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PRELIMINARY RESULTS

BENEFITS OF SOIL AND WATER CONSERVATION PROJECTS IN INDONESIA: AN ANALYSIS OF THE BENEFICIARY IMPACT STUDY OF THE CITANDUY WATERSHED AREA*

by

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A Cooperative Study by

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CONTENTS

	Page
EXECUTIVE SUMMARY	iv
INTRODUCTION	1
ANALYSIS OF PREVIOUS WORK	4
PRODUCTION FUNCTION ANALYSIS	7
Framework of Analysis	7
Estimating the Private Benefits	9
Estimation of the Value Functions	10
Determining the Efficient Levels of Inputs	11
Optimum and Actual Input Mix for All Plots	13
Optimum Farm Income Before and After Terracing	14
Other Benefits	16
CONCLUSIONS	18
RECOMMENDATIONS	21
REFERENCES	24

TABLES

Page

Table 1. Land and Labor Productivity..... 5

FIGURES

Page

Figure 1. Benefits and Costs of Terracing..... 8

Figure 2. Marginal Value of Inputs..... 15

Figure 3. Average Value Per Plot Before & After Terracing... 17

EXECUTIVE SUMMARY

This report contains the findings of a study conducted during a one month visit by Dr. Bungaran Saragih, Director of the Unit Studi Dan Evaluasi Sosial Ekonomi (USESE), at the International School for Agricultural and Resource Development (ISARD). The main objective of Dr. Saragih's visit was to use micro-computers to analyze a data set from the Citanduy II Project and to identify future research needs.

The Citanduy II Project (Procit II) started in 1981/82. Its objectives are to increase farmer incomes, reduce soil erosion, and increase employment in the uplands of the Citanduy River Basin. The project uses demonstration farms, subsidies and credit to induce farmers to construct bench terraces and to adopt new cropping patterns and input mixes.

While further analysis is still required, our one month study reached the following preliminary conclusions:

1. Farm incomes increased by an average of 310,000 rp/ha/yr because of the project, an increase of over 300 percent.
2. Terracing alone contributes an average of 80,000 rp/ha/yr. Discounted at 12 percent for 15 years, this annual return has a present value of 544,880 rp/ha.
3. Increased farm income from conservation measures is largely due to changing cropping patterns. Cassava production declined from 42 to 12 percent of the average value per plot, rice production increased from 7 to 27 percent and peanut production rose from 3 to 18 percent.

4. Labor inputs increased from an average of 860 hr/ha to 1,774 hr/ha, for an average increase of 200 percent.

Among the recommendations of this study are the following:

1. Quantification of both on- and off-farm benefits due to reduced soil erosion is necessary to fully evaluate the project.
2. A larger sample with more diversity of agro-climatic conditions needs to be collected in order to assess the importance of these conditions to the benefits of the project.
3. The costs of terracing need to be determined in order to assess the economic viability of the project.
4. The role of extension in shaping the input and output mix of farmers and their adoption of conservation measures needs to be determined.

INTRODUCTION

The Citanduy II Project (Procit II) started in 1981/82 as an extension of the Citanduy I Project (Procit I). Procit I was mainly directed toward providing flood control, rehabilitating old irrigation systems and constructing new irrigation systems in the lowlands of the Citanduy River Basin. The objectives of Procit II are to increase the incomes of the farmers, reduce erosion, and increase employment opportunities in the uplands of the Citanduy River Basin.

The core activities of Procit II are the establishment of 48 model farm units and expansion areas over a 5 year period. The model farm concept is an extension model which tries to introduce a package of upland agricultural technologies to farmer groups in contiguous areas of approximately 10 hectares. The package consists of bench terraces, new cropping patterns and systems, and new input mixes for land with slopes of less than 45 percent. Land with slopes of more than 45 percent get an agro-forestry package. In addition to a relatively intensive extension activities, the project provides subsidies and credit to farmers in order to allow them to construct terraces and to buy new inputs, such as seeds, chemical fertilizers, insecticides, and animals. Surrounding farmers, with similar land conditions to the model farm, are expected to imitate the practices of the model farm. These surrounding farmers, which are called expansion area farmers, also get some input subsidies for three years and financial credit for their activities.

Several studies have been conducted to determine the success of the model farm program and the factors that contributed to this success. A study by Sinaga (1985) measured the beneficial impacts of three model farms, which were built in 1981/82. A similar study, with a larger coverage in terms of number and age of model farms has been conducted by USESE (1986). Other studies of the model farm program include a study by Irawan (1986), which examines the marketing of selected products of model farms and their expansion areas, and a study by Tatuh (1986), which investigates credit for soil conservation and farm practices.

All of these studies, however, investigate only the socio-economic aspects of the model farms and expansion areas. An important study of the agro-climatic conditions of land resources in the model farms area has been conducted by Kucera (1985). It was intended that the Kucera study compliment the studies by Sinaga and USESE, but unfortunately these studies were conducted separately, so that it is generally not possible to correlate the results of the studies.

The original intention of the present study was to combine the studies by Sinaga and Kucera in a unified analysis of soil characteristics and beneficial impacts of the model farms and expansion areas. Unfortunately, only a small subset of the data from the Kucera study can be associated with farmers' data from the Sinaga study. In addition, the soil characteristics data which can be matched is relatively homogeneous. Therefore,

only a limited analysis was possible.* But, the Sinaga data is rich in information and provides a basis for further investigation of the beneficial impacts of the model farmers program.

