Incorporation of Local Knowledge into Soil and Water Management Interventions which Minimise Nutrient Losses in the Middle Hills of Nepal♣

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Abstract

Between the elevations of 1000 and 2000 m in the mid-hills of Nepal, over 12 million people subsist on land-holdings of less than 0.5 hectare. These farmers are have very limited access to commercial inputs such as fertilisers and are reliant on rainfall and organic manures for soil fertility maintenance. In particular, bari *lands (upper slope rain-fed crop terraces) in Nepal are increasingly becoming a focus of concern in terms of soil fertility decline and management. Previous work has shown that erosion is important during heavy rainfall events pre- monsoon in April/May and later in the season nutrient losses through leaching are significant. There is a need for soil and water management interventions which utilise locally available resources that control erosion without resulting in high leaching and so are effective in minimising total nutrient losses. Farming alternatives that conserve water and soil are urgently needed in these marginal and fragile hillside environments to sustain soil fertility and hence rural livelihoods.*

The objective of this project was to ensure that nutrient losses due to leaching and erosion are minimised by devising economically and culturally viable land, soil and water management techniques, building upon the sophisticated local knowledge of the movement of water across soil and existing scientific data, and promoting them through participatory approaches to the design of technologies. To meet this objective, the project worked towards developing a process and methodology by which technology options addressing a common constraint across a range of livelihood and biophysical circumstances could be identified and evaluated. Participatory research was conducted with farmers in three contrasting agro-ecological regions; Nayatola (1000-1500 m asl, 20-25^o slopes, l000 -1500 mm annual rainfall); Landruk (1200-2000 m asl, bench terraces 0-5^o slope, 3000-3500 mm annual rainfall); and Bandipur (550–1000 m asl, bench terraces 0-5^o slope, 1100-1500 mm annual rainfall). The project approach lay in combining farmers' local knowledge and practices with that of scientists' knowledge and findings, and supporting farmers' experimentation in developing soil and water management interventions. The process included six stages: problem identification; knowledge analysis and sharing; farmers' experimentation; monitoring and evaluation; adoption and adaptation; and scaling up. The results obtained suggest that incorporation of farmers' knowledge and perspectives in the technology development process, and giving farmers and farming communities a lead role in experimentation and decision-making not only ensures development of appropriate technologies but also empowers farmers' and increases participation in the process.

1. Introduction

The hills of Nepal occupy about 51 % of the total agricultural land of the country, and provide shelter to about 52 % of the total population with an average agricultural land holding of less than 1 ha (CBS, 1996; CBS, 1999). The middle hills, that stretch between 1,000 to 2,000 metres asl, occupy about 30% of the land area of Nepal (Carson, 1992). The agricultural land holding in the hills is very small - about 46% of the population owning less than 0.5 ha of land - and highly fragmented with about 4 parcels per holding (CBS, 1996). Crops are cultivated mainly on rain-fed upland, locally called *bari* land. *Bari* land constitutes 64 % (1,717,000 ha) of the cultivated land in Nepal, of which 61 % lies in the middle hills alone (Carson, 1992). The *bari* soils are particularly vulnerable to soil losses through

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a combination of natural factors, such as sloping topography, heavy seasonal rainfall and predominance of erosion prone soils; and human factors, such as intensive cultivation of land and erosion prone farming practices (Sherchan and Gurung, 1992; Tripathi, 1997). Various studies conducted in Nepal show that soil loss through surface erosion from agricultural land in the hills varies from less than 2 t/ha/year to as high as 105 t/ha/year (Gardner *et al.,* 2000). A recent study has revealed that nutrient losses, especially N and P, through leaching exceed those in runoff and soil erosion (Gardner *et al.,* 2000), in contradiction to the widely held belief that erosive losses are the major reason for the declining soil fertility and crop productivity in the Middle Hills of Nepal (Carson, 1992; Turton *et al.,* 1995; Vaidya *et al.,* 1995).

Previous work by the Royal Geographical Society (with the Institute of British Geographers), Queen Mary and Westfield College and Agricultural Research Station Lumle (Gardner *et al.,* 2000) sought to understand the reasons for variability in soil and nutrient loss on rainfed agricultural terraces on *bari* land in different farming systems and agro-ecological zones in Nepal. The variables measured include surface runoff, erosion, volumes and chemistry of leachate in 25 plots at three contrasting locations; Nayatola (20-25° slopes, annual rainfall 1000-1500 mm); Landruk (terraces 0 - 5° slope, 3000-3500 mm annual rainfall); Bandipur (terraces 0-5° slope, 1100-1500 mm annual rainfall). The results showed that erosion is important during heavy rainfall events pre-monsoon in April/May on steep cultivated slopes and even on low slopes because of high surface runoff and, later in the season, nutrient losses through leaching on moderate and lower slopes or where runoff is controlled are significant as infiltration throughout the monsoon is increased and high nutrient losses occur.

However, other than this, there has been very little work done to understand the dynamics of soil erosion and leaching losses of nutrients in the *bari* land in Nepal. As a result, the research and development efforts in generating management practices to control soil and nutrient losses from *bari* land so far have remained poor. At present, the availability and access to technological options that are effective in reducing such losses and that suit farmers' needs and environments are very limited. The interventions that have been directed at controlling soil erosion, including Sloping Agricultural Land Technology (SALT) (Partap and Watson, 1994), have not been widely adopted by the farmers although they are effective in reducing surface runoff and controlling soil erosion (Carson, 1992; Tang Ya, 1999). This is largely due to the fact that the research scientists involved in the technology development process have not been able to make adequate consideration of farmers' knowledge and practices, and their needs for soil and water management.

Several studies have established that farmers in the middle hills of Nepal possess good knowledge about soil and water related ecological processes and they often make rational use of them to devise practices to combat the problem of soil erosion and declining soil fertility (Gill, 1991; Tamang, 1991 and 1992; Carson, 1992; Joshi *et al.*, 1995; Nakarmi, 1995; Shah, 1995; Subedi and Lohar, 1995; and Joshy, 1997; Turton *et al.,* 1995; Turton and Sherchan, 1996). This has drawn the attention of research scientists and development workers towards the value of farmers' knowledge and its potential use in technology development. These studies, however, have been limited to documenting farmers' knowledge and practices at a more general level. The methods used in these studies have not been able to make an in-depth and systematic acquisition and analysis of farmers' knowledge, and establish the underlying causal relationship. Similarly, there has been a general lack of willingness as well as of approach in incorporating farmers' knowledge into the research process aimed to design improved soil and water management interventions.

