Terracing re-examined in the light of recent findings in Nepal and Indonesia

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ABSTRACT Bench terracing is well documented as an excellent method to reduce soil erosion from steeply sloping agricultural land in the tropics. Soil conservation projects in both Indonesia and Nepal recommend construction of terraces as a cornerstone to better upland management. The surprising fact is that introduced bench terraces often fail to be adopted or even maintained by local farmers. Research in East Java and Nepal investigated the reasons for the apparent disinterest of farmers towards adopting bench terraces. Some biophysical and socioeconomic factors are discussed based on these findings.

INTRODUCTION

One of the most advanced techniques used to promote the stability of sloping agricultural land is to build and maintain terraces. Bench terraces can greatly reduce erosion, increase infiltration, and make the land more easily managed during normal agricultural operations (Unibraw, 1986). Many traditional agricultural systems have developed extremely effective terraces that ensure the long term stability of the land. However such terraces have occasionally been promoted as the panacea to all erosion problems on sloping agricultural land. There are many reasons why this is not so.

Many of the activities carried out by soil conservation programs emphasize rapid, highly visible activities that sometimes have little relevance to local conditions and farming systems. Constructing terrace systems is a popular soil conservation activity, particularly for projects funded by foreign aid. Although one gets the impression that "something is getting done", as new terraces appear on the hillside, the terrace technology is rarely adopted by the villagers after project funds dry up. A wide range of physical and socioeconomic factors must be considered when establishing the viability of terraces on any farm.

Over the past 15 years, this author has visited a great many soil conservation projects in Nepal and Indonesia and interviewed farmers, officials and project personnel who are involved in conservation efforts (Carson, 1989). This paper investigates why introduced terraces often fail to be adopted by the villager upon the conclusion of any project.
BENCH TERRACING AS AN APPROPRIATE SOIL CONSERVATION TECHNIQUE

The researcher should start with the premise that the farmers' fields provide a sensitively balanced integration of physical and socioeconomic forces on that site (see Figure 1). Only if the researcher considers all of the factors that affect the farmer's decision to improve, maintain or abandon a particular sloping field, can he appreciate why introduced terraces are not always successfully maintained let alone adopted in an area. Conservation programs directed by simplistic and uninformed national directives rarely translate into effective local level conservation projects. Unsuccessful projects commonly occur in both Nepal and Indonesia, particularly those receiving bilateral developmental aid. Project workers sometimes fail to recognize that terracing can be physically unsuited to certain landscapes. Throughout much of the outer island arc in Indonesia, and on the deep red phyllite derived soils in Nepal, project sponsored terracing has occasionally led to greatly accelerated slope degradation.

Possibly the most serious problem encountered when establishing conservation strategies is the lack of understanding about the farming systems that the program is attempting to improve. Physical and socioeconomic conditions must be recognized in the planning stage of a project. If increased returns to production do not more than offset increased conservation costs, farmers will not embrace the new so-called "improved" technologies.

AGROECOLOGICAL ZONES AS THE BASIS FOR CONSERVATION PLANNING

Distinct agroecological zones support a unique array of terrace forms. Depending on local climatic and soil conditions and farming systems, farmers can choose from a wide range of terrace forms. Terrace benches can be strongly outward sloping, level or even gently backward sloping; terrace risers can be gently sloping to vertical, stone lined, grassed, treed or bare. Drainage may rely almost entirely on high infiltration for certain volcanic soils, whereas impervious clay soils may require heavy investment in lined spillways. The agronomic needs of a particular crop will determine how the farmer will manage the soil within any field.