Given these limitations of data and the less than one month of time for conducting this study, the following analysis is directed towards providing: (1) a verification of the analysis conducted by Sinaga, (2) an investigation of the causal relationships of the impacts observed by Sinaga, and (3) identification of future research needs.

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* A preliminary analysis of the relation between production and agro-climatic conditions found the only significant relationships to the value of production are present land use and drainage. Land use has a positive relationship, but drainage appears negatively correlated. This negative relationship, however, may represent multicollinearity with some other unknown factor. The lack of a sufficiently large data base and the homogeneity of the data available are the likely causes of the failure to find a significant relationship between the agro-climatic variables and production.

ANALYSIS OF PREVIOUS WORK

The results reported in the Sinaga (1985) study are based upon hand-calculations of preliminary data. Using micro-computers, we were able to verify these results using a complete data set. In general, the results of the Sinaga study agree with the computer calculated values.

A table from the Sinaga study of particular interest to this study is his Table 11, the recalculated version of which is shown here as Table 1. The tables differ in two ways: (1) Sinaga deflated his values by converting rupiah values into rice equivalents, we leave our values in nominal terms; and (2) in addition to computing productivity values for the model farm and impact areas, we also compute these values for non-adopters.

The total value of production per hectar (rp/ha) for both the model farm area and the impact area increased after terracing for the entire area and within each village. On average, the increase was 219 percent in the model farm areas and 240 percent in the impact areas. However, non-adopters in Sadabumi and Cibahayu had greater returns per hectare than either the model farm area or the impact area prior to terracing, and in Cibahayu they had nearly the same returns as the adopters had after terracing. The non-adopters appear to be economically rational, since they would not have gained by adoption. The larger adoption rate in Mekasari corresponds with the relatively low returns to non-adopters in this village.

Table 1. Land and Labor Productivity

	DEMFARM			Impact Farm			Non-Adopter Farm
	Before	After	Ratio of After to Before	Before	After	Ratio of After to Before	Before
I. MEKASARI							
1. Total Value per Hectare (rp/ha)	221,445	755,777	3.41	117,277	598,964	5.11	67,440
2. Labor Use (hr/ha)	781	1,960	2.51	551	1,352	2.45	104
3. Labor Productivity (rp/hr)	283	385	1.36	212	442	2.08	647
II. SADABUMI							
1. Total Value per Hectare (rp/ha)	166,349	398,385	2.39	99,222	251,195	2.53	206,705
2. Labor Use (hr/ha)	743	2,911	3.92	902	1,496	1.66	963
3. Labor Productivity (rp/hr)	223	136	0.61	109	167	1.53	214
III. CIBAHAYU							
1. Total Value per Hectare (rp/ha)	110,543	391,095	3.54	129,559	397,699	3.07	398,300
2. Labor Use (hr/ha)	1,004	2,434	2.42	1,320	2,668	2.02	1,399
3. Labor Productivity (rp/hr)	110	160	1.45	98	149	1.52	284
TOTAL SAMPLE							
1. Total Value per Hectare (rp/ha)	160,293	510,868	3.19	111,942	380,414	3.40	282,684
2. Labor Use (hr/ha)	832	2,483	2.98	891	1,664	1.87	1,077
3. Labor Productivity (rp/hr)	192	205	1.07	125	228	1.82	262

Labor use per hectare (hr/ha) increased after terracing for both the model farm areas and the impact areas. On the average, model farm use of labor increased by 198 percent and impact area labor use increased 87 percent. The model farm areas use over twice as much labor per hectare, and the impact areas use about one and a half times as much labor as the non-adopters. The largest increase in labor use was a 292 percent increase in the model farm area of Sadabumi and the smallest increase in labor use was the 66 percent increase in the impact area of Sadabumi.

Labor productivity (rp/hr) increased within both the model farm and the impact areas of Mekasari and Cibahayu. It decreased in the model farm area and increased in the impact area of Sadabumi. The largest changes in productivity occurred in Mekasari. On the average for all of the villages, labor productivity remained relatively constant in the model farms at approximately 200 rp/hr, but increased by 82 percent in the impact areas, from 125 rp/hr to 228 rp/hr. However, labor productivity for the non-adopters is, on the average, 262 rp/hr, thus providing another reason why these farmers are non-adopters.

PRODUCTION FUNCTION ANALYSIS

Verification of the Sinaga (1985) study indicates that production per hectare (rp/ha), labor productivity (rp/hr) and employment (hr/ha) all increased as a function of the model farm program. The purpose of this section is to examine the causes of these increases.

Framework of Analysis

The central problem is one of optimizing the application of terracing to the uplands region. This optimization depends upon the benefits and costs of terracing. The benefits are realized both on-farm, in the form of increased productivity, and off-farm, in the form of reduced downstream sedimentation from water erosion. Since data have not yet been collected on the off-farm benefits, the analysis must be confined to the on-farm benefits and costs.