'Participation' has become a critical concept in development, and various methodologies have emerged over the last 20 years, originating in farming systems research (FSR) or farming participatory research (FPR), participatory technology development (PTD) and Participatory Learning and Action Research (PLAR), with all advocating agricultural research in the context of the whole farming system, and including some degree of farmer participation. Yet the word 'participation' is contested, and would be interpreted differently by practitioners of these methodologies. Multidisciplinary teams of natural and social scientists have developed FSR (Okali *et al*., (1995), Amanor (1990), Farrington and Martin (1998) and others), while PTD has been evolved largely through the efforts of NGOs to tailor technical solutions to rural reality. As they are absorbed into the broader field of farmer participatory research, experience shows that modes of 'participation' in research can range from 'consultative' (scientists ask farmers for their opinions, usually at the problem-identification stage) to 'collegiate' (farmers control the research process, supported by scientists) (Biggs, 1989; Martin and Sherington, 1997; van Veldhuizen *et al*., 1997). All involve a range of methodological tools, from rural rapid appraisal (RRA) and later participatory rural appraisal (PRA) drawing on the work of Chambers (1997) and others, built into participatory learning and action research (PLAR) (Pretty *et al*., 1995; Defoer and Budelmann, 2000; Defoer, 2002). Considerable developments have recently occurred in processes of participatory monitoring and evaluation (PM&E) (Estrella, 2000), now considered intrinsic to participation. Participatory technology development (PTD), as described in the current context is considered to draw eclectically from all these methodologies.

The objective of this project was therefore to *develop a process and methodology* for the development of technology options which would ensure that nutrient losses due to leaching and erosion are minimised through economically and culturally viable land, soil and water management. The intention was to build upon the sophisticated local knowledge of the movement of water across soil and existing scientific data and incorporate both into the project design by the process of participatory technology development.

2. Defining the process

The PTD process discussed here aimed to enable and empower farmers to innovate and experiment with new soil and water management interventions by combining their local knowledge and practices with scientific knowledge and understanding of the problem in question. The process evolved through the interaction with the farmers and their community structures during the implementation of the project. However, for the purposes of presentation, it will be described in subsequent sections in a sequential manner (Figure 1).

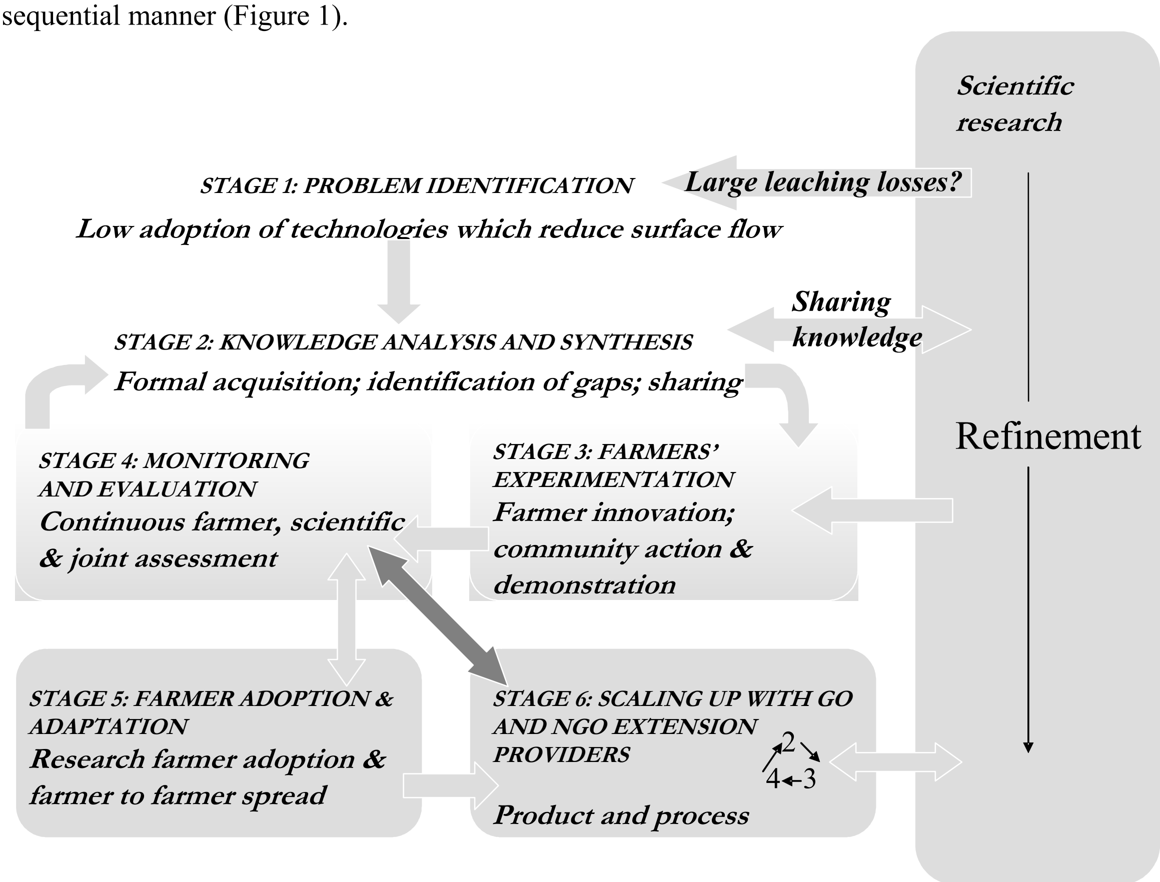


Figure 1. The Participatory Technology Development (PTD) process developed in Nepal

