JALDHAR MODEL OF IN-SITU RAIN WATER CONSERVATION

Dinabandhu Karmakar • Professional Assistance for Development Action (PRADAN) • New Delhi

INTRODUCTION

The East Indian Plateau and its adjoining areas comprise of thirty odd districts of southern Bihar, western West Bengal, eastern Madhya Pradesh and the northern and north western parts of Orissa. The landscape here is undulating, agriculture is primarily rainfed and dominated by monsoon kharif paddy cultivation.

The region receives an average yearly rainfall in excess of 1000 mm in most places. Distribution of rain, however, is very erratic. Water holding capacity of soil in general is low except in the valley bottoms which receive a lot of silt from the upper catchments. Depletion of vegetative cover (forest and the like) in the upper areas has reduced the rate of moisture recharge drastically in the ridge areas. All these factors have resulted in frequent agricultural droughts affecting upland-paddy crop in this plateau. There is very little development of irrigation infrastructure in these areas. Also, it is simply not possible to protect paddy crop in such widespread undulated areas through irrigation.

This paper describes two simple techniques – "Jaldhar 30 X 40 model" and "Jaldhar 5% model".

"Jaldhar 30 X 40 model" is the technique for treating more slopy lands including smaller hillocks. Such lands were earlier under forest, either privately owned or under the Forest Department. Presently these lands are highly erosion prone and have very little or no top soil. The "Jaldhar 30 X 40 model" is used to stop further erosion and increase the moisture regime.

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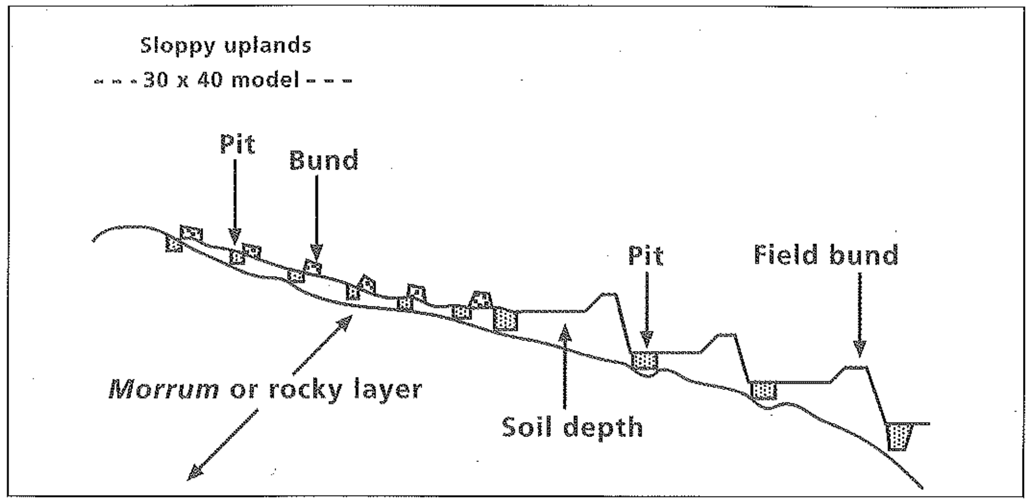
The "Jaldhar 5% model" was originally designed to save paddy crops only. Later it was used to reclaim wastelands (having less than 2% slope) as well, for paddy cultivation. These techniques are claimed to be user–friendly and within the reach of the poor farmers. It also has large-scale replication potential under various poverty alleviation programmes (e.g. EAS, JRY, DPAP, NWDP etc.) of the government. Out of these two techniques, the "5% model" has become more popular. Its design addresses the following issues:

- There is sufficient rain during monsoon but crops still die of moisture stress, particularly in the up and medium uplands. How can the crops be saved by holding moisture?
- How such a scheme to hold water can be made user-friendly and usable by the poor farmers?
- How can such a scheme be practiced anywhere and farmers do not need to depend on permanent sources of water to save their crops?
- How can such a model/structure be made so that it builds up the soil and vegetation over a period of time?

Ideally, in a typical micro watershed in this region, these two techniques should go together. The "30 X 40 model" should be adopted at the upper reaches to be followed by "5% model" at the lower reaches, to get maximum benefit. The following diagram shows the cross section of a typical landscape in the plateau and appropriate location of the proposed alternative new techniques:

The 5% model



Description of the techniques

Jaldhar 30 X 40 technique

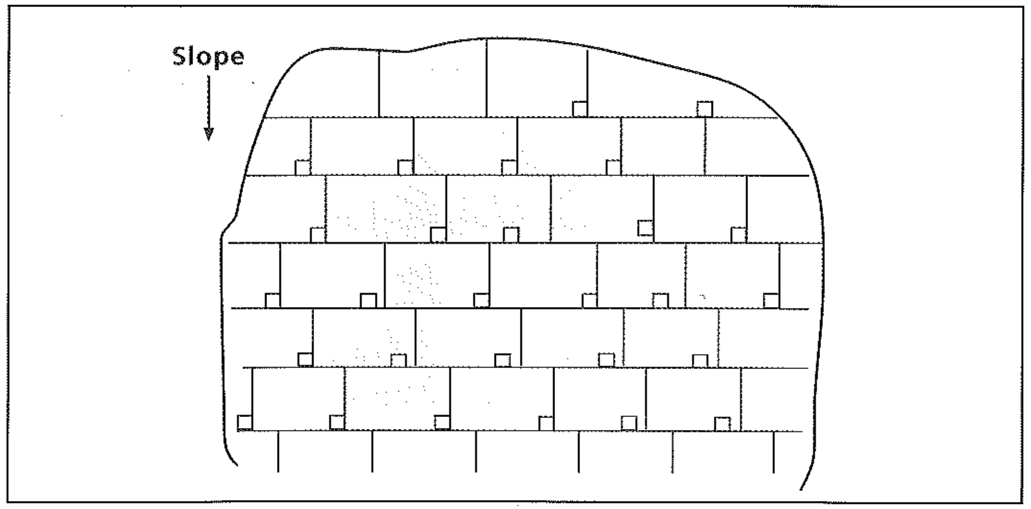
The core idea employed is plotting of unterraced and unbunded lands and creating water collection pits in each plot so that plots resist rush-off of water and pits collect them to soak. The soaked water from a large number of such plots travel below the earth, downstream to recharge the moisture regime.

The design principle

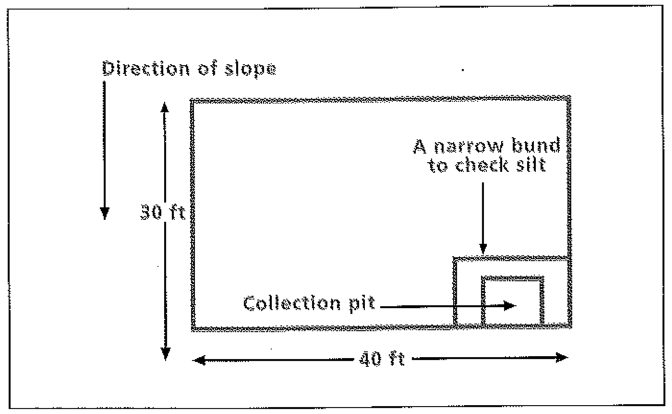
It involves plotting of uplands into smaller plots and digging collection pits in each plot. When the slope of the land is more than 8%, the design needs some modification. In this design elaboration our discussion will be limited to lands having an average slope of 3% to 5% . Each plot is maintained at 30 - 35 ft X 40 ft. 30-35 ft (along the slope) X 40 ft (across the slope). Hence the area of each plot will be 1200 to 1400 sq. ft. The volume of each collection pit is kept between 100 to 110 cu. ft. The earth excavated from the pit is used to construct the bunds of the plots. The pit should be at the lowest point of the plot.

The depth of the pit should be within 3 to 3.5 ft. The pit area should be within 3% to 4% of the individual plot. The layout of the plots should be such that they are arranged in a staggered fashion so that the pits are also staggered as far as possible. This is done to facilitate uniform seepage of water collected in the pits across the slope.

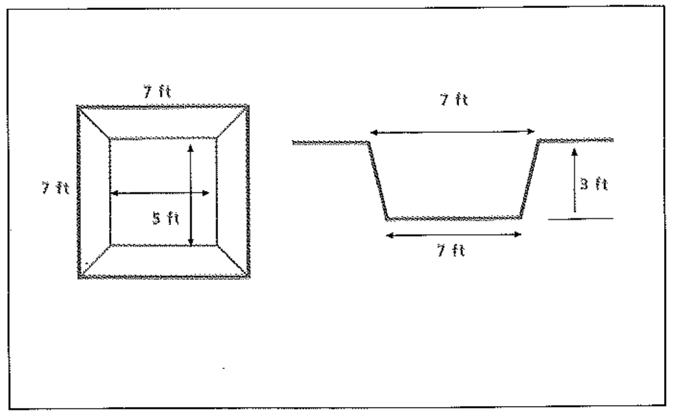
Layout



Design of a plot

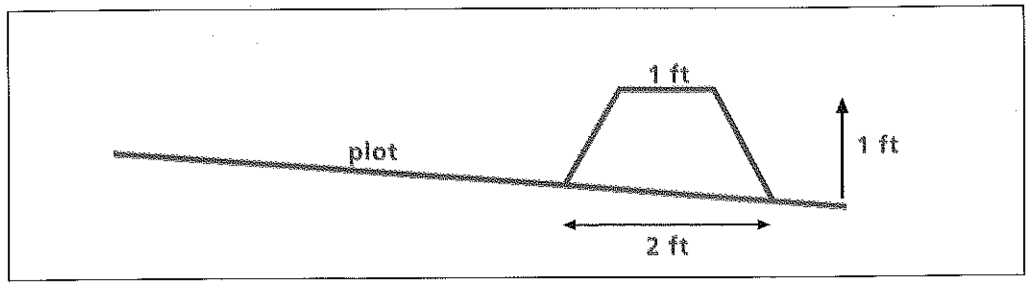


A standard pit design



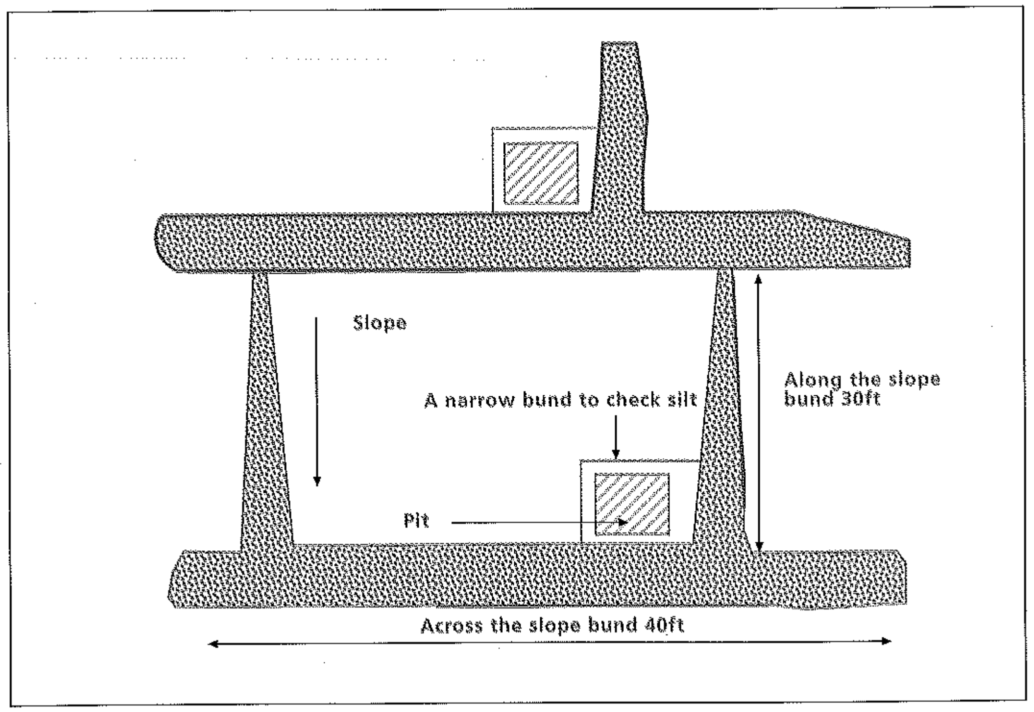
Design of the bunds

(Note: The sketches are not to scale)



The amount of soil required to prepare the bunds of each plot (30 ft x 40 ft) is equal to 70 X (2+1)/2 X 1 or 105 cu ft. This is equal to the volume of earthwork from the pit. More soil should be placed on the bunds across the slope because it will get more pressure of run-off water. Along the slope, bunds merely act as run-off divider between individual adjacent plots. The lower half of these bunds needs to be thicker than the upper half of the bund as shown in the following figure. The pit should be dug at the lowest point of the plot.