A hypothetical set of cost and benefit functions are shown in Figure 1. The total private costs (TPC) of terracing are likely to be a function of topography, since the steeper the slope the greater the volume of soil which must be moved and the greater the loss of cultivatable land. That is, costs likely increase at an increaing rate with slope.*

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* A simulation model of terracing costs demonstrates increasing and diminishing marginal returns with increasing volumes of soil terraced. No actual cost data are available. The simulated cost function cannot be compared with the benefit function at this time.

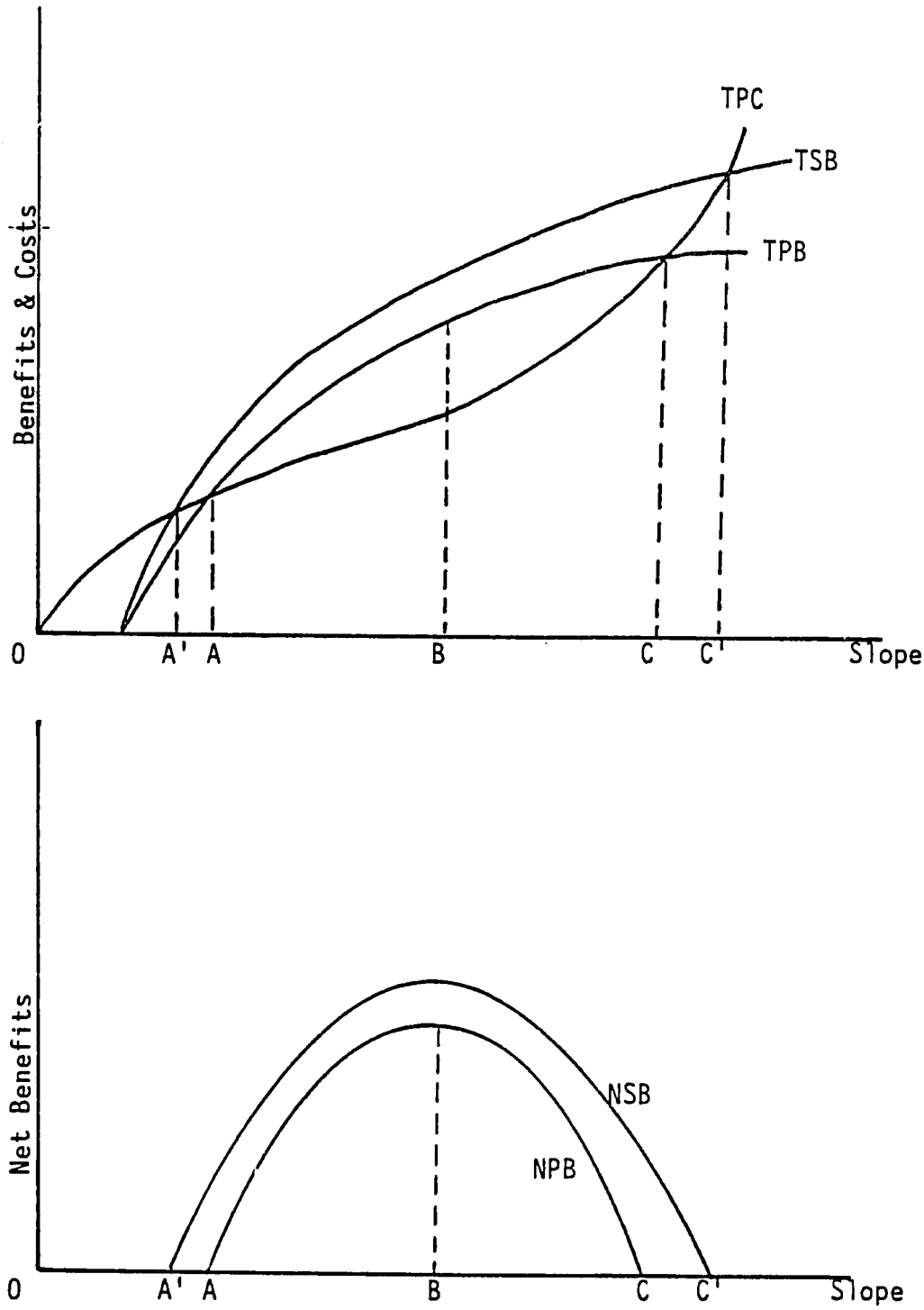


FIGURE 1. BENEFITS AND COSTS OF TERRACING

The total private benefits (TPB) of terracing are in terms of additional net farm revenues stemming from changes in the productivity of land, labor and/or chemical inputs and from changes in cropping patterns. Net farm revenues are simply the revenues earned minus the cost of hired labor and purchased inputs, net of any subsidies. Unlike the cost curve, there is no apriori reason to expect the benefit curve to take any particular shape. The benefit curve in Figure 1 assumes diminishing marginal returns from terracing as the slope gets very steep, but increasing marginal returns for more gradual slopes.

Figure 1 indicates that terracing is optimized for slopes equal to B. However, farmers cultivating land with slopes ranging from A to C would likely also terrace, since the private benefits exceed the private costs.

Summing off-farm erosion control benefits with the on-farm benefits of terracing yeilds a total social benefit (TSB) curve shown in Figure 1. When off-farm benefits are included, the socially optimum range of slopes which should be terraced is expanded by AA' on lower slopes and CC' on higher slopes. Farmers on these slopes, however, will not terrace on their own, because the private benefits are less than the private costs. Terracing on these slopes will require subsidies in order to make the private net returns from terracing positive.

