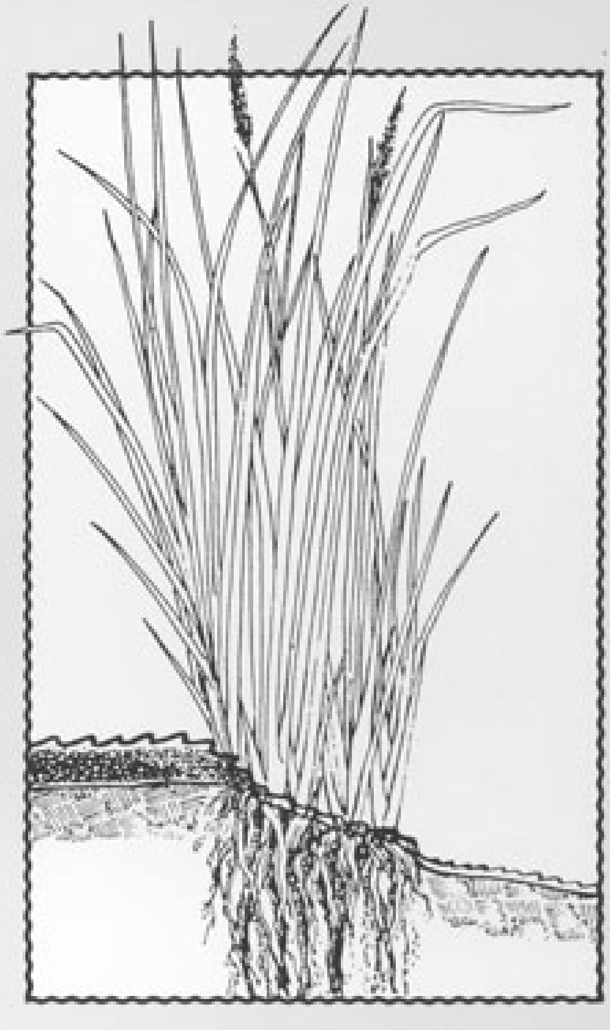
# New Vegetative Approaches to Soil and Moisture Conservation



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soils.

At ICRISAT, in Andhra Pradesh, India, a trial was established to test the ability of vetiver grass to survive under various treatments on red alfisols. The treatments included cutting the plants to ground level each month, leaving the plants completely uncut and irrigating as well as not irrigating, over a randomized block design. During the period of four seasons that the grass has been under trial, all plants have survived, and this period has witnessed the worst three-year drought in the area in many years. As part of their observations, the plant scientists at ICRISAT planted a single line hedge of the grass "on a soil [a substrate of mainly quartz gravel] it could not possibly survive on" to establish a datum point where it would not grow." This was on the inside excavated wall of a dry dam. Not only did the vetiver survive, but it formed a hedge and stopped the adjacent rill erosion. And because the hedge slowed down the runoff, natural grasses and plants established behind it within two seasons, giving a nice example of vetiver's potential for rehabilitating wasteland at little cost.

## The Economics of Vetiver Grass Hedges

One way to evaluate the economic potential of vetiver grass is through benefit-cost analysis. Annex 1 presents such an analysis, based on data from World Bank-financed projects in India's semiarid tropics, and compares the vetiver system with engineered field bunds. Both technologies provide protection against soil erosion, and hence production benefits over time (since without the conservation measures, yields would gradually decline from erosion).

The yield benefits of the two technologies are not well studied but can be roughly approximated for purpose of analysis as 50 percent for vetiver and 30 percent for field bunds.* The initial cost of establishing vetiver hedges is estimated at Rs 275 per hectare, while the initial construction costs for the field bunds is estimated at Rs 932 per hectare. While the analysis is based on a number of assumptions that are poorly known, the results are similar under essentially any feasible set of assumptions: vetiver technology appears to be at least as effective as, or more effective than, field bunds, while costs are dramatically lower. Table 3 summarizes the internal rates of return and present net values of the comparison.

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* The rationale for these estimates is discussed in annex 1.

**Table 3**
**A Summary Economic Comparison of Vetiver and Bunding Technologies for Soil Conservation**

| Technology | Yield Increase (%) | Net Present Value | Internal Rate of Return |
|---|---|---|---|
| Vetiver | 50% | Rs 8,543 | 95% |
| Bunding | 30% | Rs 3,436 | 28% |

Other benefits of the vetiver system that are not captured by these numbers include the reduction of risk brought about by moisture conservation. Particularly in semi-arid farming systems, the absence of adequate rainfall during critical periods of plant growth can result in yield losses even in times of overall normal or near-normal annual rainfall. By reducing the danger of moisture-related crop stress, the vetiver system can encourage farmers to adopt more intensive, higher payoff strategies, thus boosting their overall agricultural production.