Sketch to indicate relative thickness of bunds



5% model with good bund plantation

In estimating the volume of the pit and the plot size, attention should be given to the following factors:

a) The whole patch should be self carrying i.e. no run-off from outside the treated patch should influence it. b) The slope of the land and its local direction. c) Porosity, permeability, water holding capacity, existence of an impervious layer below the top soil. d) Peak rate of rainfall and physical properties of soil need to be considered.

(This does not mean that an individual farmer has to examine all these factors before treating the land. These are relevant only when the technique is sought to be replicated in a completely different geo-physical terrain.)

How this technique helps

Where the depth of soil is more, as we stop run-off loss through collection pits and bunding, soil gets sufficient time to absorb moisture to get saturated. However, in most places, in slopy fallow lands of the plateau, top soil depth is very little and it is porous. Often there is a semi impervious layer below it. A 1200 sq ft of plot having a soil depth of, say, 3 ft has a maximum water holding capacity 1200 cu ft. One part by volume of water can saturate 3 to 4 parts by volume of soil (typical to plateau red-lateritic soil).

After the rain stops, the water held by the soil mass starts moving down. Total gravitational water (about 60 to 70% of the maximum water holding capacity) gradually moves along the slope. This increases moisture regime in the downstream. With this kind of intensive moisture conservation, wastelands have been brought under productive use on a permanent basis (through agro-forestry, fodder cultivation or even crops like vegetables, pulses and upland paddy).

"Jaldhar 5% model"

The core idea

The core idea of the 5% model of in-situ water harvesting is that every plot should have its own water body which would be able to hold rain water which otherwise flows out of the plot as run-off. The water held in the pits would irrigate the plots during water stress. The pit will also facilitate sub-surface flow of water to downstream plots and recharge moisture regime of the area as a whole.

The technology helps in better rain water management in paddy fields to overcome the dry spells during monsoon.

Design principle

Criteria for selection of lands
Lands which do not have access to irrigation facilities.

In case of unterraced lands, those lands can be considered which have sufficient top soil depth so that after terracing/leveling at least 6" of top soil remains all over the plots.

Any paddy field which gets affected due to dry spells during monsoon can be considered.

The lands should be selected in a contiguous patch of, say, a minimum of 10 acre area.

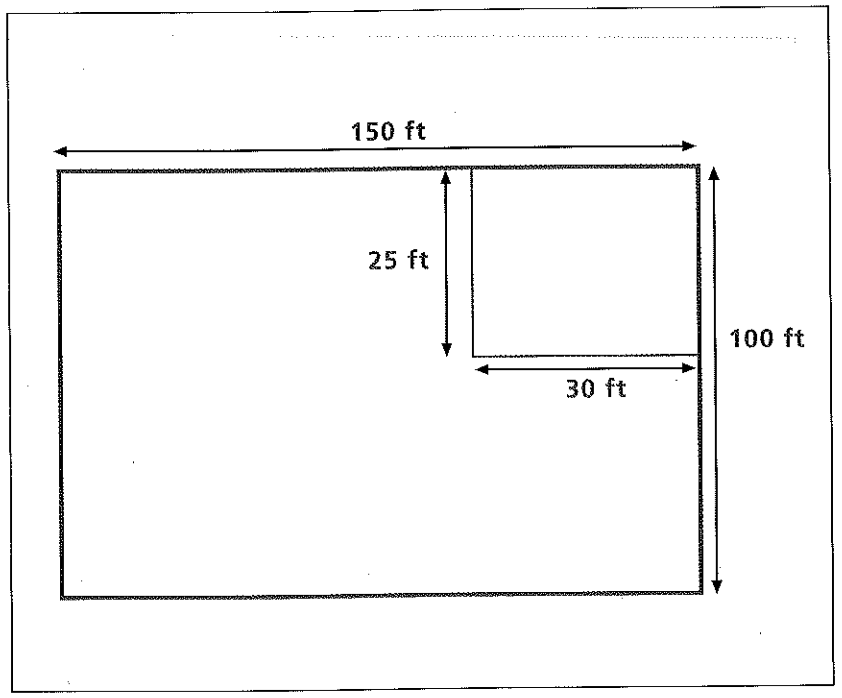
It is better for an initial demonstration to select lands in a patch having slope in one direction.

Pit design
The pit should hold enough water to meet critical irrigation requirement of 2" for the whole plot. If the area of the plot is A unit, then critical volume of water required for 2" irrigation is A x 2 unit-inches.

Here, area of the water body is 5% of the plot area i.e. 1/20th of the plot area. Suppose the depth of water body is: d

So, 1/20 x A x d = A x 2 - A x 2 x 1/20 = A x 2 (1 - 1/20)
= A x 2 x 19/20 Or A x d/20 = A x 38/2
Or d = 38; so depth is 38 inches or 3 feet 2 inches.

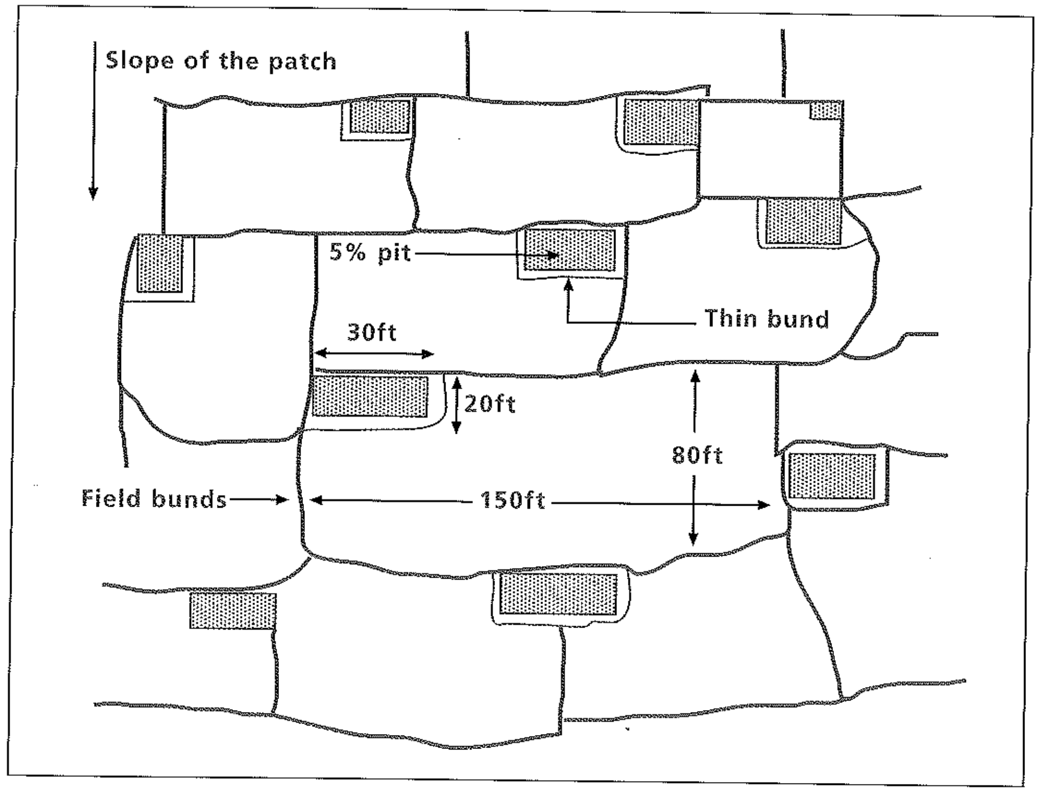
But experience shows, the rate of water loss through evaporation and seepage goes up during dry spells. Hence, the pit needs to be made deeper. Four to five feet depth is thus advised.



Layout

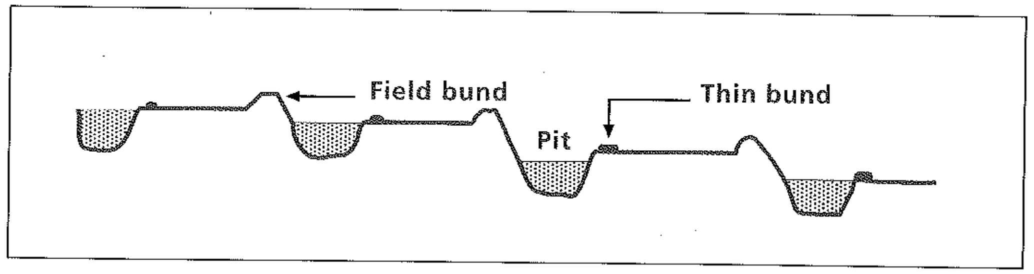
The length and width of each individual plot needs to be measured. To find out the 5% area of the plot, the average length is divided by 5 and the average width is divided by 4. An area measuring one fifth of the length and one fourth of the width of the plot is demarcated at the upper side of the plot, preferably in a corner. A simple illustration may be of help. Say, a plot is 150 ft long and 100 ft wide. So the pit area needs to be 30 ft x 25 ft or 750 sq ft.

Location of pits in treated patch



The norm of allocating 5% area is not sacrosanct, one needs to consider land qualities and farmers' preferences and other crop plans in case they need a bigger pit to store more water. While laying out the pits in successive plots along the terrain slope, one needs to see that pits are not coming in the same line along the slope.

Location of pits - a cross sectional view

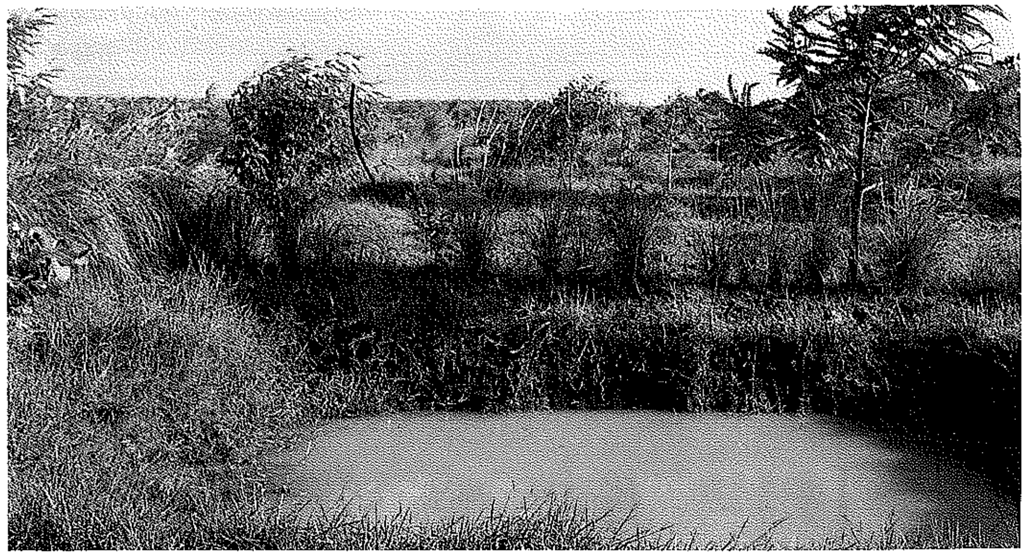


Digging of pits
After laying out of the 5% area of the plots, the pits are to be excarated to a depth of 5 feet. Proper slope should be maintained during digging so that the edges do not collapse when water spills into the pits. Where lateritic sub soil is there, steeper slopes can be maintained. But in case of loamy, sandy or clayey soil, ensuring proper slope is very important.

Strengthening field bunds
Poor farmers often fail to take care of field bunds. The excavated soil from the pits should be used to strengthen the field bunds. Those can be made thicker and higher.

Other components of the package under 5% model
The 5% model is now being tried out in lands other than paddy lands too. At the same time, it has the potential to get expanded to rainfed plain areas also. Considering all these aspects and also to harness the full potential of such infrastructure, certain other activities are integrated into it as a package.

