Soil & Tillage Research 121 (2012) 38–48

Contents lists available at SciVerse ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

# Bio-economic analysis of soil conservation technologies in the mid-hill region of Nepal

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ARTICLE INFO

*Article history:*
Received 18 August 2011
Received in revised form 28 January 2012
Accepted 30 January 2012

*Keywords:*
Soil erosion
Mid-hill region
Minimum tillage
Hedgerow intercropping
SCUAF model
Cost–benefit analysis

ABSTRACT

Soil degradation is a major threat to agricultural sustainability in Nepal. Increased anthropogenic activities in the inherently fragile ecosystem of unstable geology, steep slopes and intense monsoon rains have accelerated the loss of soil and its fertility in the Nepalese hills. This paper assesses soil conservation technologies from biophysical and economic perspectives using the integrated bio-economic analysis. The study applied a biophysical model, Soil Change Under Agroforestry (SCUAF), to project effects of the conservation technologies on soil erosion control as well as on crop yields over a thirty-year period. The technologies considered are hedgerow intercropping and minimum tillage. The outcome of the biophysical model was integrated into a cost-benefit analysis to examine the economic viability of the technologies. The results showed that these technologies are effective in reducing a substantial rate of soil erosion prevailing in the conventional system of maize cultivation. They have a variable impact on yield maintenance and the farmers' economic return over time. The hedgerow intercropping sustained crop yields in the long-term although yield was reduced in the short-term. Likewise, high costs for establishing and maintaining the hedgerow intercropping significantly reduced farmers' economic returns in the short-term. Minimum tillage technology, while better than the conventional farming system, was not able to sustain crop yield in the long-term. Yet, it provided positive returns for a longer period than the conventional system. The study concludes that though the evaluated technological options are effective in reducing the high rate of erosion resulting from the conventional maize cropping system, economically they are not viable for farmers in the short-term. Therefore, to expedite the wider adoption of these technologies and to halt and reverse soil degradation, it is suggested that farmers initially be supported with economic incentives to compensate their short-term economic loss.



## 1. Introduction

Soil erosion is a serious threat to agricultural sustainability in the Himalayan region of south Asia. The annual economic loss due to soil erosion and soil fertility depletion in the south Asian countries is estimated to be US $600 million and US $1200 million, respectively (UNEP, 1994). The consequences of soil erosion in terms of fertility degradation, sedimentation and changes in hydrological regime in downstream areas of the Himalayas in general, and in Nepal in particular, have been national and global concerns. The discussion on environmental degradation in the Nepalese hills and mountains have primarily cited forest degradation and unsuitable land-use practices, caused by rapidly growing human population, as the main causes of accelerated soil erosion and its consequent impact on ecology and economy (Eckholm, 1975, 1976; Ives and Messerli, 1989). Agricultural activities have been expanded and intensified on fragile and slopy areas through double and multiple cropping due to increasing population pressure and limited off-farm employment opportunities (Brown and Shrestha, 2000). According to Thapa (1996), agriculture land on slopy ridges suffers an unsustainable rate of soil erosion and nutrient loss due to frequent hoeing and ploughing. Apart from anthropogenic factors, many inherent natural factors such as active geology, steepness, fragility and high intensity rainfall are also equally responsible for soil degradation across the Nepalese hills and mountains (Ives and Messerli, 1989; Ives, 2004). Given the complex features of the mountain terrain, the nature and extent of soil erosion varies across the topographical situation of the country. The annual soil loss from the agricultural plots ranges from 0.1 tons ha$^{-1}$ to 105 tons ha$^{-1}$ depending on the region, type of plot, and the methodology used for estimation (Chalise and Khanal, 1997). In the rainfed upland sloping terraces of the mid-hill region, the annual soil loss may increase up to 25 tons ha$^{-1}$ (ICIMOD, 2007).

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doi:10.1016/j.still.2012.01.016

The loss of soil at the rate of 20 tons $ha^{-1}$ is equivalent to the loss of 300 kg $ha^{-1}$ organic matter, 15 kg $ha^{-1}$ nitrogen, 20 kg $ha^{-1}$ of phosphorus and 40 kg $ha^{-1}$ of potassium (Carson, 1992). Since cultivable land is scarce, protecting the soil resource base and maintaining the soil fertility is crucial to improving and sustaining yields in order to meet the region's present and future food demand.

With the goal of reducing soil degradation and ameliorating subsequent problems, several research efforts have been focused on developing sustainable soil management technologies, which protect the soil resource base while enhancing food production. To this end, the technologies such as minimum tillage and hedgerow intercropping have proven to be promising for protecting the soil and nutrients in several studies in Nepal (Bajracharya, 2001; Maskey, 2003; ICIMOD, 2004; Atreya et al., 2008). However, none of the studies have considered the cost effectiveness of these technologies as well as their short-term and long-term impacts. Any conservation practice to be sustainable must take into account the financial obligations of the farmers. Recommending a new technology without considering the broader socio-economic needs of farmers invariably brings a failure to adoption (Ya, 2003). Therefore, the demand to evaluate soil conservation technologies using a more holistic approach, which integrates a biophysical as well as an economic assessment, is currently emerging in the mid-hills of Nepal.