When the wide array of terrace forms and surface conditions are inventoried for any agroecological zone, one begins to appreciate the complexities of local land management. In a study carried out by Carson in East Java, the types and frequency of different terrace forms were observed for three distinct agroecological zones (see Table 1).
Farmer
- Economic status
- Off-farm employment
- Education
  Distance of field from home

Land tenure

Climate
- Rainfall
  • Intensity
  • Duration
  • Period of drought

Agronomic system
- Major crops
- Cropping calendar
- Yields
- Tillage method
  Potential agricultural improvements available

Economics
- Profitability of cropping system
- Subsistence or commercial
- Price of fertility inputs,
  fertiliser, compost

Presence of irrigation water

Agroecological zone
- Soil
  • texture, structure, infiltration,
    permeability, plastic index,
    consistency when dry
  • presence of stones
  • depth of horizons
- Slope
- Presence of natural drainage ways

FIGURE 1 Factors influencing the appropriateness of terracing as a conservation technique
TABLE 1 Terrace form frequency in three different agroecological zones of East Java (Carson, 1989)

<table>
<thead>
<tr>
<th>Terrace Form</th>
<th>Frequency of Occurrence</th>
<th>Percentage of land affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Elevation Volcanic Zone</td>
<td>Mid Elevation Volcanic Zone</td>
</tr>
<tr>
<td>Nonterraced</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>Strongly outward sloping terrace</td>
<td>F</td>
<td>C</td>
</tr>
<tr>
<td>Gently outward sloping terrace</td>
<td>R</td>
<td>F</td>
</tr>
<tr>
<td>Contour ditching</td>
<td>F</td>
<td>C</td>
</tr>
<tr>
<td>Level bench terracing</td>
<td>A</td>
<td>F</td>
</tr>
<tr>
<td>Bunded terrace</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Back sloped terrace</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Open drains</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Closed drains</td>
<td>A</td>
<td>F</td>
</tr>
</tbody>
</table>

**KEY:**

- **A** - Absent
- **R** - Rare
- **C** - Common
- **F** - Frequent
- **0%**
- **< 1%**
- **1-10%**
- **> 10%**

Non terraced agricultural plots frequently occurred in the high elevation volcanic zone but rarely occurred in the middle elevation volcanic zone. Despite very steep slopes and severe erosion, farmers of the high elevation zone have shown little interest in constructing any of the more advanced terrace forms. This contrasts strongly with the middle elevation areas where more than one third of the farmers' plots were well terraced. In the limestone agroecological zone, no backsloping terraces with closed drainage occurred, possibly because such slopes could not handle even normal rainfall events. Tied ridges on such terraces could lead to dangerous overtopping of storm runoff and downslope damage. In the limestone region, most of the privately owned fields were terraced. However the leased fields in the same area were still unterraced in spite of obvious slope degradation. Observing these
terrace systems, where they occurred, who owned them and what was
grown on them, it was possible to determine the reasons for the
presence of "good" and "bad" terraces.

The agronomic needs of the crop will usually determine the
surface form of the terrace. In order to maintain good surface
drainage as required for crops such as maize, fields are left
sloping outward or occasionally developed with ridges and furrows
running downslope. This may be a good short term agronomic prac­
tice but very poor for soil conservation. At the other extreme,
rice is commonly grown in banded terraces in order to keep the
surface ponded. Such fields may actually receive a net deposi­
ton of sediment from upstream.

The choice of terrace risers is usually determined by the nature
of the soil material in the area. Stone lined risers are
constructed in rocky, coarse textured soil such as occur throughout
the mica schist dominated mountains of much of the Himalayan
regions. Bare terrace risers are common where non-stony soils
contain a large portion of non-swelling clay such as found in the
volcanic region of Indonesia. Where animals are an integral part
of the farming system, risers can sometimes become a major target
for enhancing fodder production.

This study reinforced initial observations that physical and
economic factors, not ignorance or laziness on the part of the
farmer, influence the farmer's decision to adopt terraces.
Consequently, extension of conservation techniques alone are
unlikely to change land use practices in an area. Conservation
projects not targeted for a particular agroecological zone may fail
to address local conservation problems.

FACTORS AFFECTING THE SUITABILITY OF A FARMER'S FIELD FOR BENCH
TERRACING

The following is a list of factors gleaned in part from the above
study that one should consider when assessing the suitability of
a farmer's field as a candidate for terrace improvement or new
construction.