The real benefits of vetiver grass accrue from integrating this technology into local agricultural strategies, and this will certainly require a great deal of adaptive research, as well as trial and error by farmers themselves. In some areas, vetiver hedges may render a crop profitable under rain-fed conditions when it previously required irrigation. In other areas, vetiver hedges could be part of a land reclamation effort or as a measure to stabilize grazing areas.

As more becomes known about vetiver, there will undoubtedly emerge cautions and potential problems with the technology. Already there have been informal reports, but no documented studies, that vetiver grass may compete for water with economic crops, that the hedge rows can spread under certain conditions, or that the grass can harbor certain species of insect pests. Clearly, a great deal of further research is needed to better understand the potential benefits, as well as limitations, of vetiver grass technology. And research is needed not only on vetiver but also on the potential role of other plants for soil and moisture conservation.

Yet, as this paper has pointed out, we already know enough about the vetiver technology to see many opportunities for vetiver-based conservation systems. The primary constraints to broader adoption at this point are more institutional than technical. National and international agencies need to rethink their assumptions about soil conservation and to take an objective look at low-cost, low-input alternatives.

## ANNEX
## VETIVER GRASS: A BENEFIT-COST ANALYSIS[19]

As an illustration of the economic gains that can be derived from a vetiver-based conservation technology, this annex presents a benefit-cost analysis. Along with demonstrating the advantages of the vetiver system, the analysis also highlights some of the methodological problems involved in evaluating soil conservation. Indeed, the persistence of conventional structural approaches to erosion control owes much to the complexity of the arguments. As this analysis shows, there is little economic justification for constructing erosion control structures when plants can do a better job for a fraction of the cost.

The analysis compares the relative economics of a vetiver-based technology with the more conventional approach of constructing field bunds. To the extent possible, data reflect conditions on alfisols in the semiarid zones of India. Cost, yield, and input data for the initial budgets are based on estimates provided by World Bank field staff involved in a pilot watershed project, and these estimates in turn are based on on-farm research conducted by various agricultural universities. The estimates have been adjusted based on discussions with World Bank agriculturalists. The budget represents a rotation of sorghum intercropped with red gram (Cajanus cajan) and castor (Ricinus communis).

The principles behind the two conservation technologies considered here--vetiver grass hedges and earthen bunds--are similar. By interrupting the slope of the field, both technologies slow water movement, which reduces the movement of soil particles and provides greater absorption of moisture, hence increasing yields. Vetiver grass hedges are said to be more effective in slowing water and in forming soil terraces as soil accumulates along their upslope side. Bunds also promote the absorption of water but are designed as well to convey "surplus" water into drains and waterways. During intense storms, inadequate provision for transporting excess water can cause failure of bunds and damage to crops downslope. Loss of water from the root zone via waterways probably accounts for the smaller yield increase obtained from bunds. Table 4 summarizes data on the impact of three different soil and moisture conservation technologies on soil loss and water runoff.

Table 4
Impact of Soil and Moisture Conservation Technologies on Erosion and Runoff

| | Erosion or Sedimentation* | Runoff* | Location | Reference |
|---|---|---|---|---|
| Contour cultivation | 10-50 | | USA | Wischmeiar & Smith |
| Contour cultivation | 30-60 | 10-70 | India | Gupta et al. |
| | | 25 | | Dhruva Narayana |
| Grass Strips | 93 | | Indonesia | Abujamin et al. |
| Grass Strips | 40-60 | | USA | Carter |
| | 90 | | | |
| Contour Bunds | 43 | -70 | Thailand | Sheng et al. |
| Contour Bunds | 62 | | Sierra Leone | |
| | | | | Millington |

* Percentages reduced from the case where erosion control measures are not used.