30 x 40 model

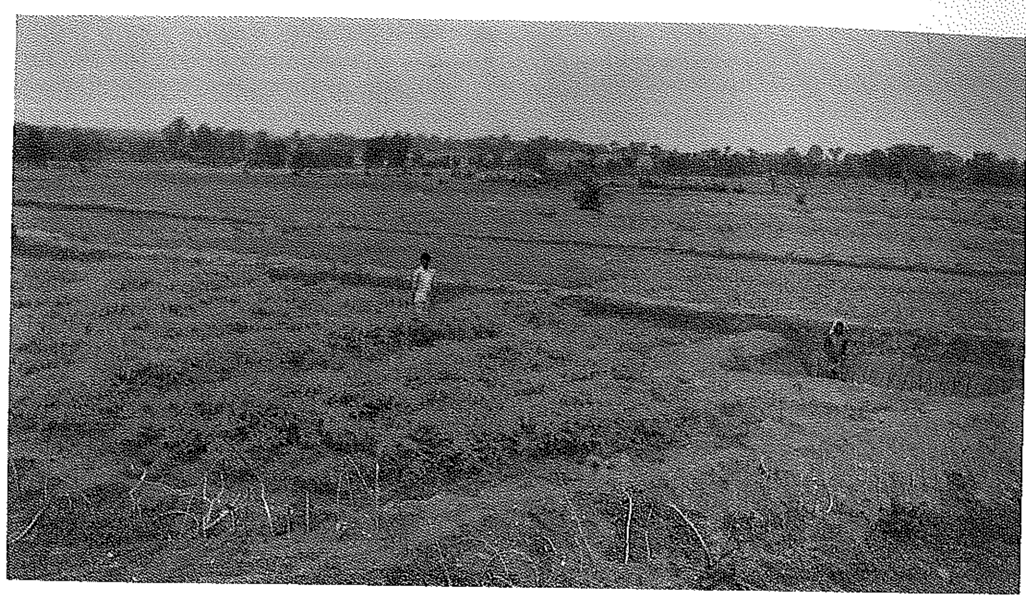


- **Practice of green manure** Due to the light texture of the soil and low organic content in the soil of undulated plateau regions, water holding capacity is low. It is more so when we think of taand (fallow lands with slope). Cultivation of sunhemp, Dhaincha, mung, etc., would help in improving both physical and chemical properties of the soil.
- **Plantation of leguminous trees on field bunds** Except in some pockets where farmers use field bunds for productive purposes, in most of the areas, on an average 5% to 10% of the total field area remain fallow as field bunds. These field bunds are made productive by planting tree species which have multipurpose use. For example, Terminalia arjuna, Mulberry, Dalbergia shisoo, Leucena leucocephala, Glyricidia anceps etc. can be successfully grown. Terminelia and Mulberry can be used as plants for sericulture. All these can be lopped every year during puddling (land preparation for paddy transplanting) to mix as green manure. Promoting trees for green manure has the additional advantage that farmers need not produce seeds every year for green manuring. Often failure to procure seeds limits the cultivation of green manuring crops.
- **Promotion of nursery in instalments** As the 5% model insures crop from dry spells (particularly September dry spells, known as Hathia failure, very common in the plateau), it is suggested that to cope with the late arrival of monsoon, farmers should raise paddy nursery in two to three instalments maintaining intervals of 7 to 15 days in between. This will ensure supply of seedlings of proper age even if rains come late.
- **Fish rearing in bigger pits** When 5% model is practiced in bigger plots, it will have bigger pits too. Farmers may go for fish rearing in those pits. Production of fingerlings from fish eggs has great potential in such small pits.

Experience of implementing 5% model in some villages:

- In Hensla village of Purulia district, the patch (of 15 ha area) treated with 5% model had more clay and elevation and difference between two successive plots along the terrain slope was less (one to two feet). In that particular year, Purulia district did not receive any effective rain for 24 days. One plot had standing water and farmers drained out excess water from some lower plots; while crops in the adjacent untreated fields dried up.

5% model - standing green manuring crop using pre-monsoon rains

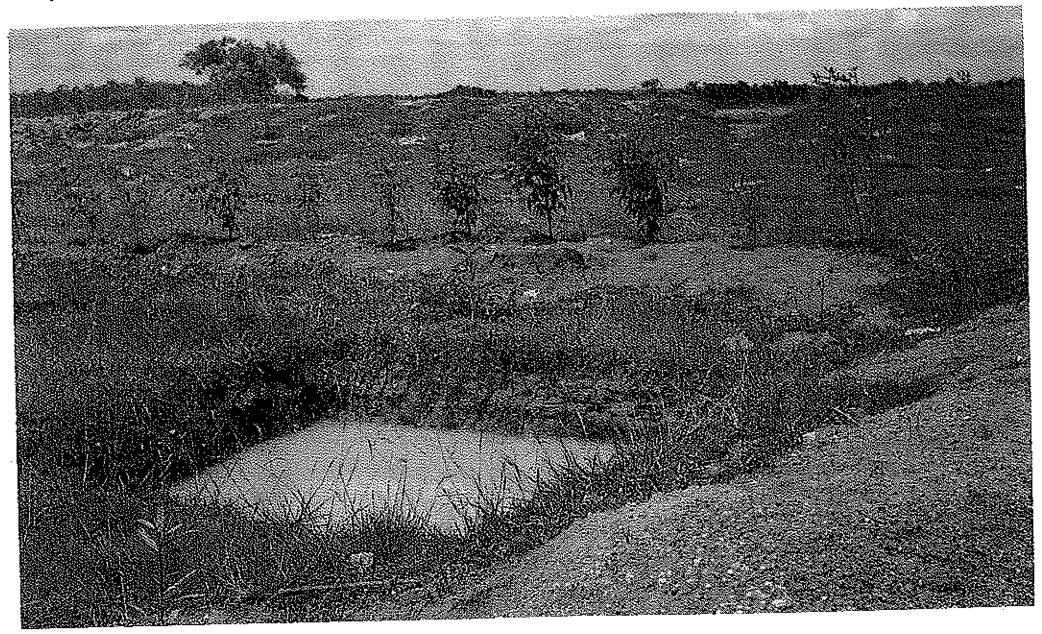


- In Sijadih village of Purulia, the terrain was higher. Elevation difference between two adjacent plots along the slope varied from 3 to 5 ft. Top soil was light textured and very thin (6 to 1). The patch treated was narrower (hardly 100 to 150 wide) and smaller (about 5ha). But at the upstream of the patch, there was a small hillock (of about 12 ha). Half of this hillock is sloping towards the patch treated with 5% model yielding significant amount of run-off. That hillock is also treated with 30 x 40 model. This combination made a significant difference to the moisture regime of the area. During the last seven years farmers have not faced any moisture stress situation there. Moreover, the moisture regime of lands below the treated patch went up to the extent that farmers started taking a second paddy crop in summer without irrigation. But in some plots, the pits were dug on the lower side of the plots. Those plots suffered most as the pits failed to hold water due to higher seepage loss.
- In Ghastoria village of Purulia, the treated patch was smaller (about 6 hectares) and the patch is situated at the ridges of the local micro watershed. Soil texture was lighter. Here the benefit of treatment was less in comparison to Hensla and Sijadih.
- In Chirugora village of Purulia, the treated patch was surrounded by rivers and the patch has a deep sandy soil layer. Though a big area of about 20 ha of land was treated with the 5% model, the pits dried up in a short dry spell of 10 days.
- In Ranhe village of Karra block of Ranchi district, a big (40 hectare) patch of wasteland was treated with the 5% model. The soil is red lateritic. The patch constitutes the areas closer to the ridge line and formed deep gullies at one end which shows the extent of run-off and erosion. After the treatment, the patch could hold all the runoff water. The soil texture is light and forms a deep permeable layer, the pits failed to hold visible water inside it. General moisture regime improved and gullies got stabilized. The total patch showed excellent growth of local grass. The field bunds directly seeded with Gamhar (Gmelina arborea) showed good and uniform growth of plantation.
- In Jagadalla village, where, the 5% model along with plantation of Dalbergia shisoo (Shishame or Shishoo) and Sesbania glandiflora (Bak phul) at 6' intervals

and Eulaliopsis binata (Sabai grass) was found to be very successful. By the third year of land treatment, the colour of the soil changed from brown to black giving the indication of more humus content and consequent increase in water holding capacity. According to the farmers, leaves that had fallen from the trees on the bunds caused this change.

- In Huchukdih village, 5% model implemented with its new design of 5 feet depth, gave most encouraging results. In addition to saving paddy from drought, farmers could grow fish in the pits and also took some vegetables using excess pit water after harvesting paddy.

30 x 40 model Place:'Dhanara, Purulia distict. Age: one month after implementation



Certain concerns expressed by the people involved in implementation of 5% model and author's response:

It cannot help in timely transplantation if monsoon does not break in time

The 5% model is not designed to store water for longer durations so that it behaves like a perennial water body. This is primarily designed for better rainwater management during kharif season once the monsoon has come.

In deep sandy soil conditions this model is not effective

That is true. This is one area where more innovation is needed. One can try the whole package of the model. Particularly promotion of green manure or field bunds to plough back more green biomass into soil is thought to be useful under such circumstances. This may increase the water holding capacity of the soil. Puddling of pit bottom with cow dung at the onset of monsoon may also give positive results.

Apart from the pit, there is very little emphasis on replication of other components of the package

The pit and thicker field bunds provide the infrastructure to create better moisture regime. Other components are mostly cultural in nature and farmers want to see efficient demonstration of those components. Field bund plantation often suffers from grazing. Rearing fish fingerlings require exposure and skills. Raising nursery in instalments is a more sophisticated idea and yet to be demonstrated.

Only ensuring water does not help in increasing yield

In a normal year of rain, the benefit of the 5% model is not much visible. Farmers may compare their return from treated plots with those from untreated ones. And it may actually show a loss to the extent 5% of the plot area would otherwise produce. That is why other components need to be integrated with pit so as to harness maximum return from the additional potential created in terms of extra water and thicker field bunds. Ploughing extra green biomass (available as green manuring crop or lopped branches and twigs from field bund plantation at the onset of monsoon) into soil would make soil better for future use.

CONCLUSIONS

The basic principle behind developing the 5% model is to create water bodies over which poor farmers will have full access and control and use the water with low cost traditional means to protect their paddy crop

The ideas narrated here were evolved based on experiences of working in small geographical pocket of Purulia district of West Bengal. Within 5 years of their birth, these techniques spread to many other districts in Bihar, Orissa, Madhya Pradesh and Andhra Pradesh. This necessitates more innovations and experimentation to make these locally appropriate, keeping the basic principles in mind. The basic principle behind developing the 5% model is to create water bodies over which poor farmers will have full access and control and use the water with low cost traditional means to protect their paddy crop. It was also thought that, when large areas are treated with 5% model (if possible along with 30 x 40 model on upper catchment) it may actually increase moisture regime so high that the treated patch would not require any irrigation during the dry spells to protect the paddy crop.

The 30 x 40 model came as a forerunner of the 5% model. The increased moisture regime observed in a treated patch with 30 x 40 model prompted us to think about such small water bodies on up paddy lands.

The proposed 5% area as water body is not sacrosanct. This figure came out through an interaction or rather we may call it a "negotiation" between the PRADAN team working in Purulia and the farmers of those village where we first implemented the 5% model. A farmer may think of maximizing total income from his piece of holding through various combination of land (for crop), field bund (for tree) and water (for water and fish). Thus where development of other suitable water resources (viz. tank, lift irrigation, well etc.) are possible, the 5% model should not be implemented with the sole purpose of saving paddy crop. But a similar in situ water conservation technique could be thought of to increase general moisture regime of the area or to replenish ground water depletion even in plain areas.

INDIGENOUS SOIL AND WATER CONSERVATION IN INDIA'S SEMI-ARID TROPICS[1]

John M. Kerr • International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) • Hyderabad
N.K. Sanghi • MANAGE • Hyderabad • Andhra Pradesh

INTRODUCTION

Soil erosion is a problem that imposes both on-and off-farm costs. As soil erodes, valuable moisture and nutrients are lost and the topsoil becomes increasingly shallow. The decline in yields that results is a private cost borne by farmers. Off the farm, downstream rivers and lakes become silted, shortening the productive lives of dams and other man-made structures. Soil particles can also transport pesticide residues, poisoning water supplies downstream. These are costs to society, but not necessarily to farmers.

Soil erosion is a problem that imposes both on-and off-farm costs. As soil erodes, valuable moisture and nutrients are lost, and the topsoil becomes increasingly shallow. The decline in yields that results is a private cost borne by farmers

While there is little disagreement among experts that soil erosion incurs costs, the magnitude of those costs is widely debated. These different perceptions about the costs of soil erosion are reflected in the value placed on soil conservation measures. Some groups argue in favour of major efforts to conserve soil without questioning their cost-effectiveness, while others assert that if soil conservation were profitable, private farmers would take care of it themselves. In any event, information is scarce about both the actual costs of soil erosion and the implications for future welfare of allowing soil to degrade at given rates.[2]

The Indian Government has invested heavily in measures to control soil erosion. Vast sums of money have been allocated to soil conservation in each five year plan. Between 1969 and 1990, the budget for soil conservation was Rs. 16 billion (between $1 and 1.5 billion).[3]

Two assumptions, one explicit and the other implicit, underlie the Government's policy. First, soil and water conservation (SWC) in a watershed context is believed to increase agricultural productivity in dryland areas. Second, achieving such an increase is considered worthwhile even though its economic profitability is subject to debate.