2.1 Problem identification

2.1.1 Conceptualising the problem and research approach and sharing these with institutional stakeholders

The PTD process started with the identification and conceptualisation of the problems and issues relevant to soil and water management prevalent in the middle hills of Nepal. In this case, the loss of soil and nutrients from *bari* land and the low adoption rate of technical interventions by farmers had already been widely identified as major research and development issues by frontline research and extension agencies. However, re-visiting these problems from the perspectives of stakeholders and building a common consensus was important before undertaking any research and development activities. A workshop of all potential stakeholders was organised for that purpose. About fifteen participants from ten different research and development organisations, both government and non-government participated in the workshop. The project team and the participating stakeholders shared their views and experiences about the problem, and then the concept and methods of the PTD process to be adopted was developed. The mechanisms and means to communicate amongst stakeholders was also discussed and agreed (McDonald, 1999). All the stakeholders showed a keen interest in the proposed research and agreed to participate throughout the research process.

2.1.2 Selection of research sites

The project was designed to build on previous research on soil erosion by Gardner *et al.*, 2000. Therefore, the same three villages involved in their research were selected for this project. These were Landruk, Ward No. 9 of Lumle Village Development Committee in Kaski district, Bandipur, Ward No. 3, 4 and 6 of Bandipur Village Development Committee in Tanahun district, and Nayatola, Ward No. 4 and 5 in Kushumkhola Village Development Committee in Palpa district in the western hills of Nepal (Figure 2). In addition to the baseline data and information about soil and nutrient losses that had been collected at these sites, a good relationship with the local farmers had already been established, which facilitated an early extension of research activities in participation with the farmers. The three locations were originally selected as being representative of the ecological and cultural diversity in the middle hills of Nepal (Shrestha, 2000; Annex E).

Landruk is a high altitude (1200-2000 m asl), high rainfall (3000-3500 mm pa) site. Typical bench terraces are narrow with 0 to 5^{o} outward slope angles and sited on steep slopes (Landruk is situated on the mid slope of a steep sided, deeply incised river valley more than one mile deep). Terrace width can be less than a metre; few are greater than five metres. In some places, at the higher altitudes, farming is marginal on narrow, very stony terraces. The main crop is maize, occasionally with a sparse undercrop, usually bean, pumpkin or water melon. The growing seasons are longer than in other sites because of the altitude. It is normal for maize either to be relayed with millet, the millet being transplanted in late July/early August, or for barley to be grown in the spring before maize is planted.

Bandipur is a mid-altitude (550-1000 m asl), low to moderate rainfall (1100-1500 mm pa) site. The bench terraces tend to be about 3 to 5 metres in width and slightly outwardly sloping, 0 to 5^{o} being typical. Soil type does vary but differences to the predominant red/brown soil tend to exist only in pockets. Hillsides have less steep slopes than in Landruk and the topography precludes run-on on most sets of terraces. Bandipur is on a good road so has permanent access to market and it is possible to sell surplus crops easily and grow some cash crops. This facilitates greater crop variety and cropping patterns and the different farmer practice required to manage each crop was the main variation tested on the erosion plots sited here. Maize is again the main crop and bean, pumpkin and water melon the main undercrops, though grown in greater densities than Landruk. Upland (rainfed) rice is an important secondary crop, as it is in many low to mid altitude sites in the Middle Hills, and there has been recent, large scale introduction of citrus trees into this area, some species of which will eventually shade out the maize undercrop.

Nayatola is a mid altitude site (1000-1500 m asl) with low to moderate rainfall (1000-1500 mm pa). The site is in Palpa district where large, steeply sloping terraces are predominant. These terraces are so constructed because size of terrace is perceived as reflecting wealth and status in this area. They contrast sharply with the flat to moderately sloped narrow terraces characteristic of most middle hill areas. In Nayatola terraces are likely to be 20 to 50 metres wide, and characterised by slope angles of 20 to 35^{o} (though are narrower and less steep where topography dictates). Whilst such terrace design might be thought to promote erosion, Gardner *et al.,* (2000; Annex C) found that rainfall and runoff/soil loss response was often low, but that the terraces seemed highly vulnerable to high magnitude events. Almost all individual terraces on steep slopes have developed an ‘S’ shape in profile. Terraces seem more prone to rilling than elsewhere. Maize, often undercropped with moderately dense cowpea, soybean, bean and pumpkin, is the main crop during the monsoon period.