The effect of alternative soil conservation technologies on crop yields has been studied in a number of experiments in India and elsewhere. Despite the apparent simplicity of the question being asked, there is as yet no definitive answer. Experimental designs are weak and researchers have often focused on questions that are peripheral to impact on yields. Table 5 summarizes available data on the impact of alternative soil conservation technologies. In the case of soil and moisture conservation using vetiver grass hedges, the quality of the crop cutting experiments that have been conducted is questionable. There are, however, other data from trials with other grass barriers that provide some indication of likely benefits. Furthermore, a significant part of the yield increase attributed to the vetiver system results from the accompanying practice of contour cultivation, since farmers are essentially forced to adopt contour cultivation in order to follow the vetiver hedge lines. As a base case, yield increases from vetiver of 50 percent have been assumed, based on the work of John Greenfield.[20]

Similarly, experiments with bunding techniques have provided only limited evidence of their efficacy of crop yields. However, in the calculations discussed in the next section, as a base case it has been assumed that bunds with contour cultivation will increase yields by 30 percent over the without-project case. For both bunding and vetiver, the percentage yield increase

## Table 5
### Impact of Selected Soil and Moisture Conservation Techniques

| Measure | Impact on Crop Yield (%increase) | Notes | Reference |
|---|---|---|---|
| Contour cultivation | | | |
| | 35 | Sorghum, India | Dhruva Narayana |
| | 12 | Sugarcane, Taiwan | Liao |
| | 60 | Cotton, USA | Unger |
| | 6 | Potatoes, India | " |
| | 46 | Maize,India | " |
| | 25 | Sorghum, Kanput | Bhatia & Chaudhary* |
| | 15 | Barley, Kanpur | " |
| Sloping agricultural land technology (SALT) | | | |
| | 107 | Corn, Philippines | Watson & Laguihon |
| Field bunds | | | |
| | 10 | Maize, Chandigarh, India | Sud et al.* |
| | 35 | Maize, Uttar Prasesh | Khan* |
| | 18 | Setarin, Tamil Nadu | Kanitkar* |
| | 11 | Cotton, Tamil Nadu | " |
| | 17 | Sorghum, Tamil Nadu | " |
| | 24 | Sorghum, Maharastra | Tamhane* |
| | 25 | Pearl Millet, Maharastra | " |
| | 36 | Sorghum, Tamil Nadu | " |
| | 25 | Pearl Millet, Tamil Nadu | " |
| | 21 | Wheat, Punjab | " |
| | 15 | Grain, Punjab | " |
| | 20 | Maize, Punjab | " |
| | 14 | Pearl Millet, Punjab | " |

* Reported in Tejwani (1989).

has also been treated as a parameter, and results have been presented for yield increases ranging from 0 to 140 percent.*

Investment costs for vetiver grass and earthen bunds have been taken from estimates made during World Bank preparation of the India Integrated Watershed Development Project (Plains). Costs for vetiver grass include labor, bullock power, fertilizer, and contingencies. Planting material is valued at full cost, including transportation, 25 percent contingencies, plus a 50 percent mark up. Costs are detailed in tables 6 and 7.

A hectare of cropland would normally require about 250 linear meters of contour hedge. At a hedge width of 0.5m this will occupy $125m^2$.** In addition to initial planting costs, allowance has been made for care in the second and third years after which it is assumed that the hedges will be fully established. It is important to note that when significant areas are treated with vetiver hedges, the hedges themselves will become a source of essentially free planting material. Ultimately, this will reduce the costs of land treatment by 50 percent.

The analogous costs for constructing and maintaining earthen bunds assume light soils and a bund cross sectional area of $0.5m^2$, which appears to be the current standard. Land estimated to be taken out of cultivation by bunds consists of the width of the bund (1.7m) and berm (0.3m) plus one half of the borrow pit (1.7m) and a provision for drains and waterways (0.3m). These costs are detailed in table 8, and total to Rs 863 per hectare.

The cost of grassing and maintaining bunds has been excluded from the analysis. Poor maintenance is one of the principal reasons for bund failure and the consequent need for frequent replacement. The base-case assumption is that bunds require replacement every five years.

The use of vetiver grass strips as a source of fodder has been observed in southern India, but there are currently no data on its value as fodder or on sustainable yield. Fodder yields have not been incorporated into the benefit flows but this could

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* There is room for considerable doubt as to whether these yield increases can actually be reached. Percentage yield increases, depend on the base, which in the case of the semiarid zone can be highly variable. It is clear that yield increase due to moisture conservation can, in percentage terms, be very high in drought years but that the same absolute increase in good years would be small in percentage terms.