The results to date of Government SWC programmes have been disappointing.[4] Farmers have neither willingly adopted recommended SWC measures nor maintained structures, etc. installed by the Government. Some SWC officials have come to the conclusion that farmers do not know or care about soil erosion.[5]

Evidence from the semi-arid tropics (SAT) of South India, however, refutes this assessment. Farmers there have developed effective soil and water conservation practices. These indigenous technologies have evolved in different places in response to local agroecological and economic conditions. Three principal factors determine the shape and scope of these efforts.

First, the designs of indigenous SWC technologies reflect the relative availability and opportunity costs of different resources, including materials, human labour, animal power and cash. Indigenous designs also vary with site-specific agro-climatic factors.

Second, they developed within the constraints of small, fragmented farms, and in accordance with farmer's preferences to invest in soil conservation individually or in co-operation with an adjacent farmer rather than in large, cooperative groups.

Third, economic factors determine adoption patterns. Soil conservation investments are simply one activity among a range of farmers' economic concerns. Farmers assimilate available information to decide how their time and money can be spent most productively. Their opportunities and constraints are not identical, so the same

activity is not equally profitable for all farmers. For example, farmers' alternative investment possibilities, their tenure status, the number of plots they own and the resources at their disposal are some of the factors that determine whether soil conservation investments will be attractive to them. As a result, farmers owning similar land with the same erosion problems may invest in soil conservation at different rates. For some farmers, SWC investments may not be profitable at all. Farmers are like other economic agents - they must choose among alternative investment possibilities, some of which may be more profitable than soil conservation.

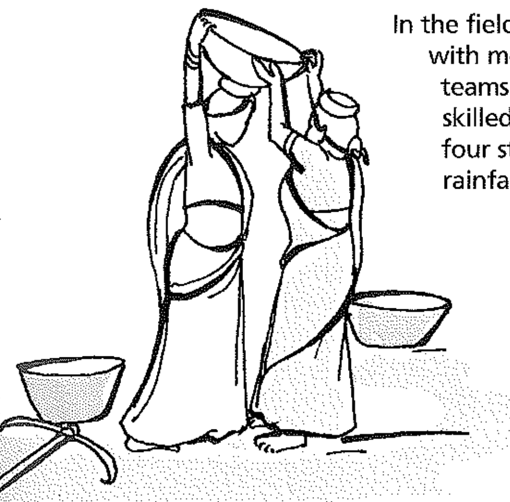
Evidence suggests that most farmers perceive that soil erosion causes on-site losses, yet only a small handful invest in measures to control it. This raises questions about the appropriate level and form of Government intervention to promote soil conservation. Economic theory suggests that the Government should only intervene if at least one of two conditions hold: first, if farmers are constrained from acting in a privately optimal way, or second, if private and social profitability diverge.[6]

There are good reasons why these conditions may hold. First, farmers may lack complete information regarding on-site costs of soil erosion or they may be reluctant to make investments with positive but variable, long term returns. Second, if farmers cannot capture all the benefits from investment in soil conservation, then they lack the incentive to invest at a socially optimal level. This is the case if the costs of erosion are mainly off-site (i.e. downstream), or if land tenure is insecure. These various conditions constrain farmers' investments in different ways, each requiring separate measures, ranging from education, to credit, to subsidies.

The Indian Government has demonstrated its commitment to investment in SWC programmes. We do not specifically address the appropriate level of Government intervention. Instead, we focus on ways to make SWC programmes more cost-effective. We believe that understanding indigenous SWC practices and adoption patterns is crucial in this effort. Specifically, we document indigenous soil conservation practices and the logic behind them and then identify conditions under which farmers invest in soil conservation and constraints inhibiting such investment. Finally, we suggest ways to overcome those constraints and create the conditions under which private investment will increase.

Specifically, we propose a set of hypotheses about economic factors that determine both the design of SWC technologies and whether people invest in them. We examine the preliminary evidence for each in more detail. We conclude with recommendations for SWC programme officials, policy makers, and researchers.

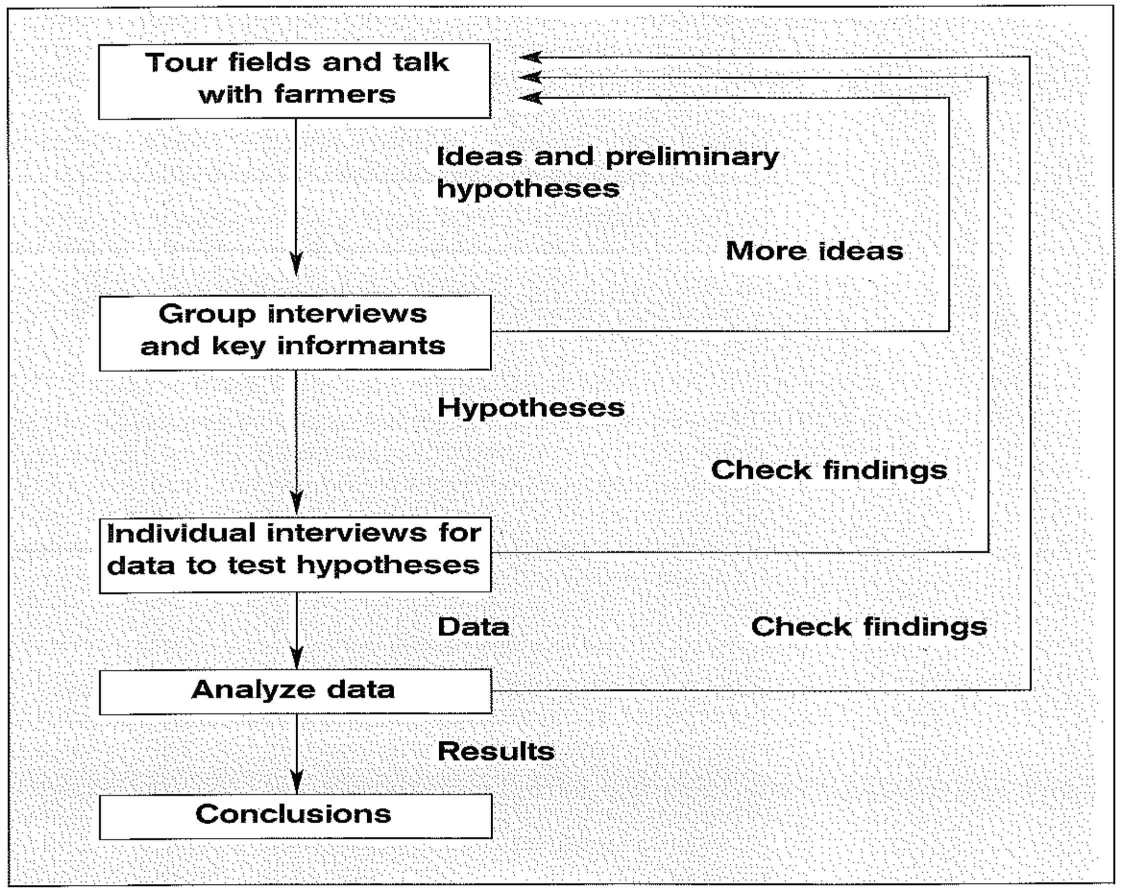
Research methods



In the field work for this research we combined rapid rural appraisal (RRA) methods with more formal individual farmer interviews. Where possible, we worked in teams of three people: an agricultural scientist, a social scientist and a person skilled in communicating with farmers. We worked in a total of 12 villages in four states of India's SAT; the villages varied by agroclimatic conditions such as rainfall, soil type and slope.[7]

We began by transecting the fields, covering different aspects of the landscape. We spoke casually with farmers whenever possible to learn about their perceptions of erosion and efforts to control it. We then conducted open-ended group interviews to help formulate hypotheses about the determinants of investment. Finally, we carried out detailed individual interviews to gather data to test those hypotheses. During the course of this process we continually repeated steps to cross-check our findings. The approach is summarized in Fig 1.

Figure 1: Field research methods



In all of the surveyed villages we observed three categories of fields keeping in mind SWC measures. First, those where indigenous practices were implemented and maintained on a regular basis, resulting in satisfactory conservation of soil and water resources. Second, those which were badly neglected, resulting in severe erosion of soil. Third, those somewhere between the first two categories. It is important to note that we could easily spot the neglected, eroded fields from a distance, even while driving on the road. Fields protected by indigenous technologies, on the other hand, could not be appreciated until we visited them individually.

WHY FARMERS IN THE INDIAN SEMI-ARID TROPICS REJECT RECOMMENDED SOIL AND WATER CONSERVATION PRACTICES

Both soil conservation professionals and farmers are aware of erosion and the need to control it but their perceptions of the problems and approaches to solving them often diverge. For future research and development to be effective, these differences must be understood and reconciled. In this section we first compare the perceptions that have guided indigenous and recommended bunding systems, then describe the technologies, and finally explain why farmers will not accept recommended contour bunding methods.

Farmers have multiple objectives

Indigenous and recommended SWC bunding designs have evolved on the basis of different objectives. Soil conservation programmes in India traditionally have had a single objective: to design and introduce technologies that conserve the maximum amount of soil and water. Even in integrated watershed programmes, there is little co-ordination among line departments concerned with different tasks, and soil conservation is undertaken in isolation.[8] Farmers, on the other hand, have multiple objectives, of which soil conservation is only one. For example, bunds demarcate property lines and protect against encroachment by a neighbour. They are often lined with thorny barriers to keep trespassers out or they may be lined with vegetation to produce valuable commodities such as fuel, fodder or fruit. They may create new fields or protected environments, reducing the high risk that characterizes rainfed agriculture in the SAT. To make field operations convenient, they are usually built in straight lines. The resulting demarcations also facilitate partitioning land for inheritance. Farmers are most likely to accept improved SWC techniques that are consistent with as many of these objectives as possible. As a result, the best soil conservation practice from a farmer's perspective is not necessarily that which conserves the most soil.

Bunds increase in height and width as slope, rainfall intensity and erodibility of the soil increase. Often vegetation is preserved or planted on the bunds to strengthen them and provide fodder and other products

This discrepancy in objectives leads to two important differences in SWC technologies. First, recommended SWC structures are positioned on the contour while indigenous technologies are boundary-based. Second, recommended SWC practices emphasize long term productivity benefits from maximum protection of the soil, while farmers' practices emphasize short term productivity as well as conservation. Farmers try to achieve this by concentrating soil rather than simply conserving it, as we will explain.

Dryland farmers reject contour bunds

Soil scientists and SWC engineers recommend that bunds be located on the contour so that the pressure of runoff water is spread evenly. The bunds reduce runoff, increase infiltration, and divert excess runoff to a central waterway. SWC programmes have introduced continuous contour bunding covering an entire watershed.[9] Fig 2 explains the basic design of contour and graded bunding systems.

Indigenous SWC structures on small farms of the study regions lie almost uniformly on field boundaries, which rarely correspond exactly to contours. Indigenous practices vary more widely than recommended practices, reflecting the diverse conditions under which they have evolved. Boundary bunds are made either from earth or stone or a combination of both, depending on relative abundance of these materials. Bunds increase in height and width as slope, rainfall intensity and erodibility of the soil increase. Often vegetation is preserved or planted on the bunds to strengthen them and provide fodder and other products.

Methods to dispose off excess runoff are also based on boundary lines. In areas with red soil and low rainfall, some farmers build small earthen bunds to keep all the moisture on the field. Where the land is stony, they build stone bunds that retain soil but allow water to filter through. In medium rainfall zones, especially in black soil areas where waterlogging can be a problem, farmers build stone waste weirs (drains) to dispose of runoff into the field below theirs. In the highest rainfall zones, the waste weirs deposit water into boundary waterways, protecting the lower fields. Sometimes grass strips are planted on the lower end of the field to arrest soil while allowing the water to drain. These three systems are shown in Fig 3.