Estimating the Private Benefits

The methodology employed was shaped to a large extent by the data available. It would have been ideal if production functions could have been estimated for the individual crops, and a model constructed to optimize the mix of labor, chemicals, seeds, and

land prior to and after terracing. The data provided only the value of production by sample plot, the labor hours, and the value of purchased inputs. At best, before and after revenue functions could be estimated from this information. Given these limitations, the optimum mix of chemical and labor inputs were computed before and after terracing.

Estimation of the Value Functions

A Cobb-Douglass form of value function was utilized to estimate the value functions, as shown in equation (1):

(1) $VALUE = \exp(C)\ L^{a1}\ IN^{a2}$

where: VALUE = the value of production in rp per ha;
C = the constant from the regression equation;
a1 = the coefficient attached to labor;
a2 = the coefficient attached to the other inputs;
IN = the other inputs measured in rp per ha; and
L = labor hours divided by ha.

Value, labor and chemical inputs were divided by plot area. This implies constant returns to scale for all three inputs, a restriction we were willing to tolerate since the sample plot areas proved to be in almost all instances less than a hectare. Generalizing from these data in order to extrapolate to larger farms was considered too risky. Several supporting studies were conducted to determine whether the constant returns argument could be justified. The results strongly suggest that such an assumption is warranted.

Ordinary least square regressions were performed on the log transformations of value, labor and chemical inputs for both before and after the terraces were constructed. The resulting two revenue functions were utilized to determine the optimal combination of inputs and outputs, before and after implementing

the technology. The difference in output value, given an economically efficient mix of labor and chemical inputs should provides a consistent measure of the impact of terracing upland agricultural regions. This strategy is superior to simply comparing the before and after yields per hectare, since productivity might have changed for reasons unrelated to the terraces. Other reasons for increases in productivity include increases in the efficiency with which factor inputs are used and using new cropping patterns. The likelihood of mistaking these and similar enhancements to production for the effects of terracing is diminished when the most efficient approaches before and after are used as benchmarks for the purpose of comparison.

Determining The Efficient Levels of Inputs

The functions represented by equation (1) provide the basis for determining how each additional labor hour per hectare or rupiah of chemical input per hectare influences the value of production. This is, of course, simply the first derivative of equation (1) with respect to L and IN, as shown in equations (2) and (3). The optimum combination of these ingredients is one which equates these marginal values to the resource costs.

(2) $$VMP_L = a1 \exp(C)\ L^{(a1-1)}\ IN^{a2}$$

where: VMP_1 is the additional value (in rp) of an additional hour of labor.

(3) $$VMP_{IN} = a2 \exp(C)\ L^{a1}\ IN^{(a2-1)}$$

where: VMP_{IN} is the additional value (in rp) of an additional unit of chemical inputs (in rp).

The wages for female and male workers were obtained by regressing the hired wage bill against the hired worker hours.

The resulting wage rates and the fact that the marginal resource cost of chemical inputs is 1 rp were used to solve equations (2) and (3) for the optimal mix of inputs. These were then used in conjunction with (1) to determine the optimum revenue for the average farm.

One problem inherent in this approach is the marginal resource cost to charge for family labor. Men, women and children all have different chores which are likely to differ from those assigned to off-farm laborers. The wage bills included in the data provide information about payments to off-farm help. It is questionable whether these rates should be applied to family members. No doubt the shadow price of on-farm labor should be tied to what one could earn off the farm. But the analysis is never that simple. In the absence of any better information, we assumed that this shadow price was equivalent to that which a hired female worker would earn. It was thought that the wages of hired males would reflect heavy work which might not conform to the activities of the farm family.

The private benefits received by both the farm families and hired labor were computed by multiplying the optimal labor hours on and off farm by the marginal wage rate. Rents to the landowner were derived by computing the value of production via equation (1) and subtracting the wage bill and purchased inputs. We assumed that subsidies were not necessary and that farmers could pay for fertilizers, seeds, and chemicals. The benefits received by the landowners are, therefore, understated by the amount of government subsidy the government wishes to offer. In structuring the problem this way we were able to determine

whether such subsidies could be phased out, that is, whether terracing was worthwhile even without government involvement.

Optimum and Actual Input Mix for All Plots

Prior to terracing, farmers employed labor up to the point where the value of an additional hour was 37.5 rp. This implies significant over-employment of labor, since the cost of an additional hired female and male worker is estimated to be 79 and 206 rp. Assuming that the weighted average marginal cost of labor prior to terracing is 100 rp/hr, then 286 labor hours per hectare would produce an economically efficient solution. This is admittedly a small number and we know that on average farmers actually employed 1,178 hours per hectare. The reason for this discrepancy between what is considered economically optimal and actual practice may lie in the shadow price attached to family labor; 100 rp/hr is likely too high. It is likely that significant under employment or unemployment exists, thereby decreasing opportunity costs.

It also appears that prior to terracing, the value received from the application of chemical inputs is only 25 percent of their cost, with the subsidy. The efficient level of application is only 4,900 rp/ha. One can only speculate as to why this might be the case. Additional analyses reported below provides at least a partial explanation.

