6.4. Yield, costs and returns, by walking distance from the *Rugo* to the bean field.

Variable	Distance from *Rugo* (minutes) ≤ 1.0	1.0-10.0	≥ 10.0	Tot.	Std Dev
(N =)	25	31	25	81	
YIELD: kg/					
ha	873 b	670 ab	562 a	699	491
hr of labor	0.43	0.32	0.31	0.35	0.25
Gross Returns (FRw)					
/ha	21,820 a	16,761 ab	14,040 a	17,483	12,266
/hr of Labor	10.72	7.99	7.84	8.79	6.17
Cash Costs, FRw/ha	4,218	3,757	6,286	4,680	5,820
Labor Costs, FRw/ha	19,525	18,423	16,246	18,091	10,197
Returns/ha Less					
Cash Costs	17,602 b	13,004 ab	7,755 a	12,803	13,481
Total Costs[1]	-2,872	-7,986	-7,174	-5,628	12,805

[1]Cash costs plus economic (opportunity) cost of labor, seed and equipment (excluding stakes).

Table A.6.5. Percentage of fields in different field categories, by walking distance from the *Rugo* to the bean field.[1]

Variable	Distance from *Rugo* (minutes) ≤ 1.0	1.0-10.0	≥ 10.0	Tot.
(N =)	25	31	25	81
Category 1	24.0	32.3	40.0	32.1
Category 2	36.0 b	25.8 ab	0.8 a	23.5
Category 3	36.0	35.5	48.0	39.5
Bush	60.0 a	67.7 a	88.0 b	71.6
Pure (> 88% bean)	60.0	58.1	48.0	55.6

[1]See "caveat" at the beginning of the appendix.