Soil infiltration and permeability

The viability of bench terraces as a conservation technique is
partially dependent on the infiltration rate and deep permeability
of the soil. All other factors constant, the higher the rates of
infiltration and permeability, the less will be the need to build
and maintain expensive surface drainage structures. In some of
the terraces constructed on the sandy micaceous schist soils of
the middle mountains of Nepal, surface drainage control is not
required because the intensity for short and long duration rainfall
events rarely exceed the ability of the soil to receive and trans­
mit water into the subsoil. Some soils have high infiltration
rates but permeability of the subsoil is low (common with (Alfisols).
Such soils may be able to withstand extremely intense short duration
rainfall (which are considered to be the most erosive) but at the
same time, suffer heavy runoff and severe erosion during moderately
intense, long duration rainfalls. Where infiltration and permeabilities are naturally low, such as on Tertiary marls, rainfall intensities frequently exceed the ability of the soil to receive or hold water regardless of the surface cover or slope form. Even under natural forest conditions, surface runoff generally flows downslope as unchannelled sheet flow and can result in moderately high rates of erosion. When such slopes are cleared and terraced, the naturally low infiltration and permeability combined with the greatly increased ponding and channelling of water on the slope can result in severe surface erosion and mass wasting. Rarely can the expense of terrace construction and maintenance be justified on such slopes.

Slope

Inherent slope stability is a critical factor when determining the suitability of slopes for terracing. Some natural slopes are extremely stable, others are conditionally stable while others are extremely unstable. In order to determine the suitability for terracing one must superimpose the various management options possible to ensure adequate conservation to maintain the integrity of that slope. This was done for three distinct slopes in Java by this author. The results are presented in Figure 2. The volcanic soils (Andosols) of Java are extremely stable at 28 degrees, with minimum maintenance, whereas on some of the marine clays of Timor, slopes were unstable and virtually untraceable at gradients above 8 degrees. Generally, 25 degrees is given as the upper limit to successful bench terracing. This discussion cautions the use of absolute limits without reference to which environment they are intended.

Tied closely with slope gradient is the overall length and position on the slope. Mismanagement of fields upslope occasionally caused serious degradation to downslope fields, a result of concentrated runoff. Gentle slopes receiving storm runoff from above may have a much higher erosion hazard than very steep slopes near a ridge top.

As indicated in Figure 2, conservation inputs can counterbalance different degrees of slope instability. However, before one can determine which slopes are suitable for terracing, conservation inputs must be weighed against increases in the productivity of the system made possible by the conservation package.

Consistency of the Soil

Consistency of the soil is largely a function of texture, type of clay, structure and amount of organic matter. If a soil is sticky and plastic when wet, such as occurs on the red clay soils of the Tansen area of Nepal, farmers will not accept level bench terraces because the seed bed will not be suited to the survival of maize, their major crop. The farmer's strategy is to remove water as quickly as possible from the slope, in a non concentrated manner to ensure an adequately aerated root zone. At the other extreme, certain sandy volcanic soils of Java are stable when wet, (their
FIGURE 2 Relationship between slope stability and surface gradients of three different parent materials
high internal drainage precludes saturation). However, upon drying, these same soils lose all their internal strength and become a loose structureless mass incapable of holding a terrace form. Where long dry seasons are normal, terracing such slopes may require major dry season stabilization and wind erosion protection.

The Presence of Stones

Providing the basic soil matrix is suitable for crop production, stones can enhance the ease with which stable terraces can be built and maintained. Terrace risers, drop structures, spillways and gabions can all enhance the long term stability of a slope. There are many examples of farmers building irrigated terraces on extremely coarse colluvial debris, where soil for a growth medium is carried into the area or deposited from sediment laden irrigation waters. Construction of terraces on stony soils is somewhat more time consuming but rarely seems to be a limitation under traditional agricultural systems.