After terracing the situation seems to improve significantly. Figure 2 shows the extent to which terracing has shifted the factor demand curves. Farmers achieved close to an optimum input combination after terracing. According to the

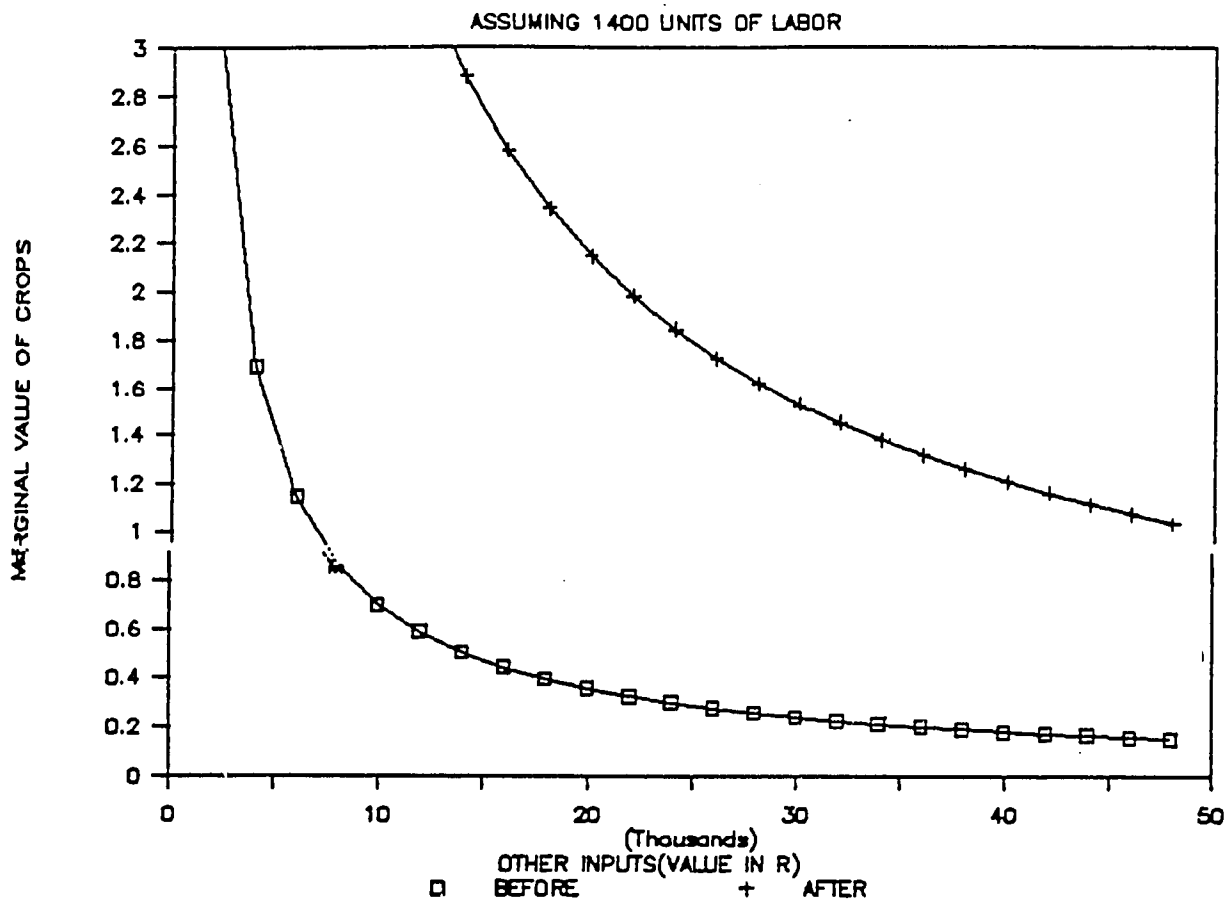
estimated value function, the value maximizing level of employment and chemical input use is 1,450 labor hours/ha and 51,000 rp, respectively. The average farmer employed 1,774 hours and 57,400 rp. This is somewhat surprising since chemical inputs were subsidized. Under such conditions one would have expected that these inputs would have been over-utilized. Perhaps the government limited the amount of subsidies to a level which either by accident or design produced an economically efficient solution.