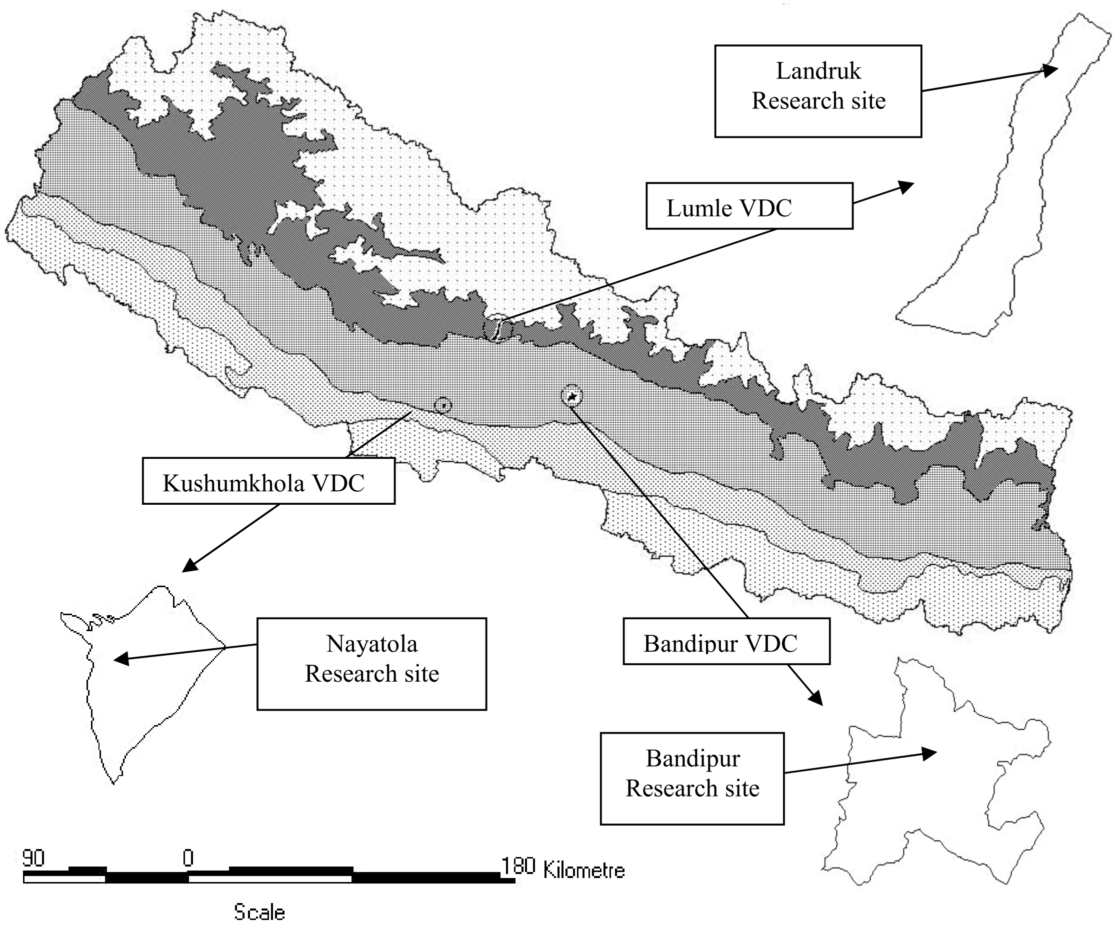


Figure 2. Location of the three research sites in the western hills of Nepal.

Within the project, we continued to monitor the existing plots established by Gardner *et al.* functioning as control plots to provide long-term data on nutrient losses by erosion, surface runoff and leaching. The interventions were implemented in adjacent plots to test their effectiveness. These plots were maintained by farmers’, but monitored by scientists to generate scientifically sound data on erosion and leaching losses. Thus, a subset of farmers was involved in rigorously designed and replicated field experiments testing interventions (Section 2.4); hereafter referred to as researcher-managed trials. These interventions were disseminated by a wide network of trials which were wholly farmer managed (Section 2.3); hereafter referred to as farmer-managed trials.

At the outset of the project, surveys were conducted in each village to characterize the farming communities in terms of their ecological and socio-economic features and farming systems and practices. Information was collected at both the village (farming community level), and at the household level. The former information was largely exploratory and descriptive in nature and described circumstances common to the majority of households such as types and access to community natural resources, types of crops and cropping systems, livestock systems and sources of off-farm income. The information was collected using a selection of PRA tools (mapping, diagrams, seasonal calendars, matrix scoring) during focus groups discussions, and triangulated by field observations. The focus group discussions typically involved 15 to 20 key informants at each site selected purposively with the help of village leaders. The key informants were farmers likely to provide information and insights about community natural resources and management, tradition and practices of farming, and about farming households in the community. Care was taken to ensure representation of key informants from different ethnic groups, wealth status, gender and different *tols* (hamlets) of the village. A checklist was used to guide a semi-structured discussion.

Information at the household level was collected by interviewing farming households using a structured questionnaire. The households were selected randomly, and the number of households interviewed was derived from:

$n = NZ^2P(1\text{-}P)/Nd^2+Z^2P(1\text{-}P)$ (Parel *et al.,* 1973)

where ;

n = number of households interviewed
N = total number of households in the village (115 for Landruk; 167 for Bandipur; 70 for Nayatola – figures obtained by social mapping)
d = maximum acceptable error (taken as 10%)
Z = normal variable (taken as 1.64 to correspond to 90% reliability)
P = proportion of the population likely to adopt improved soil and water management practices (estimated as a maximum of 50% to give largest possible sample size)

This resulted in sample sizes of 42 for Landruk, 47 for Bandipur and 34 for Nayatola, but more household were included at the interview stage to allow for the exclusion of outliers and incomplete responses. The final sample size was therefore 50 each for Landruk and 36 for Nayatola.

The village characterisations are presented in Shrestha (2000) and the resulting categorisation used in the interpretation of the results later in this document. The ethnic composition of the communities was not reported in Shrestha (2000) but is described in detail in Shrestha (2003). In summary, the caste system in Nepal is hierarchical in structure and each caste is related to one of four *varna* (caste group) in the classical Hindu caste hierarchy with Brahmin on top of the hierarchy with a role as priest and teacher, followed by Khastriya (warrior and administrator), then Vaishya (trading and farming) and Shudra at the bottom engaged in work socially regarded as inferior and involving high levels of drudgery (Bennet, 1983; Bista, 1991). For the purposes of this study, a modified model of caste hierarchy was adopted which classifies all castes into three major ethnic groups (Bista, 1991); *tagadhari* (those wearing sacred thread), *matawali* (those who drink alcohol) and *pani nachalne jat*[1] (untouchables from whom drinking water is not accepted). Based on this Brahmin, Chhetri and Gharti (BCG) represented *tagadhari*; Gurung, Magar and Newar (GMN) represented *matawali*, and Kami, Damai and Sarki (KDS) as *pani nachalne jat.*

[1] Called *sano jat* (lower caste) in the community, and also known as occupational castes since each caste is associated with a different occupation, e.g. Kami is blacksmith; Sarki is shoemaker and tanner; Damai is tailor.

There are general differences between these groupings in their distribution, social behaviour and attitude towards farming. As found in the eastern hills (Thapa, 1994) as well as in other parts of the western hills (Turton et *al.*, 1996), BCG ethnic groups dominate in the lower parts of the mid-hills and GMN in the upper parts while KDS are small in number and mixed in the communities at both altitudes. Households of BCG are largely dependent on farming as their main sources of livelihood, and tend to be enterprising in farming. GMN are traditionally more involved in off-farm activities (Gurung and Magar being known for their involvement in the army, and Newar in business). The KDS ethnic groups, with their limited resource endowment, are also more generally dependent on their traditional occupation work and labouring than farming alone.