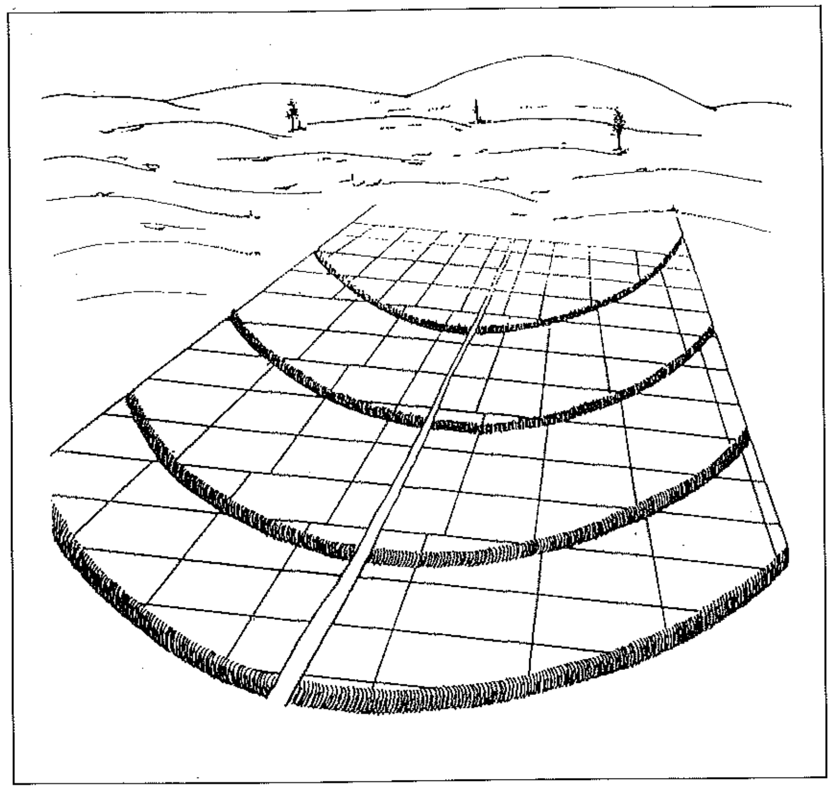


Figure 2:
Contour/Graded Bund System

The contour/graded bund system has long been the standard recommended practice in Indian SWC programmes. This picture demonstrates the problem that arises because contour lines (the heavy black curved line) rarely match boundary lines (the light lines in the grid). The contour bunds and central waterways tend to cut corners on small fields.[10]

Contour farming, however, is not unknown to Indian farmers; they adopt it in hilly areas to make indigenous terraces and in lowland areas for paddy fields under tank irrigation. It is quite common to find the same farmer using contour bunds on his tank-irrigated paddy land but boundary-based erosion control measures on his rainfed land. Farmers recognize the efficiency of contour-based systems for conserving soil and water, but they feel that on rainfed land the benefits are not great enough to justify foregoing the other advantages of indigenous, boundary-based systems.

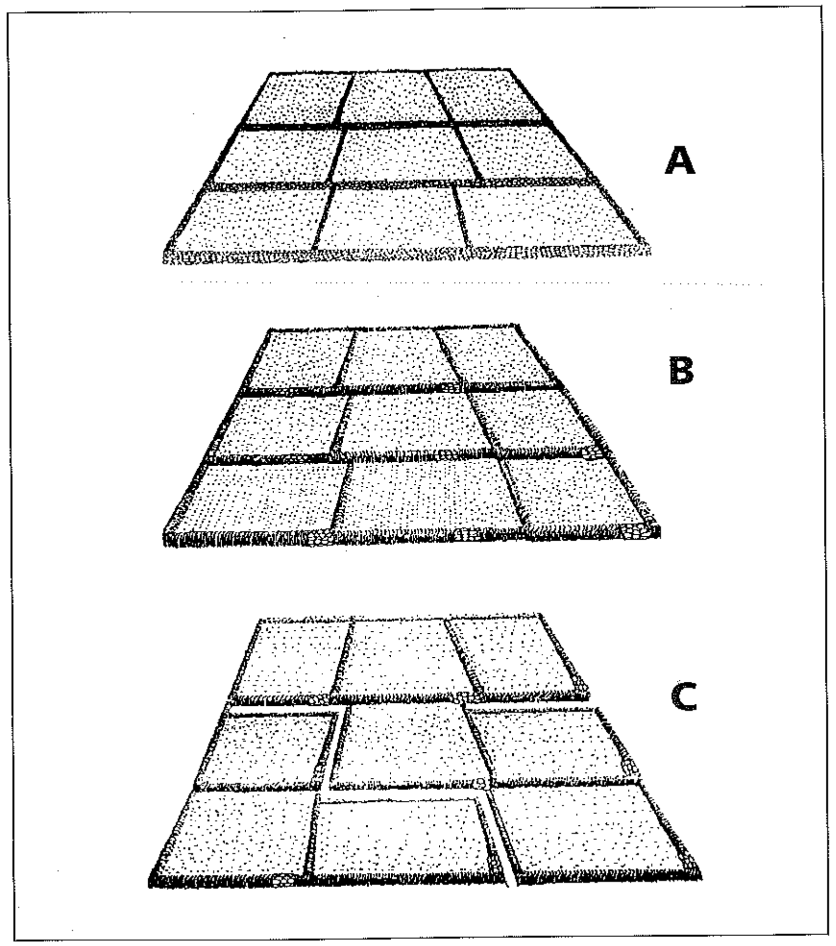


Figure 3:
Boundary Bund and Drainage System

Panel A shows boundary bunds in hilly, stony, red soil areas. Stones are cleared from the field to build bunds. Excess runoff drains through the stone bunds. Panel B displays earthen boundary bunds with field to field runoff disposal through stone waste weirs. These are found in medium to high rainfall red soil areas and low to medium black soil areas. In Panel C, high rainfall conditions require that excess water be drained through boundary waterways, which eventually lead to natural streams.

Farmers note several reasons for favouring boundary bunds. First, boundary bunds serve the dual purposes of conserving soil and demarcating property. Contour bunds cut across farm boundaries, leaving corners in some fields and creating the risk of losing a piece of land to the neighbouring field.

Second, because they tend to run in straight lines, boundary bunds make plowing more convenient than with winding contour bunds, particularly where multi-row implements are used.

Contour farming also reduces the efficiency of operations (where traditional desi plows are used) because it requires repeated cultivation in the same direction. With desi plows (unlike tractors), farmers must alternate directions to turn the soil effectively.

Third, boundary-based systems enable individual farmers to invest without having to cooperate in large groups. Limited group action among adjacent farmers is sufficient. In contrast, conventional systems require co-operation among all the farmers in the watershed. This is because they distribute benefits and costs unevenly, depending on the location of bunds and drains, as shown in Fig 2. The central waterway is constructed at the end of the graded bund, encroaching on the adjacent fields. In boundary-based runoff disposal, waterways are decentralized and associated costs - land and maintenance time - are shared more widely. This reduces conflict, increasing the likelihood of adoption. Tables 1-6 provide a more detailed comparison of indigenous and recommended practices in different agroclimatic zones. Farmers will not accept contour bunds alongside boundary bunds because they take up too much space on the small farms. They also refuse to accept contour bunds without boundary bunds, because the soil below the contour bunds will move downhill to the neighbour's field.

Conventional graded and contour bunding systems appear to be suitable only where land holdings are large or tractors are used. If plots are large, preferably covering an entire micro watershed, the central waterways do not cause a clash of interests among farmers. However, large plots are rare in India. It is not surprising that the conventional bunding system, which was developed for large farms in the United States and tested successfully on institutional farms in India, continues to be rejected by small farmers.

Contour bunds will not gain widespread acceptance on small farms, and to recommend that farmers build them is a wasted effort. Rather, SWC programmes must adapt, possibly by promoting boundary bunds, which are far more readily accepted than contour bunds. To take the opposite approach - promoting contour bunds - would require a very ambitious programme to change boundary lines to match contours. This would be very complicated, requiring institutional and legal changes as well as much cooperation among farmers. Moreover, in the Indian SAT, soil quality often varies significantly over very small areas, inhibiting plot exchange.[11] Research on boundary bunds is needed to compare their efficiency with that of contour bunds on small plots.

It is important to note that the Indian SAT and West African SAT, where much similar research has been done, differ in acceptance of contour bunds. Research from West Africa suggests that contour bunds are much more readily accepted than in India.[12] More work is needed to understand location-specific conditions that affect SWC technology adoption.

Table 1: Recommended and indigenous soil and water conservation practices; black soil, low rainfall areas; Sholapur District, Maharashtra and Bellary district, Karnataka

Item	Practices	
	Recommended	Indigenous
Soil conservation	Continuous contour bunds	Field bunds with waste weirs
Moisture conservation	Contour farming	Land leveling Deep plowing Kharif fallowing 2 - 3 intercultures Soil mulching for closing cracks in post rainy season
Runoff disposal	Field to field through earthen hooks on contour bunds	Field to field through stone waste-weirs
Gully control	Stone checks at regular intervals to stabilize gullies	Stone checks on boundary to harvest soil and reclaim gullies
Water harvesting	Percolation tanks	Needs further investigation

Table 2: Recommended and indigenous soil and water conservation practices; black soil, high rainfall areas; Medak district, Andhra Pradesh and Akola district, Maharashtra

Item	Practices	
	Recommended	Indigenous
Soil conservation	Continuous graded bunds Broad bed and furrow	Field bunds with conservation drains with waste weirs Grass strips on boundaries in field with mild slope
Moisture conservation Runoff disposal	Contour farming Central waterways Broad bed and furrow	Normal tillage and interculture operations Boundary waterways
Water harvesting	Farm ponds in gullies or private fields for supplemental irrigation	Community tanks on private holdings; post rainy crop raised with residual moisture in tank bed
Gully control	Stone checks at regular intervals to stabilize gullies	Stone checks on boundary to harvest soil and reclaim gullies

Farmers invest in conservation as a byproduct of productivity

Indigenous SWC designs suggest that conservation measures are most likely to be adopted if they increase productivity. Conservation investments are measured like other investments: they are undertaken only if they are profitable.

Soil conservation measures that produce the most rapid return on investment are the most favoured. These include bunds that require relatively small initial investment, provide fodder or fuel, and conserve moisture on-site (as opposed to downstream through groundwater percolation or runoff to a farm pond). Such opportunities to combine conservation with quick increases in productivity are limited, but they should be exploited to the extent possible.

Table 3: Recommended and indigenous soil and water conservation practices; red soil, low to medium rainfall areas; Mahbunagar, Anantapur, Ranga Reddy and Nalgonda districts, Andhra Pradesh

Item	Practices	
	Recommended	Indigenous
Soil Conservation	Continuous contour bunds	Low cost stone checks across rills (in the middle of the fields) Field bunds with waste weirs in upper watershed Field drains with waste weirs in upper watershed
Runoff disposal	Field to field through earthen hooks	Field to field through stone waste weirs in upper watershed Boundary water ways in lower watershed
Moisture conservation	Contour bunding	Short-term fallowing (Anantapur) Frequent shallow interculture Furrowing as a part of sowing and interculture (Mahbunagar) Cross plowing in the standing crop (Nalgonda)
Gully control	Stone checks to stabilize gullies	More investigation needed
Water harvesting	Farm pond for supplemental irrigation	Percolation tanks in individual holdings, or community tanks for percolation/irrigation

Farmers increase the productivity of SWC by concentrating soil at appropriate locations, rather than merely conserving it.[13] This distinguishes their practices from recommended ones, which stress in situ conservation of soil.

Similarly, in the lowlands, terraces slowly form behind indigenous field bunds and waste weirs as soil is gradually deposited at the lower end or corner of the protected field. Farmers must raise their bunds regularly

There are many examples of farmers' efforts to concentrate soil. In hilly areas some farmers induce erosion in the upper end of their holding in order to concentrate the soil in the lower part. Similarly, in the lowlands, terraces slowly form behind indigenous field bunds and waste weirs as soil is gradually deposited at the lower end or corner of the protected field. Farmers must raise their bunds regularly as the deposited silt accumulates to the top of the structure. Farmers control rills and small gullies in their fields with small stone or boulder checks across the flow. Silt fills behind the stones until the area becomes level.