The objective of this study was to assess the effects of minimum tillage and hedgerow intercropping on long-term soil erosion control, crop yields and farmers' economic returns, using the techniques of integrated bio-economic analysis. This study differs from other biophysical studies on erosion assessment conducted in the mid-hills because of its integrated approach and long-term perspective. Furthermore, integrating economic analysis provides a better understanding of evaluating soil conservation technologies from the farmers' point of view and therefore, impacting viability and the widespread adoption of these technologies.

## 2. Materials and methods

### 2.1. Description of the study site and conservation technologies

The study was conducted in the Kavrepalanchowk district of Nepal (Fig. 1). The elevation of the district ranges between 280 m to 3018 m. The precipitation level ranges from 985 mm to 2587 mm with the mean annual precipitation of 1500 mm (CBS, 2005). The maximum and minimum average temperature is 28 °C and 9 °C, respectively. The district has the typical bio-physical characteristics of the mid-hill region, where soil erosion and nutrient exhaustion are key issues. Sloping terrain and highly weathered red soil with a low organic matter reflects the poor condition of the soil (Schreier and Shah, 2006). The cropping system is predominantly maize-based, which is grown in rainfed sloping terraces. In this analysis, therefore, soil conservation technologies are considered under a maize-based cropping system.

Maize is cultivated in the rainy season by the intensive tillage technique. The commonly used tillage tools are the ox-driven wooden plough and hand hoe. The latter is mainly used when terraces are narrower than 1.5 m (Bajracharya, 2001). Farmers plough their land two to three times before maize sowing (Atreya et al., 2008). The first tillage is done before the onset of the pre-monsoon (February/March), the second, after applying farm yard manure, usually after 20–25 days of the first tillage (March/April). The third tillage takes place at the time of maize sowing, after 2/3 pre-monsoonal rainfall events. Farmers believe that the exposure of land to the sun, rain and air for a long period helps to improve soil fertility (Thapa and Poudel, 2002). But the impact of intensive rainfall in the pre-monsoon season, when the soil surface is devoid of vegetation, causes high amounts of soil and nutrient loss from the sloping terraces (Gardener and Gerrard, 2003).

The application of minimum tillage as a conservation technology has been limited to only a few farmers in the mid-hill region. According to Atreya et al. (2008), maize cultivation with minimum tillage in the central hilly region of Nepal mainly involves less soil disturbance than in conventional practices. In this system, land is ploughed only once during maize sowing, either with a hand hoe or ox-driven wooden plough, after applying farmyard manure on the field. Other inter-cultural activities such as weeding and chemical fertilization are similar to the conventional tillage practice.

Hedgerow intercropping, a form of agroforestry is another conservation technology that has been applied in the rainfed land of the mid-hill region. Agroforestry, traditionally practiced in many parts of Nepal, is a technique in which various species of trees, hedges, and grass strips are planted along the bunds, and on the terrace risers, to conserve soil. The hedgerow intercropping analyzed in this study is a slight variant of the traditional agroforestry system in which outward sloping terraces are converted into a series of level terraces by reshaping the land. Various hedgerow species are then planted on the riser and bunds of level terraces. This technology is locally known as "*Garha Sudhar*". The commonly used hedgerow species are *Flemingia macrophylla* (*Pennisetum purpuream*), (*Melinis minutiflora*) and (*Stylosanthes guianesis*). In this analysis *F. macrophylla* has been used as hedgerow, as it is one of the recommended hedgerow species for hilly regions (Ya and Thapa, 2004). The hedges form strong barriers against the runoff and protect the terraces from soil erosion. Maize is planted between the rows of hedges. Based on their rate of growth, hedges are pruned periodically to prevent shading of the crop. Hedge species are perennial but, depending on their nature of growth, they need to be replanted every three to five years. An established hedgerow system is also a good source of animal fodder.

### 2.2. Data

The study uses biophysical and economic data collected from primary and secondary sources. The data on cropping practices, conservation technologies, and the prices of various inputs and outputs were collected from a household survey conducted in the Kavrepalanchowk district from June to December 2007. Farm households were selected from the upper zone and lower zone of the *Anshikhola* watershed. Two-hundred-eighty farm households, 140 from each zone, were selected as the sample size for data collection. Within each zone, simple random sampling was used to select the households. The sample households comprise 28% of the total farm households in the watershed and about 0.72% of the total farm households in the district (CBS, 2005). Data on the input costs of conservation technologies and conventional systems was received from the farmers in the district who practiced them. For the purposes of biophysical modeling, information on climatic pattern, agronomic, and soil parameters was collected from research stations, household survey and from previous research studies. Soil sample analysis was done for the 30 surveyed farm households to have specific information on the physical and the chemical properties of the soil.

### 2.3. Framework of the bio-economic analysis used in the study

The study applies the approach of bio-economic analysis whereby it incorporates the outcome of a biophysical model, Soil Change Under Agroforestry (SCUAF), into a cost–benefit analysis to evaluate the economic performance of soil conservation technologies. In this section, we first present the justification of the approach we applied, followed by a framework of the analysis.