This was reflected in the three study villages, where, as in other parts of the middle hills of Nepal, the communities were multi-ethnic in composition (Figure 3). Gurung was the dominant ethnic group at Landruk, which is characteristic of the upper mid-hills. The ethnic composition of Bandipur reflects its historical development as a trading centre in the region. The proportion of Kami households was uncharacteristically high as they are tenant farmers in a community where the majority of land belongs to Brahmin Chhetri and Newars also involved in business and other activities. Nayatola was dominated by the Magar ethnic group.

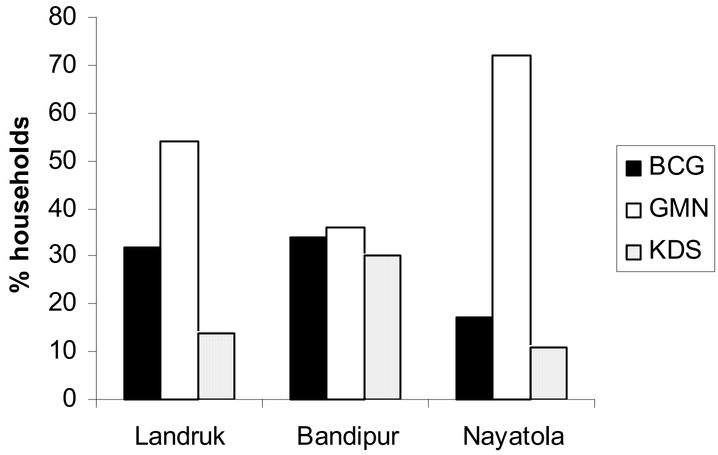


Figure 3. Proportion of households by ethnic groupings

2.2 Knowledge analysis and sharing

The purpose of the project was to enable farmers' to innovate and experiment with new soil and water management interventions by combining their local knowledge and practices with scientific knowledge and understanding of the problem in question. Therefore, the collection, synthesis and analysis of knowledge were critical steps in the development of intervention options (Figure 4; Table 1).

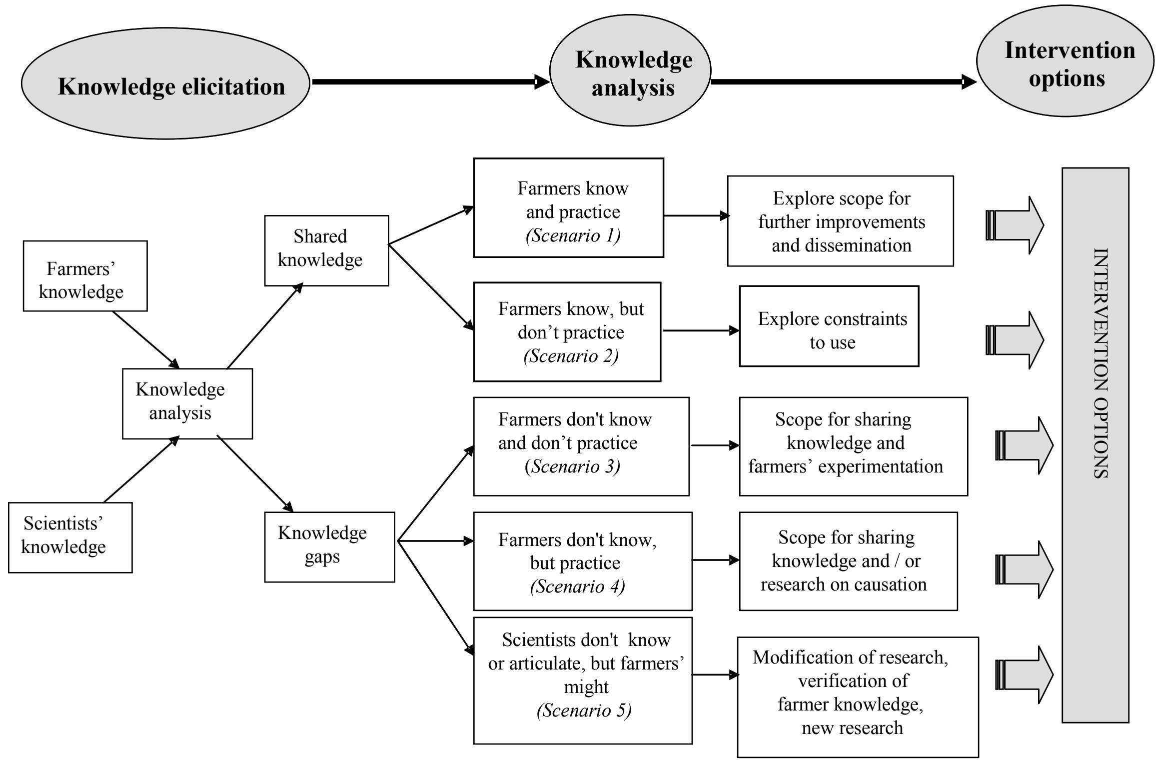


Figure 4. Developing interventions from farmers' and scientists' knowledge. (Adapted from Shrestha *et al.,* 2001)

2.2.1 Knowledge elicitation

2.2.1.1 Farmers' knowledge

The collection, storage and analysis of farmers' knowledge were done using the Agro-ecological Knowledge Toolkit (AKT5) developed by the University of Wales, Bangor (Dixon *et al*., 2000). The AKT methodology uses an ethnographic approach to knowledge acquisition and applies artificial intelligence and computer technology in storing, retrieving and assessing knowledge (Thapa *et al*., 1995; Walker *et al*., 1995; Walker *et al*., 1997; Sinclair and Walker, 1998; and Walker and Sinclair, 1998). Farmers' local knowledge is elicited using various participatory rural appraisal (PRA) tools and semi-structured interviews with individual farmers, tailored to suit available resources and local circumstances.