** A square, one hectare plot with a slop of 2.5 percent would require approximately this much material.

Table 6
Nursery Costs of Vetiver Slips
(Rupees)

| | Units | Cost/ Units | Per Ha No. of Units | Total Units |
|---|---|---|---|---|
| Labor and Machinery Costs | | | | |
| Plowing | Bprs | 45 | 10 | 450 |
| Breaking clods | Mdays | 12 | 50 | 600 |
| Spreading manure | Mdays | 12 | 10 | 120 |
| Forming ridges & furrows | Bprs | 45 | 5 | 225 |
| Loading & unloading from mother nursery | Mdays | 12 | 10 | 120 |
| Treatment dressings* | Mdays | 12 | 15 | 180 |
| Pruning and sorting | Mdays | 12 | 20 | 240 |
| Planting of slips | Mdays | 12 | 75 | 900 |
| Weeding | Bprs | 45 | 15 | 675 |
| Weeding & topping | Mdays | 12 | 150 | 1,800 |
| Uprooting clumps | Mdays | 12 | 25 | 300 |
| Subtotal | | 2,244 | | 5,610 |
| Input Costs | | | | |
| Purchase of slips* | 000 | 10 | 6.5 | 625 |
| Manure | Tons | 50 | 25 | 1,250 |
| DAP | Kgs | 3.5 | 250 | 875 |
| Urea | Kgs | 2.6 | 375 | 975 |
| Atrazine (ai) | Kgs | 167 | 1.5 | 250 |
| BHC (10%) | Kgs | 2 | 25 | 50 |
| Irrigation | Total | | | 250 |
| Subtotal | | | | 4,275 |
| Base Costs | | | | 9,885 |
| Contingencies, losses, etc. | % | 25 | | 2,471 |
| TOTAL COSTS | | | | 12,356 |
| Outputs slips** | 000 | | 1,875 | |
| Average cost per slip** | Paise | | | .66 |
| Sales Price*** | Paise | | | 1.00 |

* Including transport costs.
** Basis for costing purposes is 30 slips per clump.
*** Assumes 50 percent markup.

Note: Direct nursery costs are not included in project costing tables. Costs are covered indirectly by a charge of 1 paise per slip for all field treatments.

## Table 7
## Costs of Establishing Vegetative Hedges
(Rupees)

| | Units | Cost/ Units | No. of Units Yr1 | Yr2 | Yr3 | Year of Establishment Year 1 | Year 2 | Year3 | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Contour Hedge Establishment per 1,000 running meters** | | | | | | | | | |
| *Labor* | | | | | | | | | |
| Opening furrows[1] | Bprs | 45 | 0.5 | | | 22.5 | 0.0 | 0.0 | 22.5 |
| Forming bunds | Mdays | 12 | 5 | | | 60.0 | 0.0 | 0.0 | 60.0 |
| Pruning, separating, loading, & unloading | Mdays | 12 | 2 | 0.4 | | 24.0 | 4.8 | 0.0 | 28.8 |
| Planting & dressing | Mdays | 12 | 4 | 0.8 | | 48.0 | 9.6 | 0.0 | 57.6 |
| Weeding | Mdays | 12 | 2 | | | 24.0 | 0.0 | 0.0 | 24.0 |
| **Subtotal** | | | | | | **178.5** | **14.4** | **0.0** | **192.9** |
| *Inputs* | | | | | | | | | |
| Purchase cost of slips[2] | 000 | 10 | 40 | 8 | | 400.0 | 80.0 | 0.0 | 480.0 |
| Transport of slips[3] | % | | 10 | | | 40.0 | 0.0 | 0.0 | 40.0 |
| DAP | Kgs | 3.5 | 20 | | | 70.0 | 0.0 | 0.0 | 70.0 |
| Urea (3 split dressings) | Kgs | 2.5 | 60 | | | 150.0 | 0.0 | 0.0 | 150.0 |
| BHC (10 %) | Kgs | 2 | 40 | 4 | | 80.0 | 8.0 | 0.0 | 88.0 |
| Contingencies | % | | 10 | 10 | | 74.0 | 8.8 | 0.0 | 82.8 |
| **Subtotal** | | | | | | **814.0** | **96.8** | **0.0** | **910.8** |
| **TOTAL COST** | | | | | | **992.5** | **111.2** | **0.0** | **1103.7** |
| Rounded Cost | | | | | | 990 | 110 | | 1100 |
| **Treatment Cost per Hectare[4]** | | | | | | | | | |
| Labor | | | | | | 44.6 | 3.6 | 0.0 | 48.2 |
| Inputs | | | | | | 203.5 | 24.2 | 0.0 | 227.7 |
| **TOTAL COST** | | | | | | **248.1** | **27.8** | **0.0** | **275.9** |
| Rounded Cost | | | | | | 250 | 25 | | 275 |
| **Project Cost per Hectare** | | | | | | | | | |
| Labor[5] | % of above | | 100 | 100 | | 44.6 | 3.6 | 0.0 | 48.2 |
| Inputs | % of above | | 100 | 100 | | 203.5 | 24.2 | 0.0 | 227.7 |
| **TOTAL COST** | | | | | | 248.1 | 27.8 | 0.0 | 275.9 |
| Rounded Cost | | | | | | 250 | 25 | | 275 |