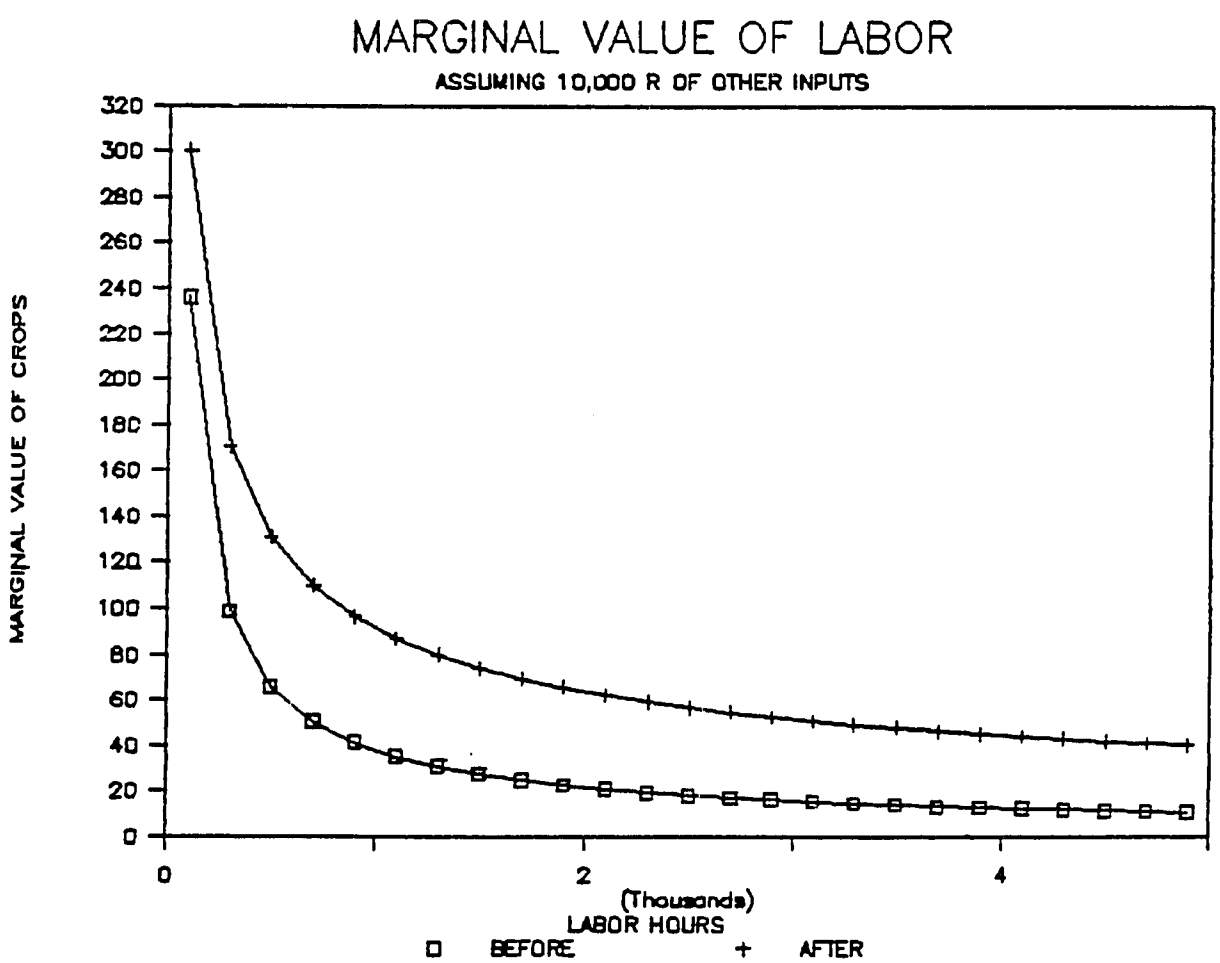
Optimum Farm Income Before and After Terracing

Given the efficient mixes of labor and chemical inputs reported above, it was possible to compute the "best practice" solutions before and after terracing. The private benefits to the farmer were computed as follows. The optimum mixes were used to attain the maximum value per hectare. Hired labor and chemical input costs were subtracted. The remainder comprised on-farm income which combines both rents and on-farm wages.

Terracing boosts on farm income (both rents and implicit wages) by 79,983 rp/ha/yr. This benefit is net of chemical input costs, which are subsidized. The gain an average farmer perceives would be approximately 80,000 rp plus 51,000 rp in input expenses. The present worth of these gains using a 12 percent discount rate for 15 years is 544,880 rp/ha without subsidies and 892,241 rp/ha with subsidies. To the extent terracing costs are less than 544,880 rp, one would expect farmers to voluntarily adopt the practice and subsidies should not be required, but credit may become very important.

Figure 2


MARGINAL VALUE OF OTHER INPUTS
ASSUMING 1400 UNITS OF LABOR
MARGINAL VALUE OF CROPS
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
(Thousands)
OTHER INPUTS(VALUE IN R)
BEFORE
AFTER


MARGINAL VALUE OF LABOR
ASSUMING 10,000 R OF OTHER INPUTS
MARGINAL VALUE OF CROPS
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
2
4
(Thousands)
LABOR HOURS
BEFORE
AFTER