Soil Depth and Subsurface Characteristics

Soil depth influences decisions to construct bench terraces in a number of ways. On the shallow limestone soils, farmers are concerned about soil depth as a rooting medium and will construct terraces where ever farming systems justify the expenditure. In such cases the farmer recognizes that the future sustainability of his plot depends on terracing. Ten years under cassava production without terracing causes sufficient erosion to make future cassava production uneconomical. The shallower the soil, the more difficult it is to build a terrace system and the greater the chance that one will run into serious subsoil fertility problems.

An unusual situation occurs in Java where vegetable farmers on the deep volcanic soils adjacent to active volcanoes are not at all concerned about erosion, as they experience no obvious negative effects from extremely high rates of erosion over relatively long periods of time. Subsoils on these Andosols can be equally as fertile as the original top soil. In these areas conservation projects have been singularly unsuccessful.

Climatic Conditions

Climatic characteristics can influence the suitability of terracing systems. In the first place, climate controls the type and productivity of any rain fed crop for any area. As an example, high value crops such as apples only grow within a narrow altitudinal range in Java. The excellent bench terraces constructed for apple production are too expensive for other lower value tree crops that can grow outside of this climatic zone. Rainfall characteristics including duration and intensity of various storm events will affect the terrace form and surface drainage requirements.
SOCIOECONOMIC FACTORS INFLUENCING TERRACE CONSTRUCTION AND MANAGEMENT

In addition to the more obvious physical constraints to bench terrace construction, a number of socioeconomic factors must be considered such as discussed by Blaikie (1985). Factors found to be of particular importance in the East Java study include.

**Land Tenure**

Many farmers do not have assured tenure over the land that they work. Sometimes when a researcher encounters agricultural practices that are degrading the land, the farmer himself is aware of the problem and the conservation techniques required to overcome the problem. However, lack of long term tenure alone dissuades farmers from investing where returns are not assured. In many cases, if tenurial rights cannot be guaranteed to the satisfaction of the farmer, terracing efforts are unlikely to succeed. Oddly enough, where land reform policies are meant to provide tenurial rights to the small farmer, the results are often less than satisfactory. In many cases the land's ownership becomes tied in litigation, and neither the original land owner nor new recipient is willing to make the heavy capital investments that bench terracing requires. Both will exploit the slope, neither will invest.

**Economic Status of the Farmer**

The wealth of any farmer plays an important role in his ability to adopt new soil conservation techniques. Any conservation techniques that require significant inputs of labour or capital are unlikely to be taken up by the poor farmer strictly because those inputs are unavailable. The majority of poor farmers are debt ridden so any spare money they may acquire is used to service debt.

**Nature of Farming System**

Farmers who are engaged in subsistence agriculture are concerned with steady, minimum risk production. Planting of soil conserving cash crops such as cloves, coffee, vanilla in Indonesia or apples, mango or citrus in Nepal is likely to occur only if markets are readily available to sell produce and secure staples. The new lease on agriculture land and increased terrace construction in the area adjacent to the Kathmandu Valley is a direct response to the new market interest for fruits and vegetables of the city dwellers.

**Profitability of the Farming System**

The more profitable the farming system, the more likely that the farmer is willing to invest in its sustainability. As maintenance of bench terraces can be time consuming on certain landscapes, the farming system must be sufficiently profitable so that the farmer is willing to construct and maintain bench terraces.
Community Organization

Strong community co-operation is essential to ensure that terracing projects are effectively and safely executed. If ownership of a long steep slope is divided into many small individual fields, close co-operation between the farmers is required to ensure that conservation measures carried out on upslope fields does not damage fields below.

Conclusions

While terracing is often an excellent technique to enhance the productivity and sustainability of sloping agricultural land, a blanket policy of encouraging terrace construction is in itself unlikely to speed their adoption. The traditional farming systems of Indonesia and Nepal have often already used terracing when it was appropriate to do so. While there is considerable scope for expanding terracing in many parts of the world, conservationists should focus on the local physical and socioeconomic conditions to determine if and how terraces might improve local farming systems.

REFERENCES