Gully control is another case in which farmers concentrate soil to increase productivity. Loose boulder checks with occasional vegetative barriers on the boundary lines help "harvest" the soil. Over the years, the heights of these barriers are increased so that eroded lands can be reclaimed and new patches of cultivable land created within the gullies. Silt harvesting structures are displayed in Fig 4. In hilly areas, such deposition fields are the most productive land because the gully supplies continuous moisture. Such favourable micro environments are also important for reducing risks in rainfed agriculture.[15]

Table 4: Recommended and indigenous soil and water conservation practices; red soil, medium to high rainfall areas; Mysore and Bangalore districts, Karnataka

Item	Practices	
	Recommended	Indigenous
Soil conservation	Graded bunds	Fields bunds with waste weirs Fields drains with iwaste weirs Vetiver grass on field bund/drains with waste weirs
Moisture conservation	Contour farming	Short-term fallowing Criss-cross plowing Seeding across the major slope Tied ridging as a part of interculture (Bangalore) Frequent interculture
Runoff disposal	Central waterways	Field to field through waste weirs Boundary waterways
Gully control	Stone checks to stabilize gullies	More investigation needed
Water harvesting	Farm ponds for supplemental irrigation	Divert runoff from gullies for perennial crops (by gravity flow)

Table 5: Recommended and indigenous soil and water conservation practices; hilly, low rainfall areas; Kurnool and Anantapur districts, Andhra Pradesh

Item	Practices	
	Recommended	Indigenous
Soil conservation	Continuous contour bunds	Stone bunds on the boundary (across the major slope)
Moisture conservation	Contour farming	Frequent shallow tillage and interculture Stone mulching
Disposal of runoff	Field to field through earthen hook on contour bunds	Field to field through stone bunds
Gully control	Stone checks to stabilize gullies	Stone checks on boundary to harvest soil and reclaim gullies
Water harvesting	Farm pond	More investigation needed

Table 6: Recommended and indigenous soil and water conservation practices; hilly, high rainfall areas; Bangalore district, Karnataka and Baruch district, Gujarat

Item	Practices	
	Recommended	Indigenous
Soil conservation	Continuous graded bunds	Stone bunds on the boundary (across the major slope)
Moisture conservation	Contour farming	Frequent shallow tillage and interculture
Runoff disposal	Central waterways	Boundary waterways
Gully control	Stone checks to stabilize gullies	Stone checks on boundary to harvest soil and reclaim gullies
Water harvesting	Farm pond	More investigation needed

Another way to increase the productivity of SWC investments is to line field bunds with fodder grass or other useful plants, both to strengthen them and provide additional income. Custard apple trees often grow through stone bunds, for example. Past programmes did not emphasize this opportunity.

Some new programmes promote vegetative bunds rather than earthen bunds.[16] Perennial grass bunds can satisfy the requirements of multiple objectives (if they provide fodder or fuel, for example) and, depending on growth conditions, require only a small initial investment. More experimentation is needed on multipurpose vegetative bunds. To date, programmes have promoted grass bunds placed on the contour, but they have not tried them on boundaries.[17]

In summary, field observations indicate that researchers and extension workers can learn from indigenous SWC technologies. These technologies meet farmers' multiple objectives more effectively than do recommended practices based on contour bunds, leading to greater acceptance and higher adoption on small, fragmented farms. To achieve maximum impact, SWC programmes should be flexible to blend indigenous and recommended practices. Several innovative programmes in India are experimenting with such flexible approaches. Their early experience has shown that farmer input into technology design, increases adoption. NGOs have pioneered these efforts, and some government schemes have followed suit.[18] National watershed development authorities have proposed a more flexible strategy to promote SWC; concrete plans are still being formulated.[19]

Economic determinants of investment in indigenous soil and water conservation practices

The discussion of indigenous SWC technologies clearly indicates that farmers are aware of soil erosion and have developed effective means to control it. However, the fact remains that most farmers do not undertake sufficient measures to control erosion effectively. In this section of the paper we attempt to explain why this is so. We propose seven hypotheses regarding the determinants of investment in SWC, all of which are based on field observations.[20]

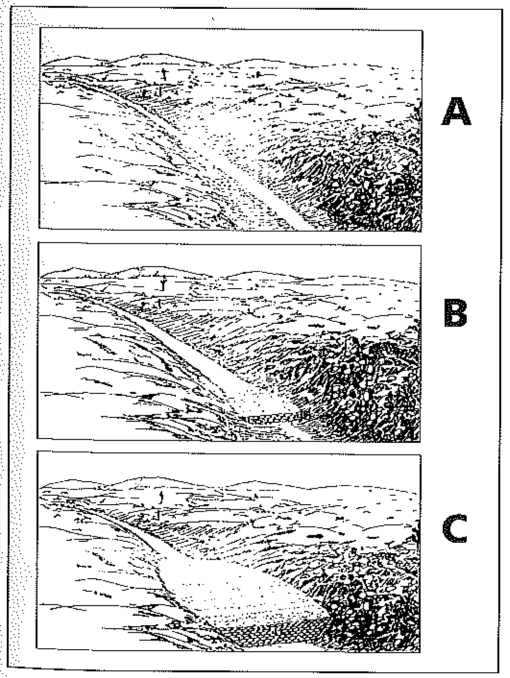


Figure 4:
Silt harvesting structure

Panel A depicts an untreated gully. In Panel B, the farmer has placed a stone check across the boundary and created the small field by trapping silt. In Panel C, the farmer has enlarged the wall to keep pace with the accumulating silt. Moisture from the gully enables double cropping in medium to high rainfall areas. Such silt deposition fields are commonly found in series, with gully plugs built on each farm boundary.

- Farmers clearly perceive soil erosion and believe that it reduces yields. They are more concerned about the loss of water and nutrients associated with soil erosion than reduced depth of the soil itself.
- Farmers' investments fall as the opportunity cost of their time and other resource rise: other activities may have a higher return than conservation investments. This is commonly the case for farmers with substantial off-farm income.
- Farmers invest more if they have more resources at their disposal, other things being equal: those with bullocks and healthy family labour are more likely to invest than those without.

The tenure arrangements under which farmers operate affect investment levels: those who cultivate their own land are much more likely to invest in soil conservation than those renting or sharecropping someone else's land

- The tenure arrangements under which farmers operate affect investment levels: those who cultivate their own land are much more likely to invest in soil conservation than those renting or sharecropping someone else's land. Likewise, landlords leasing out their land do not appear to invest much in soil conservation.
- Land quality also determines investment levels. Most farmers have more than one plot, and they invest in their most productive plot first. Those who have irrigated land invest less on their dryland plots than those without irrigated land.
- Where it is technically feasible, farmers invest in soil conservation in a stepwise manner, strengthening structures annually as needed. This reduces the initial investment and postpones costs to the future.
- Farmers prefer to invest in soil conservation individually or in cooperation with an adjacent farmer rather than in large, cooperative groups.

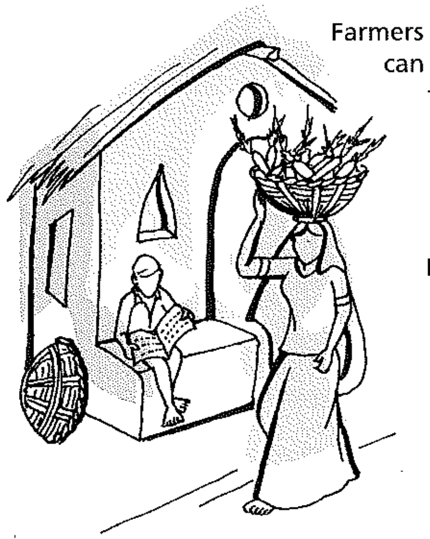
Hypothesis 1: Awareness of soil erosion and its consequences

Farmers will only invest in soil conservation if they are aware of erosion and its potential yield-reducing effects. Our research indicates that they are very clearly aware. Virtually all farmers surveyed explained in detail the erosion threat to their land and its effects on production, the measures required for prevention, and their costs.

Farmers list three main harmful effects of erosion: loss of soil, loss of water and loss of nutrients (farm yard manure and fertilizer) from their fields. Where soil is shallow, they stress that losing large amounts of soil is unacceptable. However, when soil is deep and erosion is mild, they are more concerned about losing nutrients and water than losing soil. Not surprisingly, SWC investment appears to be positively correlated to application of farm yard manure.

Farmers also distinguish between damage to soil that they perceive as irreversible and that which they believe can be corrected. Nutrient loss is seen as perhaps the major cost of soil erosion, and it is clearly reversible. Generous application of fertilizer and organic matter can rebuild eroded soil within five years, according to most farmers surveyed. Likewise, gully erosion is seen as reversible. This is because it only affects a small portion of the field. Once the gully is plugged, it is gradually filled by soil from upper fields and within the same field. On the other hand, sheet erosion is seen to cause irreversible damage, especially where soil is very shallow. (In deep soil areas farmers appear not to perceive sheet erosion.)

Farmers are not necessarily correct in thinking that damage due to gully erosion can be fully reversed, unless they gain soil from erosion upstream. It is likely that we do not fully understand their perceptions in this regard; we found that their answers on this issue varied greatly with the way the question was asked. We need to investigate this question further.



Hypothesis 2: Opportunity cost of time

Farmers with substantial off-farm employment and income tend to invest less in soil conservation that those without. In part, this appears to be so because the opportunity cost of their time is greater[21]. They find that they can spend their time more profitably pursuing activities other than soil conservation.

The cost of soil conservation depends in part on the value of the time of the person who does the work. In the simplest case, the cost of soil conservation using hired labour depends on the wage that is paid.

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We have observed that farmers usually do SWC work themselves rather than hire workers. This implies that they calculate the benefits of soil conservation and compare it to the value of their time. Because this value differs among people, investment behaviour will vary. The amount of family labour invested in soil conservation determines not only who invests, but also when investments are likely to take place because each farmer's opportunity cost of time is not constant. Rather, it is high when there are other pressing things to do, but low when there are not.[22]

Farmers will hire labour for soil conservation if two conditions hold. First, the returns must be higher than the wage. Second, they must have cash (or grain) available to pay the wage. If either of these conditions does not hold, soil conservation work will only be done using family labour, if at all.

Seasonal variations
The opportunity cost of time changes seasonally for farmers - it is high during planting and harvesting, for example, and low during the slack season. This is reflected by changes in daily wage rates over the course of the year. Accordingly, to the extent possible soil and water conservation programmes should operate when wages are lowest.

Fluctuations within the day
Other fluctuations in the opportunity cost of time are not reflected in the daily labour market. In particular, over the course of a single day people may be more or less busy. Many people spread their land care work over a long period of time, working only at odd hours when there is little else to do.

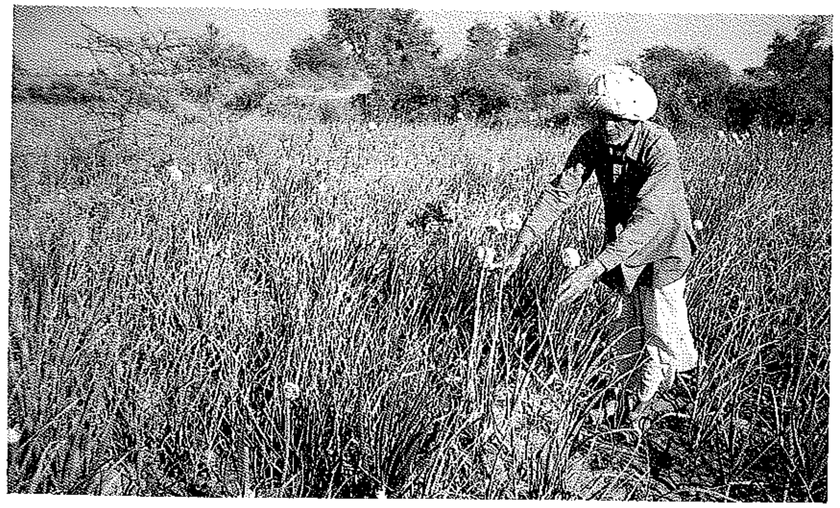
This has important implications for the design of SWC programmes. Cost effective use of time dictates that the landowner do his soil conservation work when the value of his time is low. A good example of this principle is offered by a farmer in Aurepalle (Mahbubnagar District, Andhra Pradesh), one of the study villages, whose field was eroding. He was able to explain the problem and the necessary corrective measures, but said he did not have time to devote the five days needed for the work just yet. He was asked if he would do the work if he were paid Rs. 7 per day (the daily wage in Aurepalle is Rs. 20). He thought about it and said that he would not do so if he had to work full time for five days, but would work for the equivalent of Rs. 7 per day if he could spread the job out over two months, working during his free time.

Examples of variations in the opportunity cost of time
Farmers whose time is especially valuable tend to be those with significant off-farm sources of income. A good example found in almost every village is the part-time farmer who obtains most of his income from an office job. Many part-time farmers in Aurepalle earn their living primarily from tapping palm wine or herding animals. Investment in soil conservation on dryland appears to be lower near large towns and cities than in more remote areas, because employment in the towns gives higher returns than working on soil conservation. Seasonal migrants have a high opportunity cost of time in the slack season, when most farmers do soil conservation work. Investment is relatively low in villages with high seasonal migration; this has also been found to be a major constraint to investmetn in West Africa.[23] All of these categories of people earn more from their alternative employment than they could if they were full-time farmers caring for their land. As a result, their fields tend to be more degraded than those of full-time farmers.[24]

Other farmers, such as large landowners who employ regular farm workers or long-term labourers, have a low opportunity cost of time. Their employees are paid by the season, and are available to the employer on a daily basis at zero marginal cost. Therefore during slack times these farmers can have their regular labourers do soil conservation work. It is profitable even if the returns are quite low. A similar case is that of farmers who simply refuse to enter the daily labour market, even when they have little other productive work to do. Investigators found that in Aurepalle many people, including poor but high caste people, prefer to do self-employed work than join the daily labour market, even if the returns are lower. We need to examine this further.