**Notes:**

1. Costs entered as bullock pair days.
2. See nursery cost table.
3. From nursery to field site.
4. Based on 40m HI equivalent to 250m per hectare (1m VI).
5. Since the labor cost is a small proporation of total cost, the entire amount has been included as a cost to the project and would be paid as a completion incentive to the beneficiary who would be responsible for providing the necessary labor.

Table 8
**Comparative Costs of Earthen Bunds and Vegetative Barrier Hedges**
(1989 Costs)

| | Notes | Slope % 1 | 2.5 | 4 |
|---|---|---|---|---|
| Construction costs | | | | |
| Average bund length | per ha | 100 | 250 | 400 |
| Average earth works | $m^3$/ha | 50 | 125 | 200 |
| Field bunding costs | Rs | 300 | 750 | 1,200 |
| Associated costs* | Rs | 45 | 113 | 180 |
| **Cost per gross hectare** | **Rs** | **345** | **863** | **1,380** |
| Loss of arable land | | | | |
| Affected width | $m^2$ of bund | 4.0 | 4.0 | 4.0 |
| Adjusted width | $m^2$ of bund | 3.0 | 3.0 | 3.0 |
| Area affected | square meters | 400 | 1,000 | 1,600 |
| Net loss | square meters | 300 | 750 | 1,200 |
| Proportion affected | % | 4.0 | 10.0 | 16.0 |
| Net loss | % | 3.0 | 7.5 | 12.0 |
| **Cost per net hectare** | **Rs** | **356** | **932** | **1,368** |

* For associated diversion channels and waterways--15 percent of direct costs.

Assumptions: Bunds established at 1m vertical interval, bund cross section equals 0.5 $m^2$, and labor rate is equal to Rp 6/$m^3$ for earth work.

Table 9
**Results of Economic Analysis of Alternative Soil Conservation Technologies under Various Parameters**

| Technology | Yield Increase (%) | Erosion Loss Prevented (%) | Net Present Value* (Rp/ha) | Est. Rate of Return (%) |
|---|---|---|---|---|
| Vetiver | 50% | 1.25-0.95 | 8,543 | 95% |
| Field bunds | 35% | 1.25-0.95 | 3,436 | 28% |
| Vetiver | 50% | 0.00 | 6,765 | 87% |
| Field bunds | 35% | 0.00 | 1,659 | 22% |
| Field bunds (no replacement required) | 35% | 1.25-0.95 | 4,719 | 34% |

* 10 percent discount.

easily be done as additional data become available.*

**Results**

The results of calculations on the comparative costs of vetiver grass hedges and earthen bunds are summarized in table 9. Using the base case assumptions, both vetiver grass hedges and earthen field bunds appear economically viable. However, vetiver with a net present value (NPV) of Rp 8,543 per hectare (IRR = 95 percent) is clearly superior to bunding (NPV = Rp 3,436 per hectare, IRR = 28 percent).

The dominance of the vetiver technology, holds for any plausible combination of parameters. This arises mainly from the cost advantage of vetiver. Figure 3 illustrates the outcome of alternative productivity impact assumptions. Even if it is assumed that the impact of vetiver is only to prevent erosion, a yield impact from bunds of nearly 40 percent (higher than the optimistic base-case assumption) would be required before bunding would become the most desirable option.

If damage from erosion is ignored, the impact of a 50 percent production increase from vetiver still yields a return of 87 percent. On the other hand, under the same assumption, a 35 percent production benefit from bunding returns only 22 percent. Since neither conservation technology will completely stop erosion, the actual rate of return would lie somewhere between these two estimates.