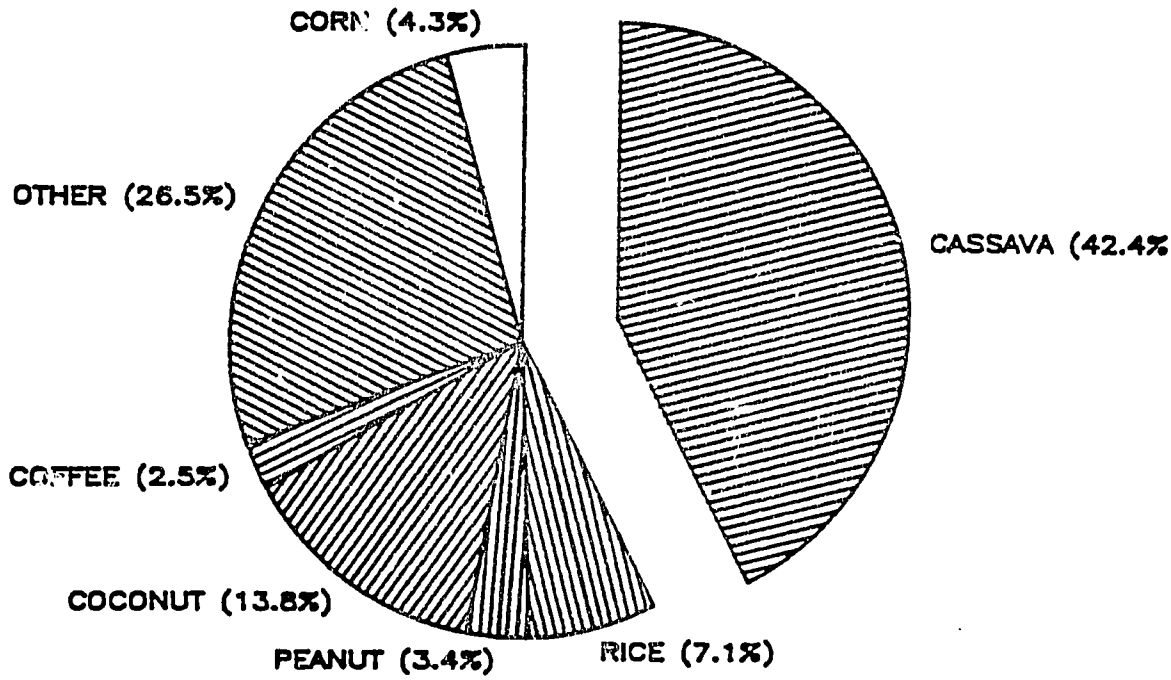
Other Benefits

The magnitude of the potential gains attributable to terracing caused us to wonder whether the practice was enhancing the productivity of farm inputs given the same cropping patterns or whether it facilitated a change in the mix of outputs. By regressing physical production against farm revenue, we were able to obtain the price of each crop, before and after introducing the technology. Applying these estimated prices to the levels of production reported, provided a breakdown of farm income by crop. Figure 3 reveals that terracing has significantly altered the source of incomes. It has induced farmers to shift from low valued crops such as cassava to those which earn 3 to 5 times more per kilogram, particularly rice, peanuts and coconuts.

Figure 3

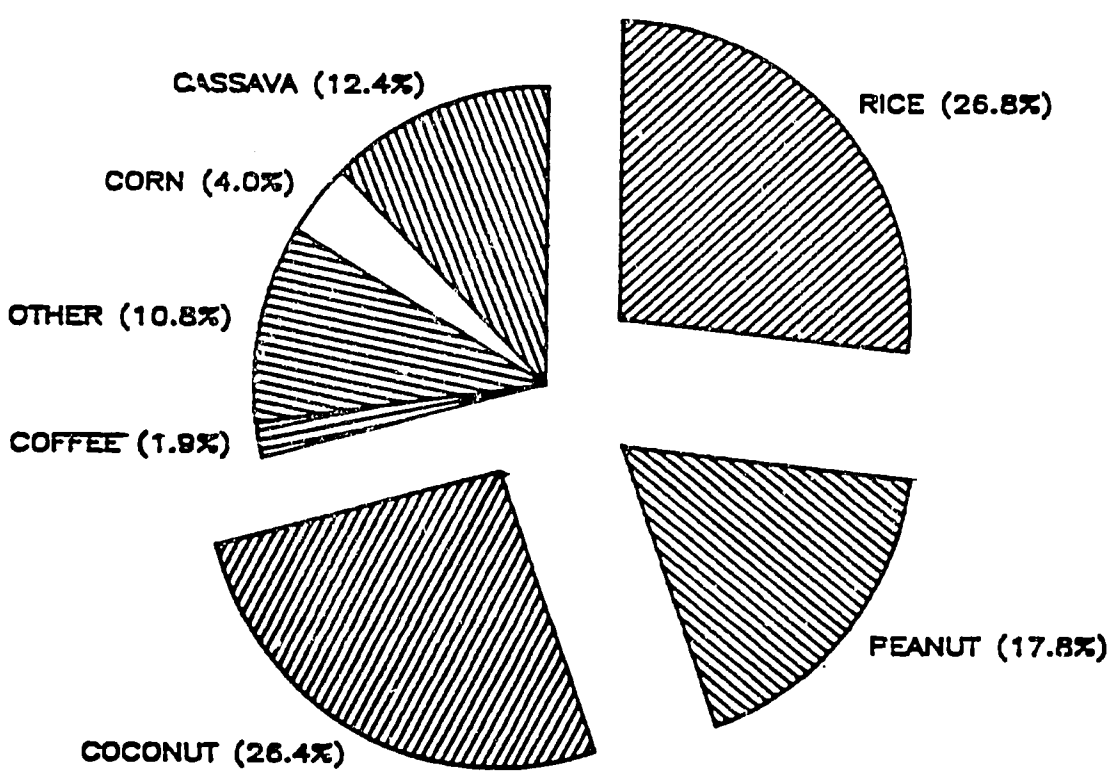
AVERAGE VALUE PER PLOT

BEFORE TERRACING



AVERAGE VALUE PER PLOT

AFTER TERRACING



CONCLUSIONS

The following preliminary conclusions can be drawn from the analysis:

1. The actual value of output within the model farm and impact areas increased from an average value of 136,000 rp/ha before terracing to 446,000 rp/ha after terracing.
   a. That is, average output increased by approximately 310,000 rp/ha.
   b. But this change is only partially attributable to terracing; changes in input and output mixes account for the largest amount of the change.
   c. Of course, terracing must also be given credit for facilitating the changes in input and output mixes, and the model farms program also provided critical information necessary for these changes.
2. Labor inputs within the model farm and impact area increased from an average of 860 hr/ha before terracing to 1,774 hr/ha after terracing and labor productivity increased from an average of 158 rp/hr to 216 rp/hr.
3. Terracing alone contributes an average of 80,000 rp/ha/yr to the value of output.
   a. This result is derived assuming optimal before and after input mixes, so that the increased returns are solely due to terracing.
   b. Discounting at 12 percent for 15 years yields a present value of terracing equal to 544,880 rp/ha.

4. The actual farming input mix of labor and fertilizer went from being suboptimal before terracing to nearly optimal after terracing.

   a. Prior to terracing, the optimal input of labor was 286 hr/ha, but the actual input was 1,178 hr/ha.

   b. After terracing, the farmers achieved a near optimal combination of labor and fertilizer inputs. The optimum labor input was 1,450 hr/ha and actual employment was approximately 1,774 hr/ha. Optimum fertilizer use was 51,000 rp of fertilizer and actual use was 57,400 rp of fertilizer.

5. Both the marginal value of labor and fertilizer increased significantly with terracing.

   a. For example, the marginal value of the 1,400th hour of labor increased from approximately 25 rp to 75 rp, assuming 10,000 rp of fertilizer inputs.

   b. The marginal value of the 10,000th rp of fertilizer increased from approximately 0.7 rp to 4 rp, assuming 1,400 hr of labor input.

6. The productivity of labor increased in the production of rice and peanuts, while remaining constant in the production of cassava.

   a. In rice production, labor productivity increased from 1.43 hr/kg before terracing to 0.66 hr/kg after terracing.

   b. In peanut production, labor productivity increased from 2.5 hr/kg to 1.2 hr/kg.

c. In cassava production, labor productivity remained roughly constant at approximately 0.15 hr/kg.

7. Increased returns from terracing are largely associated with changing cropping patterns.

   a. Cassava production fell from 42.4 to 12.4 percent of the average value per plot, while rice production increased from 7.1 to 26.8 percent and peanut production rose from 3.4 to 17.8 percent.

   b. The most dramatic shifts occurred on slopes greater than 20 percent, where rice production increased from 193 to 46,427 rp per plot, peanut production increased from 0 to 22,374 rp per plot and cassava production fell from 35,050 to 20,703 rp per plot.

   c. One of the functions of terracing is to conserve moisture in the soil. The fact that terracing increased rice production by nearly 400 percent shows that this function was achieved.

RECOMMENDATIONS

A number of important questions remain which cannot be answered by this study. The questions and the necessary steps to answering them include:

1. Data for the model farm program covers only 3 years. This is too short a period to project whether benefits will increase, decrease or remain constant in the future. Therefore, further monitoring is needed in order to assess the long-run potential of terracing.
2. The observed changes in cropping patterns contribute to the economic viability of terracing. However, there may exist other cropping patterns and, perhaps even new crops, which would result in even larger gains from terracing. Research is needed to assess these possibilities.
3. This study was only able to identify agro-climatic data with the model farms, which have relatively homogeneous characteristics. As a consequence, little can be said about the relationship between agro-climatic conditions and productivity changes. A larger sample with more diversity of agro-climatic conditions is necessary in order to assess this relationship.
4. The present study is confined to on-farm benefits of terracing, but there may also be significant off-farm benefits downstream from reduced soil erosion. Quantification of these off-farm benefits is necessary to fully evaluate the model farm program and are critical to policy decisions regarding subsidies for adoption of the program.

5. On the cost side, no data are available to assess the construction costs of terracing. This information is necessary in order to determine the range of privately feasible terracing and to evaluate government subsidy programs to induce terracing. Actual cost data needs to be collected for the model farms and impact areas.
6. Also on the cost side, there may be hidden costs of organization and control associated with the operation and maintenance of the terraces and waterways. Understanding and measuring these costs is necessary to determining the private feasibility of terracing and for assessing the need for and success of government incentives to terrace.
7. The present study is confined to an assessment of bench terraces, but a complete analysis requires an examination of alternative methods of achieving the goals of increased productivity and reduced erosion. Investigation of the benefits and costs of agro-forestry and of other methods of cropping different slopes and soil types is needed in order to determine the optimum program mix.
8. This study found that the observed mix of inputs (i.e., labor and fertilizers) was suboptimal prior to terracing, but that after terracing the actual mix approached the optimal mix. Moreover, the output mix of farmers changed with terracing. One possible explanation of these changes is that the extension activities of the model farms provided improved information to farmers on optimum input and output mixes.

However, the available data is not sufficient to test this hypothesis. Further research is needed to assess the role of extension activities in the production decisions of farmers.

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