The finding that investment in soil and water conservation falls as the opportunity cost of labour rises has troubling implications. It suggests that development and sustainability objectives work against each other. Upwardly mobile people - those with off-farm income and those who have found better work in the city - do not take good care of their land, and they do not appear to find it profitable to hire others to do the work for them. However, these people are the success stories of development, as diversification of village economies is crucial to their growth. Ways must be sought to support such progress without neglecting the land.

Hypothesis 3: Access to resources



Farmers often say they do not conserve soil because they lack the resources to do so. These resources include labour, bullock or tractor power (to transport materials), or the cash to hire them. Farmers without labour and bullock power must hire them at the market rate, which may exceed the returns from soil conservation. Farmers who have their own bullock and labour power, on the other hand, can utilize them when their cost is below the market rate, making soil conservation work less expensive.[25]

Field observations have revealed that when farmers say they cannot undertake SWC, we need to be certain whether they mean (1) soil conservation is profitable but they are constrained from investing because they lack access to credit, or (2) soil conservation is simply not profitable. Some conservation investments, such as gully control in hilly areas, appear to give positive profits and others do not, and all must be weighed against alternative investment opportunities that may be more attractive. Our research has not yet reached firm conclusions about the profitability of different soil conservation practices in different zones.

Credit for soil and water conservation investments

Farmers could conceivably obtain credit to overcome cash flow problems for soil conservation practices that are profitable at market wage rates. This would enable the Government to let farmers pay for practices that are privately profitable, limiting subsidies to those that are not. To date we have identified silt harvesting structures, terracing on deep black soil and minor runoff disposal systems as investments that are potentially bankable, more research is needed to identify others.

However, we have found little or no evidence of farmers taking loans for soil conservation. First, formal credit institutions do not have credit facilities for indigenous soil and water conservation investments. Second, farmers say that if they were to take a loan, they usually have more pressing investment priorities.

A successful loan programme for soil conservation would have to be designed in accordance with the nature of such investments. Most importantly, it would have to recognize that soil conservation work is commonly carried out in stages, not all at

once. Loan funds would have to be made available small amounts at a time, over several years. In addition , farmers would have to be given flexibility to do the soil conservation work in ways they please, using family labour or hired labour. Hired labour may do other tasks in order to create time for the family to do the soil conservation work themselves.

Hypothesis 4: Land tenure

Farmers who cultivate their own land are much more likely to invest in soil conservation than those renting or sharecropping someone else's land. Observations in the study villages suggest that rented and sharecropped land, which covers about 15% of the area in the study villages[26], is almost invariably characterized by low investment in soil conservation.

Tenants

Short-term tenants to do invest in long-term land productivity because they are not likely to reap the returns.[27] This phenomenon has two important implications. First, it strengthens the point that to increase adoption, soil and water conservation practices should be by-products of activities that increase short-term productivity. Second, it suggests a need for policy changes regarding land tenure. Indian farmers shy away from land leases longer than one season because they fear that tenants can lay ownership claim to the property. Legal changes that removed this fear would encourage longer term leases, perhaps making land care investments more attractive to tenants.

Landlords

It was also observed that landowners who lease out their lands and those who exclusively use hired labour to cultivate these fail to invest in soil conservation. In neither case can this failure be attributed solely to a short time horizon, since the owners still maintain long-term tenure ? Instead, it appears that such landowners are unaware of the problems, or do not consider them worth worrying about. Alternatively, some landlords are too poor to invest in SWC. They lease or sharecrop their land because they do not have the resources (such as bullocks or manpower) to cultivate their land, let alone invest in SWC. It is likely that absentees who own large tracts do not find land care problems worth their time and worry. That they are absent to begin with suggests that they have alternative employment with higher returns than farming. In this case they will not devote their own labour to soil conservation. They may hold land as a source of long-term security, not for agricultural production per se, and so are unconcerned if erosion reduces productivity.

Preliminary surveys by the authors suggest that even eroded land appreciates in value at rates that make it an attractive asset. Moreover, differences in land values between eroded and protected land appear to be small compared to differences in productivity between the two. This can probably be attributed to the fact that most farmers perceive the damage from gully erosion to be largely reversible. Farmers also suggest that land is a prized but increasingly scarce asset, so that even degraded lands command a good price. In any case, this phenomenon would clearly reduce the incentive for absentees to invest in erosion control measures.

The prominence of degradation problems on the land of absentees has important policy implications. If erosion on such land imposes costs on society, then policies should be introduced to encourage better care. Policies should have any of four objectives. First, they should allow long term tenancy arrangements without threatening the landlord's ownership rights. Second, they could induce absentee landowners to adopt soil conservation measures or grow trees on it. Third, if erosion on their land damages neighbours' fields, the neighbours should be given access to the land to introduce soil conservation measures. Such arrangements have been found in some of the study villages in the case of runoff management and gully control. Fourth, policies could discourage tenancy by introducing policies to encourage absentee landowners to sell their land. However, tenancy provides some farmers with land that they could not obtain by other means, so more research is needed to assess the likely consequences of discouraging tenancy. A tax on land owned by non-residents might encourage sale to full-time farmers.

Hypothesis 5: Characteristics of the land

Costs and returns of soil conservation vary with characteristics of the land. Therefore we can expect the greatest investment in soil conservation on land where its costs are low and its returns are high. Costs vary with the location of the land in relation to materials needed for soil conservation; returns to soil conservation vary with the quality of the land.

Location

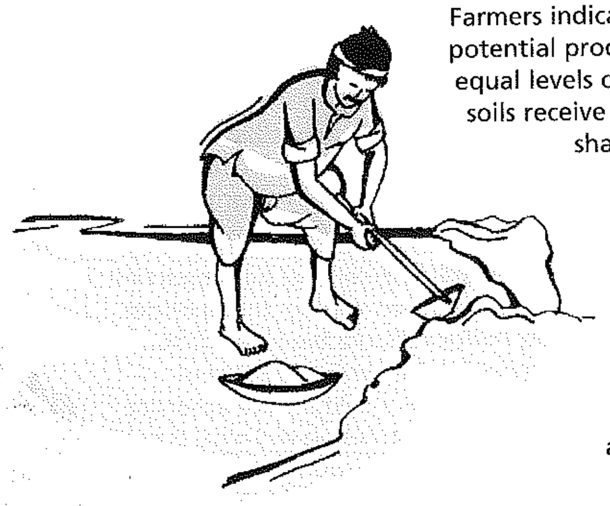
Soil conservation is least expensive on land that has abundant sources of needed resources. For example, where soil is deep and stones are sparse, earthen bunds predominate. This is the case in the flat plains where soil is fairly deep. On the other hand, very rocky areas, such as hilly zones of the Deccan Plateau, tend to be full of stone bunds. Where soil is shallow and stones are scarce, as in Aurepalle, bunds tend to be very small.[28]

This pattern of investment implies that soil conservation programmes should take advantage of local materials for constructing bunds. Farmers in the stony, shallow soil areas of Kamlapur (Gulbarga District, Karnataka) reported that one government programme insisted they use earthen bunds, even though the soil was very scarce, because they were found to be optimal under research station conditions. A more flexible programme would offer more sensible, cost-effective designs.

A second implication concerns places where lack of materials is the major constraint to soil conservation investment. Government programmes might find it cost effective to transport stones from places where they are too abundant to places where they are too scarce, but could be used to construct bunds or waste weirs. In Shirapur (Sholapur District, Maharashtra), for example, some of the land is littered with surplus stones excavated during construction of a canal. Farmers indicate that stone bunds are cheap in Shirapur as a result, and also that some land is uncultivable because of the stones. Transporting these stones to nearby regions may not only promote soil conservation in those places, but also clear land for cultivation along the canal.

Quality

Farmers indicate that they invest more in soil conservation on land with higher potential productivity than on land with lower potential productivity, given equal levels of erosion. For example, farmers in Aurepalle say that their black soils receive the most soil conservation investment, followed by less productive shallow red soils. On one pocket of saline soil in Aurepalle old soil conservation structures are not maintained, and new ones are not built because yields on that land are so meager that the soil is not considered worth conserving.



It also might be expected that farmers would be more concerned about losing scarce soil on shallow fields than on good land where soil is deep and abundant. However, farmers are more concerned about erosion on good land than erosion on bad land, mainly because good land generally receives greater applications of fertilizer and farm yard manure. As farmers say that

removal of nutrients is often the most serious implication of erosion, top quality land is likely to receive the greatest soil conservation investment.

Irrigated land receives the most soil conservation investment. The primary objective of this investment is water management, with soil conservation as a by-product. This further strengthens the notion that soil conservation programmes should look for complementarities between investments with short-term and long-term payoffs.

Farmers who own and operate both irrigated and unirrigated land appear to invest little in soil conservation on their unirrigated plots. Their irrigated land provides opportunities for productive investments that cannot be matched by SWC measures on dryland. Caring for unirrigated land becomes a low priority for those farmers. Preliminary evidence suggests that farmers without irrigation take better care of their dryland plots than do farmers who also own irrigated land. This is another disturbing prospect, since irrigation development is an important component of agricultural development strategies, and farmers tend to try to gain access to some irrigated land to protect against weather-related risk. As irrigation spreads, it is likely that dryland plots will be relatively neglected.

Hypothesis 6: Stepwise investment

Where it is technically feasible, most farmers build soil conservation structures in stages, rather than all at once. This not only postpones costs but also reduces them to the extent that future costs are discounted. Short term financial constraints are mitigated and risk is reduced.

Soil conservation sometimes requires collective action by farmers. This is the case when an erosion problem transcends farm boundaries

Stone gully plugs that trap silt, as shown in Fig 4, illustrate this principle well. Such structures are commonly 2.5 meters high and 2 meters thick. They harvest silt that moves through the gully, gradually building up a fertile plot. Because the silt accumulates slowly, at first only a small structure is needed, but it must be enlarged every 1 to 3 years. The investment needed to build such a structure is thus significantly reduced at any given point in time. Our observations show that construction of ordinary field bunds follow a similar pattern.

Hypothesis 7: Willingness to cooperate

Soil conservation sometimes requires collective action by farmers. This is the case when an erosion problem transcends farm boundaries. Farmers' willingness to cooperate is an important determinant of soil conservation investment in these cases.

There is a tendency to neglect severe erosion problems in big gullies that cross boundaries. This may be due to the magnitude of the investment needed to control the problem. In fact, the cost may be increased by the need for cooperation: cooperation is not cost free, but rather requires time for organisation and administration. It also may impose psychic and social costs on people who prefer not to associate with other members of the group from other communities.

On the other hand, our observations show that there is much potential for cooperation by two adjacent farmers or four farmers sharing a common boundary as long as the activity relates to that boundary. In these cases they tend to follow certain local "rules" or "norms" set by the village.

However, for technologies such as contour or graded bunds that cross farm boundaries, group action is not undertaken. A major problem with such technologies is that their benefits and costs are distributed unevenly among the affected people. On the research station or in large scale agriculture, such uneven distribution is acceptable as long as overall productivity rises sufficiently. Under

Indian conditions, however, it means that some people gain from SWC technology and others do not. Those situated at the end of graded bunds where central waterways are constructed, for example, lose, and they have an incentive to undermine the system. In general, SWC technologies are likely to fail if they divide benefits unevenly but require nearly universal cooperation to make them work. In this case, equity becomes a prerequisite to efficiency.

Clearly, the conditions under which farmers will cooperate with each other need to be understood, and alternative approaches to encouraging cooperation should be explored. In addition, SWC programmes in India should focus whenever possible on technologies that require minimal cooperation. A good technology that can be introduced on individual farms is likely to give better results that an excellent one that requires significant cooperation among farmers.

We should note that research from Africa seems to suggest a greater capacity for cooperation there than in India.[29]

RECOMMENDATIONS

Our research has several implications for its primary clients, SWC programme officials, policy makers and researchers. In general, the main lessons from farmers' indigenous practices are as follows:

Farmers' objectives should be clearly understood so that SWC programmes can be designed that they will accept rather than reject.