The elicitation of farmers' local knowledge on soil and water management was conducted at the three research villages. More than twenty farmers, both men and women, were purposively selected at each site. These farmers were repeatedly interviewed informally by both male and female project staff that were living with the farmers in their village. It took about three to four weeks for three persons to complete the knowledge elicitation in each research village. The knowledge documented was then represented in an electronic knowledge base using the AKT5 computer software. The analysis of knowledge gaps between farmers' and scientists' understanding was done using the automated reasoning capacity built into the AKT5 software (Kendon *et al*., 1995). The creation of electronic knowledge bases and subsequent analysis of them for consistency took about one month. Characteristic of the ethnographic studies, the process was relatively resource intensive but generated valuable insights about the wealth of farmers' knowledge that, because it is durably recorded, will be available for future as well as present purposes.

The rigorous method of knowledge acquisition used in the study identified a number of cases that strongly suggests that farmers' soil and water management practices are not necessarily and always a true reflection of what they know, and supports the view that practice and knowledge are not synonymous (Sinclair and Walker, 1999). Understanding farmers' knowledge underpinning their practices or linking farmers' practices to their underlying knowledge provided further insights into farmers' decision-making process and the determinants of use and non-use of their knowledge into practice. For example, despite a well-developed explanatory knowledge about the volatilisation loss of nutrients, farmers were often late in incorporating animal manure into the soil due to shortage of labour and oxen to plough land. Similarly, non-use of a proper compost making practice, non-practice of diverting runoff water from individual *bari* terraces, scraping of terrace risers despite their negative impacts on soil erosion and inclusion of fodder trees on *bari* land, and cultivation of crops on sloping land were not because farmers lacked knowledge but were either constrained in resources or were making deliberate trade-offs. These findings, therefore, support the view that the application of knowledge in practice is influenced or determined by farmers' ecological, economic and social factors in general and more specifically by their assessment of costs and the resulting benefits (Gurung, 1989; Garforth and Gregory, 1997; Sinclair and Walker, 1999).

The study produced a comprehensive knowledge base containing over 1100 knowledge statements covering six different aspects of soil and water management, namely soil classification and soil properties, soil fertility, soil water, soil and nutrient losses and plant-soil interaction. The use of a systematic and well-structured knowledge acquisition method, that involved an iterative cycle of knowledge elicitation, formal representation and evaluation, was very effective in capturing an unambiguous, consistent, coherent and detailed stock of farmers' knowledge about soil and water management. The use of WinAKT in creating an electronic knowledge base was helpful in the analysis of knowledge and for maintaining a dynamic store of knowledge for wider access and use. A detailed description of the information contained in the knowledge base is presented in Annex B.

It was clear that farmers clearly recognise links between fertility, nutrient supply and soil texture. Soils of different textures were reported to interact differently with various factors of production. Fertile *(malilo*) soil is thought to have the capacity to absorb and retain large amounts of nutrients released from manure and make them readily available to crops, when there is adequate water. Clay-rich *garungo mato* (‘heavy soil’) exhibits this quality more than sandy *halka mato* (‘light soil’). Farmers relate the differential water requirements of light and heavy soil to how they supply soil nutrients to crops. So, farmers rank the fertility of light and heavy soils differently, depending upon rainfall, with the fertility of light soil being considered high when rainfall is moderate but low when rainfall is high. The opposite is considered to be true for heavy soil. Farmers explain this in terms of excessive rainfall washing away light soil, including the nutrients and manure it contains, which is detrimental to crop growth - typically inducing yellowing of the leaves. On the other hand, farmers perceive heavy soil as requiring a large amount of water to saturate and 'melt' it: only then will soil nutrients be available to crops. As a result of this knowledge, farmers apply more animal manure to heavy soil than to light soil, if they have sufficient manure to do so. Farmers describe light soils as ‘coarse’, ‘granular’ or ‘loose’, a quality which they believe both facilitates the movement of water through the soil and promotes good root growth, as root penetration and spread is easy. However, because the water retention capacity of such a soil is low, frequent rainfall or irrigation is required for good crop production. There was considerable variation in the use of local terminology for soil types when the soil colour was not distinct or where soils exist with a gradation of texture. Use of the terms *malilo* and *rukho* for fertile and unfertile soils respectively were used generically by farmers in a number of ways, for example to classify trees based on the effect they have on soil and crops. *Malilo* soils contain high levels of organic matter; are deep (with few or no stones); are soft and friable; retain moisture for a long time; absorb and hold nutrients added through manure; can be easily ploughed; and produce good, healthy crops with a high yield. *Rukho* soils, on the other hand, are sandy or stony; contain little or no organic matter; are shallow; retain moisture for only a short period;

do not easily absorb and hold nutrients; are difficult to cultivate; and are associated with low crop yields. The farmers perceive the high fertility of *malilo* soils to be an inherent property, related to texture. These soils are, therefore, potentially more productive than other soils. Farmers also perceive that some soils are inherently *rukho*, though they are not able to explain why this is so. *Kamere mato* (white calcareous soil with a large amount of mica), *Jogi mato* (reddish mixed coloured soil with mottling) and yellow clayey soil, fall into this category. Farmers know that crop yield is low on these soils even if a large quantity of animal manure is applied to them.

Overall, the study showed that farmers in the middle hills of Nepal possess an intimate and sophisticated knowledge about the nature and properties of *bari* soils and its management for the production of crops and livestock and that such knowledge was based on their observations and experimentations. Farmers' knowledge was also dynamic in the sense that farmers were found to learn new knowledge through their own experimentation with new interventions and/or acquired from neighbours, extension agencies or other sources. It has also illustrated that knowledge and practices were not synonymous and that translation of knowledge into practices depended on farmers' ecological, social and cultural circumstances. The study has indicated that much of farmers' knowledge on soil and water management, both in content and details of explanation, was quite similar across the three research villages. Some variations found in articulation of knowledge were influenced largely by differences in ecological environments, such as altitude and rainfall rather than on the cultural context of the farming communities.

In terms of linking to the research, the important implications were that farmers' knowledge about a number of below ground processes that were not easily observable was quite rudimentary and not well developed. Farmers were unable to articulate the leaching losses of soil nutrients, chelating and buffering properties of soil organic matters and many other bio-chemical interactions taking place in soil and crops. This provided a strong rationale for sharing scientific knowledge with farmers to enable them to make better decisions in improving their existing soil and water management practices or in experiments with new interventions.