The assumption that field bunds will need to be replaced every five years has relatively minor impact on the profitability of this technology. From the base-case rate of return of 28 percent with replacement, if bunds are assumed to last the entire 30-year planning horizon, the rate of return rises only 6 percent, thus amounting to 34 percent. The present value of future costs of replacement are so small as to have little impact at that high an implicit rate of discount. At a more modest 10 percent discount rate, the present value rises from Rp 3,436 per hectare to Rp 4,719 per hectare. Nonetheless, even if bunds are maintenance free, vetiver is still preferred.

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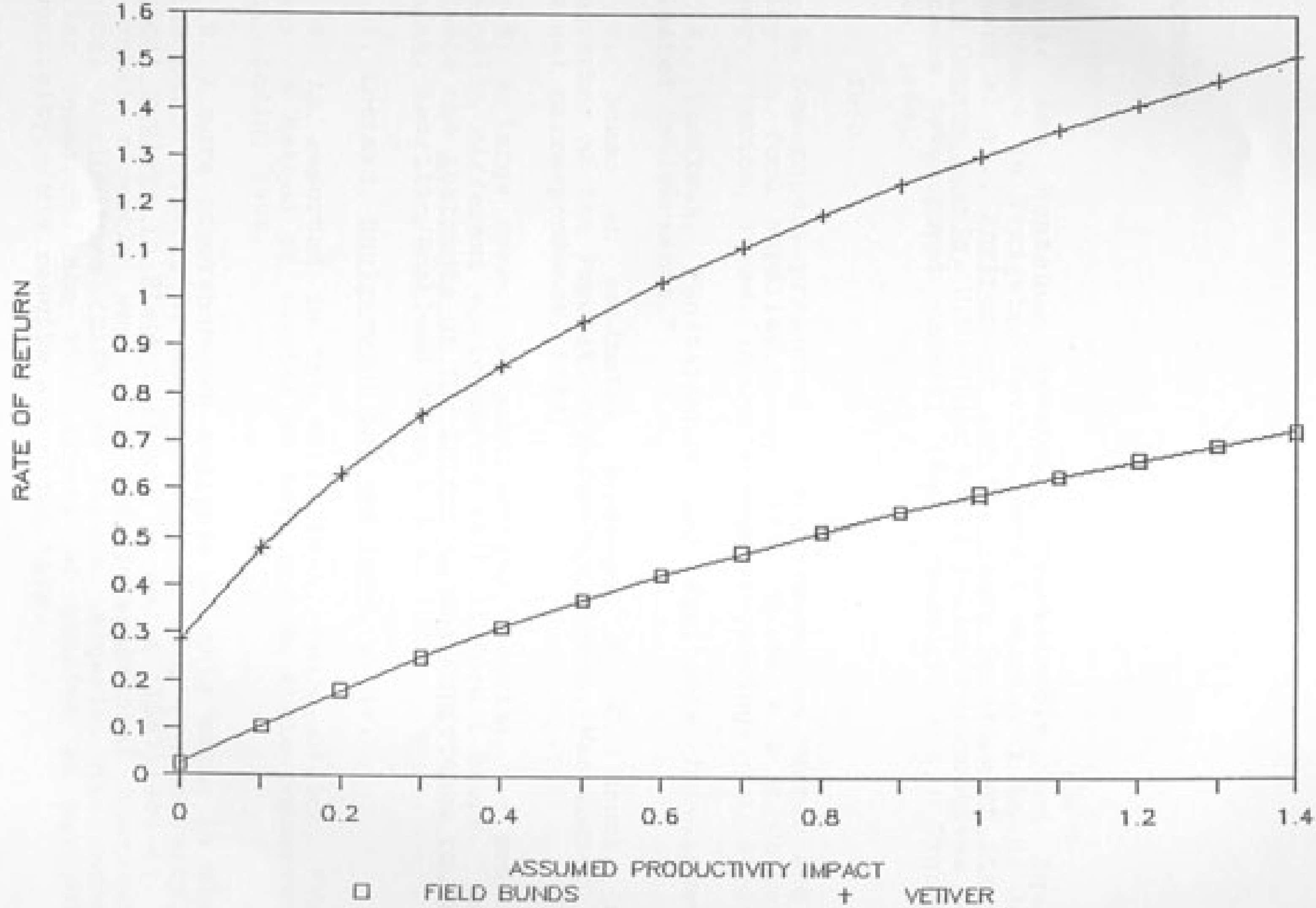
* This could be an important consideration, especially with respect to promoting adoption, given the importance that small farmers often attach to livestock.

Figure 3
Impact of Alternative Productivity Assumptions on Rates of Return

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