SWC programmes should minimize expenditures that farmers would be willing to make on their own. They should provide enabling conditions to increase SWC investment in a cost-effective manner.

Profitability is a major constraint to adoption, so cheaper technologies need to be developed. Divergences between private and social benefits of SWC should be identified to guide policies and indicate circumstances in which subsidies are justified.

How these general points translate into specific recommendations for the three primary client groups is the subject of this last section.

Soil and water conservation programme authorities

The objective of SWC officials should be to design and implement programmes with maximum cost effectiveness. This requires that their efforts be accepted by farmers. Accordingly, programme officials must examine what types of SWC investments farmers make on their own, and how they have responded to programme initiatives.

Programmes should be planned and implemented in full participation with farmers in order to identify in advance what the farmers will accept and what they will not.

Likewise, arrangements should be made with farmers to carry out the work on their own land to ensure that they are satisfied with it and to save money.

SWC officials must make a basic choice between designing SWC practices around contour lines (the recommended method) or around boundary lines (farmers' preferred method). They must understand the reasons why farmers have rejected contour bunds, and they must not simply impose a contour-based system or it will not be maintained. They can offer education about the efficiency of recommended practices in conserving soil, but they must not provide special incentives such as free seeds and fertilizer to adopters of recommended practices. This may induce farmers to adopt contour bunds without any intention of maintaining them.

Alternatively, programme officials should support indigenous technologies based on boundary lines. Boundary-based systems, though less technically efficient than the recommended contour-based systems from the narrow perspective of only conserving soil, may provide the greatest net benefits because experience shows that farmers are more willing to adopt and maintain them. Given the proper mandate, SWC programmes are in a unique position to experiment with different approaches to maximize effectiveness. They can compare the efficiency of different technologies at the field level and test how much farmers are willing to pay for them, analyze the varying interests of different groups and the distribution of benefits and costs among them and experiment to identify circumstances under which farmers are willing to cooperate with each other. This work should be done in collaboration with agricultural and social science researchers.

SWC programmes can only gain such vital information, however, if they eliminate the current orientation toward measuring success by physical targets achieved. This narrow, inflexible focus makes it impossible to explore and benefit from the diverse and often subtle factors that determine adoption and maintenance of SWC practices.

Education and information dissemination can be a very important tool for promoting SWC. Experience in Australia and Africa has found that increasing public awareness has improved the performance of SWC programmes.[30] Spreading information about the costs of erosion and alternative means of controlling it should be an integral component of SWC efforts.

Policy makers

Researchers must continue to develop new, less expensive soil conservation technologies. This may be the best way to make SWC profitable and encourage busy, upwardly mobile farmers to invest more

The government should subsidize SWC only in those situations when it is socially profitable to do so, and policy makers should encourage researchers to provide them with information to indicate when this is the case. But even outside the area of financial incentives, policy makers have a large sphere of influence on erosion through the manipulation of policy. In this regard, particular efforts are needed to address erosion problems on the fields of short-term tenants and non-practicing or absentee landlords. One option is to subsidize SWC investments by tenants, but policy makers can and should encourage longer-term tenancy, selectively discourage absenteeism by large landowners (perhaps by means of a land tax), and encourage remaining absentees to plant perennial vegetation on their land. Likewise, in order to encourage farmers to plant more trees, policy makers should relax laws restricting harvesting and transporting trees from private land. Continued research on farmer adoption patterns is needed to supply policy makers with information necessary for designing precise policies.

Macroeconomic policies also influence SWC investments by affecting the prices of farm inputs and outputs. This changes the profits of different farming activities, including conservation investments. References are given for readers interested in this subject.[31]

Researchers

Researchers should provide information to be used by policy makers to formulate cost-effective SWC programmes. This requires calculating the costs and benefits of different technologies and the conditions under which farmers do or do not invest in them.

By studying the technical and economic efficiency of indigenous and recommended practices, researchers will provide information to SWC programme authorities about the trade-off between technically optimal practices that farmers have been reluctant to accept and indigenous practices that are second best technically but have proven acceptable to farmers. Since recommended practices often require cooperation among farmers, an important component of such a study would be to identify conditions when such cooperation is forthcoming.

Researchers should identify which practices are economically viable and can be financed through commercial credit. They should also identify the conditions in which the social benefits of SWC exceed the private benefits, such as when farmers lack sufficient information, are excessively averse to risk, or have a short time horizon. This will indicate when and to what extent subsidies are justified, and suggest policies to overcome constraints to farmers' investments.

Researchers must continue to develop new, less expensive soil conservation technologies. This may be the best way to make SWC profitable and encourage busy, upwardly mobile farmers to invest more. An example of such an effort is the World Bank's recent promotion of vetiver grass, which - in favourable growth conditions - is inexpensive to plant and maintain. It is also compatible with Indian SAT farmers' preferences for boundary-based SWC technology that concentrates soil at the lower end of the field. However, it is unrealistic to think that vetiver or any other technology - is likely to be the single best option for every situation. For example, recent research suggests that in the Indian SAT, maintenance costs of vetiver are actually very high due to the dry conditions.[32] Researchers should experiment with other vegetative SWC measures that are also highly valued for other uses, such as fodder, fuel, fruit etc. Again, the best vegetative SWC measure may not be the one that conserves soil the most effectively.

Finally, researchers should work in collaboration with SWC programme managers to test different technologies and institutional arrangements in the field.[33]

In conclusion, soil conservation programmes can become more cost-effective if they are based on an understanding of farmers' perceptions about soil erosion and the conditions under which they adopt and maintain soil conservation measures. Farmers would benefit by receiving land care assistance that suits their needs, and society at large would benefit because public funds would be better spent and the country's soil resources managed more efficiently.

Much more research is needed to measure the actual costs of erosion, both to farmers and to society. This information is needed to determine how much should be spent to control erosion. The preliminary findings reported here, meanwhile, will enable funds already devoted to promoting soil conservation to be used more effectively.

END NOTES

1 An earlier version of this paper presented at the workshop on Farmers' Practices and Soil and Water Conservation Programmes, held 19-21 June 1991 at ICRISAT, Patancheru, Andhra Pradesh, India. The summary proceedings of that workshop are available from John Kerr at ICRISAT. A version of the paper also appears in Natural Resource Economic of India: A Guide for Researchers, Policy Makers and Managers, Oxford and IBH Publishers, New Delhi, forthcoming in 1993. The views expressed are those of the authors only.

2 Seckler discusses alternative views on the costs of soil erosion.

3 Fourth to Seventh Five Year Plans, Government of India4 Planning Commission; Vaidyanathan

5 Numerous conversations with SWC programme managers and scientists have revealed this sentiment.

6 Private profits are those calculated according to market prices. Social profits are calculated according to prices that

would prevail if all resources were used in a socially optimal way. Private and social profits diverge when prices are distorted by either market failures or government policies. Market failures occur when people have short time horizons, putting too high a value on the present at the cost of the future, or when profitable investments require collective action that is not forthcoming, or when they do not undertake profitable but risky investments. Government policies that distort prices include taxes, subsidies and quotas that raise money or protect a certain industry. Such distorting policies need to be distinguished from those introduced in order to correct market failures. Private and social prices are discussed further in Gittinger, Dasgupta, Monke and Pearson, and elsewhere.

7 The four states are Andhra Pradesh, Karnataka, Maharashtra and Gujarat. The research sites include ICRISAT study villages (Walker and Ryan) and villages where NGO, state and national watershed programmes (Planning Commission) have been active.

8 Vaidyanathan, pg.12. It is important to note that reducing the isolation of soil conservation efforts is an important priority in government programmes.

9 Sing, et al, describe State of the art recommended SWC practices in India10 Drawings by A.A. Majid, ICRISAT

11 Walker and Ryan, pg.192.

12 Reji, Critchley

13 Chambers, Sanghi & Kerr14 Field observations is Bangalore District, personal communication with P.D. Prem Kumar.

15 Chambers16 The World Bank's promotion of vetiver grass is the most notable of these programmes.

17 Discussions with watershed officials and visits to watersheds.

18 MYRADA and the Aga Khan Rural Support Programme were among the pioneers in the field. Numerous other NGOs have taken up similar approaches. Innovative government programmes with which we are familiar include the Kabbalnala watershed in Karnataka and some of the Andhra Pradesh state programmes. See Kerr, for details.

19 Flanning Commission20 As the research is still in progress, the findings reported here are confined to general hypotheses that have yet to be tested empirically.

21 Opportunity cost refers to the costs of foregoing an alternative opportunity and the gains obtainable from it.

22 The opportunity cost of time is a subject of great debate in development and labor economics. We are not proposing a general hypothesis here, but simply reporting what we have observed in the context of soil conservation investments.

23 See Reardon et al., also Reji.

24 Further case-by-case analysis is needed to determine under what circumstances these farmers could profit by hiring labour to do soil conservation work.

25 This depends on the opportunity cost of labor. Farmers in the study villages indicate that the opportunity cost of bullock power and human labor is sometimes less than the market rate, due to preferences not to enter the hire market. Bullock owners sometimes prefer to leave their bullocks idle rather than hire them out, and sometimes they prefer to use them on their own land rather than hire them out. (Source: Conservations with farmers in Aurepalle village and in kanzara village, Akola district, Maharashtra).

26 Jodha

27 This is a well-documented phenomenon. See Ervin;, Venkataraman

28 Vegetative bunds follow the same pattern: they are most common where they are easiest to grow, or where they augment scarce fodder supplies, and where other materials are more expensive.

29 Critchley highlights successful cooperative SWC efforts in Africa30 Chamala and Mortiss, Allwright, Critchley

31 See Miraowski; Barbier, and Conway and Barbier.

32 Sivamohan, Scott and Walter.

33 Conway and Barbier explain why on -farm research is so important in fragile agricultural environments.

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ENLISTING PEOPLE'S PARTICIPATION IN SOIL AND WATER CONSERVATION PROGRAMMES: THE INDIAN EXPERIENCE

Katar Singh • Institute of Rural Management • Anand • Gujarat

INTRODUCTION

Unless the programme clientele, i.e., beneficiary farmers are convinced that it is in their own personal interest to protect their lands from erosion and to harvest, store and conserve rain-water and spend their energy and money in construction, repair and maintenance of necessary soil and water conservation structures, no soil and water conservation programme can succeed

India has a very long history of state support for soil and water conservation programmes (GoI, 1976; 243-247), starting from 1884 when the government for the first time took over from Zamindars ravines and degraded wastelands in the United Provinces (now in Uttar Pradesh). Till date, the central and state governments have sponsored and funded many soil and water conservation programmes, made soil conservation legislations and set up necessary administrative machinery for their planning and implementation. Like most other government-sponsored agricultural and rural development programmes, soil and water conservation programmes too have often failed to enlist people's participation and to mobilize and utilize their energies and resources. The consequences are: wastage of public funds expended on construction of soil and water conservation structures which are broken or washed away by rains every year and have to be constructed again and again. With continued degradation of lands prone to erosion and consequent declining yields of crops, there is increasing sedimentation of reservoirs and riverbeds and recurring floods and droughts. Unless the programme clientele, i.e., beneficiary farmers are convinced that it is in their own personal interest to protect their lands from erosion and to harvest, store and conserve rain-water and spend their energy and money in construction, repair and maintenance of necessary soil and water conservation structures, no soil and water conservation programme can succeed. Chandrakanth et al (1988) in a study of a watershed development project in a drought prone region of India found that the chances of a satisfactory impact of the project was higher when the farmers were truly involved in its implementation. Similarly, there are many other studies that highlight the importance of people's participation in rural development.

What is meant by participation ? Why do farmers participate and not participate in soil and water conservation programmes and how could they be motivated to participate, are some of the questions that have been addressed in this paper. An attempt has been made here to throw light on these and other related questions drawing upon the experiences of a few selected soil and water conservation programmes in India.

THE CONCEPT OF PARTICIPATION

Participation means different things to different people. In common parlance, it is used to mean 'act or fact of partaking' or 'sharing in'. According to Banki (1981) participation means "a dynamic group process in which all members of a (work) group contribute, share or are influenced by the interchange of ideas and activities towards problem solving or decision making". Uphoff, Cohen and Goldsmith (1979) consider it meaningful to study participation in terms of (a) what is involved in participative behaviour; (b) who participates; (c) how participation occurs ; and (d) the contexts in terms of project characteristics and task environment which influence participative conduct. In the context of this paper, I use the term to mean the act of partaking (by farmers) in all stages of soil and water conservation programmes right from designing of various structures through monitoring and evaluation of their performance. Such a participation requires among other things that the target group of farmers voluntarily spend their time, energy and money on the programme and