2.2.1.2 Scientists knowledge

Our project followed on from the earlier assessments of soil loss on a wide range of land use types in the middle hills of Nepal (Gardner *et al.,* 2000; Annex C). These studies concluded that measured rates of soil erosion are for the most part relatively low in "average" monsoons (generally less than 5 t ha^{-1} yr^{-1} , as determined in 100 m^2 erosion plots). Furthermore the majority of rain falling on the soil infiltrates to depth – runoff usually accounts for less than 10%. Therefore, nutrient losses resulting from runoff and erosion are much less than losses incurred from leaching. Thus, while erosion is a not an insignificant cause of soil and nutrient loss, the perceived problem of excessive soil loss from *bari* land in the Middle Hills of Nepal by erosion was not in general supported by the data collected. They concluded that surface soil erosion hazard on *bari* land should be viewed from the point of view of risk management rather than in terms of widespread need for additional soil conservation measures on the bench terraces. There remains huge potential for soil erosion but it is reasonably well under control at present in many terraced locations. However, when introducing any changes to the farming system and land management in the future the likely impact on erosion must be considered. In addition, when alternative options for development of the farming systems are on offer, then those providing additional soil conservation benefits as a by product should be sought out and favoured, all other things being equal.

Soil loss can be high, but only usually when there are specific, local reasons. The prime reasons were increased surface water fluxes resulting from (a) excessive uncontrolled run on of water from the hillslope above; (b) high magnitude and infrequent rainfall events; and (c) subsurface piping of water leading to concentrated outflows onto fields. The effects of all of these, which may act singly or in combination, are exacerbated by fine textured soils. Comparisons of the common cropping patterns suggest that crop type is not a major factor in differential soil losses.

Differences in soil losses at the regional scale within Nepal are driven overall by rainfall totals and erosivity. The relative severity of soil loss at a particular site in any one year is determined by the interaction between rainfall erosivity and rainfall timing in relation to the ground cover conditions. Ground cover is largely a function of the farmers' management practices and cropping pattern together with antecedent soil moisture. It is the timing of severe storms in the pre-monsoon phase, when the soil is more exposed and vulnerable, that is often critical in defining the terrace response in a particular year. Thus it follows that inter-annual variation in soil and nutrient loss can be high, both because of different temporal patterns of rainfall in relation to farming practices and overall rainfall levels. Furthermore, any further interventions should be focused on reducing losses in the vulnerable period in the early season.

Nutrient losses from runoff were found to be negligible, but nitrate losses in subsurface leaching, measured for the first time in Nepal, were relatively high and exhibited a strong seasonal pattern. Early season nitrate concentrations exceeded 30 mg l^{-1}, but fell following the onset of regular rain in the main monsoon to levels of 5 mg l^{-1} and less. Taking note of seasonality in nitrate concentrations and in infiltration of soil water to depth, net losses of nitrate-N by leaching were greatest in June and July. Over the monsoon as a whole they reached levels of up to 45 kg per hectare. Notable differences in total loss occurred between the three regional sites investigated in detail.

There are clear temporal variations in the soil hydrological and erosion/leaching processes. In particular there are two distinct phases within the monsoon between which climate and soil hydrology at the terrace scale change markedly; June is the transition period separating them. An understanding of these temporal patterns is as essential to an understanding of the complexities of soil and nutrient loss in the Middle Hills as is the knowledge of farmer actions.

The research concluded that further work on the bench terraces should be directed towards:

- Verification of the seasonal nitrate losses through leaching, runoff and soil erosion;
- Greater understanding of their importance in the overall nitrogen cycle;
- Intervention measures to reduce the nitrate losses via leaching;
- Intervention measures to control erosion during the early season vulnerable period under those combinations of biophysical and land management circumstances that promote high levels of risk.

Lastly, qualitative measurements were undertaken on over 350 terraces in 1996 and 1997. The aim was to assess which combinations of biophysical and management factors led to high susceptibility to soil losses, and to determine if a simple farmer-based method of relative susceptibility could be devised. The results indicate that simple structured observation of morphological characteristics of terrace surfaces offers some scope for assessment of relative susceptibility, but that this could not sensibly be extended to provide estimates of quantitative losses or comparisons between areas. Further development of these indicators was conducted in our project, and reported in this document (Section 2.4).

2.2.2 Knowledge analysis

2.2.2.1 Shared knowledge

Physical features of soil, such as texture, structure, colour and stone content extensively used in scientific soil classification were also used by farmers as the primary basis for their soil classification. Similarly, the roles of soil texture and structure in combination with soil organic matter in influencing soil nutrient retention and availability and soil water absorption, infiltration and retention dynamics are scientifically well established and these were also articulated in a similar manner by farmers. The farmers regarded soil fertility as an inherent property of soil associated with particular type of soil. They were also aware that inherent fertility of soil could be temporarily altered by the different management regime applied to soil. Although the farmers' knowledge about the effect of soil temperature on soil conditions and plant growth was poorly developed among farmers, their description of the role of soil temperature on development and growth of crop roots was consistent with science.

Farmers possess a good knowledge about the seasonal patterns of rainfall and soil loss which appeared to accord with the scientific data collected by Gardner *et al.*, 2000, and this was subsequently proven by the end of the project (Figure 5; full details in Annex B). The analysis revealed two important features of farmers' knowledge about the seasonal pattern of soil loss from *bari* land. First, the rainfall and soil loss patterns stated by farmers matched quite closely with patterns based on scientific data and both followed almost exactly similar trends in the changes in the amount of rainfall and soil loss over the season. Second, despite low rainfall, the soil loss during pre-monsoon months of *Baisakh* to *Jestha* (mid-April to mid-June) was much higher than the heavy monsoon rainfall months after *Asadha* (mid-June). A similar trend was found in the scientific studies conducted in Andheri Khola Sub-watershed (Carver and Nakarmi, 1995) and Kulekhani Watershed (Sthapit, 1995). This shows that farmers were not only able to identify the critical period of soil loss from their *bari* land but were also knowledgeable about factors other than rainfall that were important in determining the amount of soil losses from the *bari* land. However, the farmers attributed such erosion to high nutrient losses, which was contrary to the scientific findings (Section 2.4).

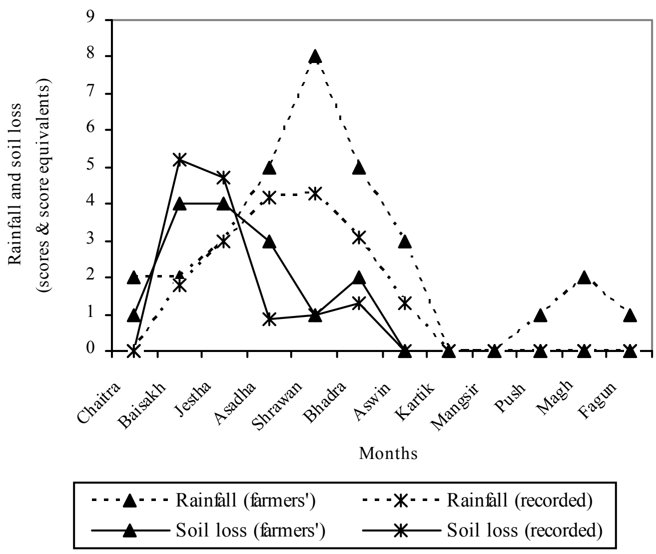


Figure 5. Comparison between farmers' perceived and scientists' recorded rainfall and soil loss pattern averaged for three years at Landruk

Explanations for high soil erosion during pre-monsoon period were also well developed among farmers. The three main reasons or factors mentioned for this were: a) loose, dry and dusty state of soil - soil erodibility determined by soil texture, structure and water content; b) high intensity and low duration occasional rainstorms often combined with hailstorms - rainfall erosivity determined by rainfall intensity; and c) bare soil condition or poor crop cover - soil vegetative cover. These factors were also considered to influence amount of *bari* soil erosion throughout the rainy season. In addition to these, land features - slope, size and shape of terraces; and crop and soil management practices, including erosion control measures were also said to affect amount of soil erosion from the *bari* land.

2.2.2.2 Knowledge gaps

Although, there was a substantial amount of shared knowledge (Section 2.2.2.1), there were some key aspects known only to farmers or only to scientists and these represented the knowledge gaps between farmers and scientists. The nature of the shared and unique knowledge showed that farmers knew more about above ground than below ground ecological processes. When the farmers' and scientists shared knowledge was compared, it was concluded that farmers' knowledge was largely explanatory, experiential and commonly held amongst farmers of the community. The scientists knowledge was based on an understanding of the fundamental processes elucidated using their available methodology, which may be complex, but misses out on the sophistication of farmers' knowledge of interactions, even if the mechanisms of the interactions cannot be articulated. This led to recognition of what type of research could be useful (by supplementing knowledge gaps) which could increase farmers' knowledge and support their innovation, while developing an overall improved understanding of the dynamics of complex farming systems. Such an understanding, if appropriately communicated can enrich their knowledge which may reduce vulnerability by ensuring that farmers are better able to cope with new stresses and problems - including ones which have not been previously anticipated (Joshi *et al*., 2003; Annex G).

Some of the farmers' and scientists' knowledge gaps which therefore had implications for the research (Shrestha *et al.*, 2001) were:

Farmers did not know, or had little knowledge about:

- Movement of rainwater through infiltration being higher than through surface runoff.
- Nutrient losses through leaching being greater than losses through surface soil erosion.
- Soil texture influencing the nutrient holding capacity of soil and so influencing leaching losses.
- Organic matter increasing nutrient holding capacity of soil and so minimising leaching losses.
- The role of deep-rooted plants in nutrient recycling.
- The role of legume root nodules and the phenomenon of nitrogen fixation

Scientists had little knowledge about:

- Multiple ploughing causing an increase in maize yield. It mixes manure well into the soil and the resulting soil condition provides a good growth environment for seed and roots.
- Farmers classification of a large number of fodder trees as *malilo* (contributing to soil fertility and not too competitive with crops) or *rukho* (detrimental to soil fertility and competitive with crops). The classification is based on the decomposition of litter and competition for light and nutrients with the crop.

The analysis of knowledge gaps between farmers and scientists done in this way provided a basis for sharing knowledge with the farmers. The knowledge analysis also looked into causal relationships and used the resulting information to evaluate farmers' soil and water management practices. The causal analysis clearly established disparities between farmers' knowledge and their practices. There was knowledge that was not translated into practice, as well as a number of practices that were followed without much understanding of why they were effective. The analysis of knowledge and practices provided a basis for the identification of potential intervention options, which were then used as ideas for designing new soil and water management interventions together with farmers (section 2.2.3).

2.2.3 Intervention options

The knowledge elicitation and analysis of the knowledge gaps permitted the development of a range of intervention options (Table 1) which facilitated features such as new grass species which had faster growth rates, earlier flushing, longer duration and higher nutritive value than wild grasses; diverting run-on by developing community actions to dig channels (development of social capital); introduction of fodder trees which do not compete with crops, or minimising the competitive interface; management of leaching by incorporation of deep rooting legumes and other species which provide a safety net to trap labile nutrients. The specifics of the interventions (niches, appropriate species) were decided following exposure to practical examples (Section 2.3).

Table 1. Scenarios of shared knowledge/knowledge gaps leading to the development of interventions (from Shrestha *et al*., 2001)

Scenario 1: Farmers know and practice

Farmers' knowledge	Farmers' practices	Scope for improvement	Intervention options
1. Increase in outward slope of land causes an increase in soil erosion through increased velocity of *bhal* (runoff).	Construction of bench terraces for crop cultivation.	Some bench terraces are not aligned properly.	Explore reasons and find out difference in soil losses from such terraces
2. Diversion of *bhal* reduces soil erosion through reduced amount and velocity of *bhal*.	A few farmers, having their land close to natural drainage outlets, have dug diversion channels to drain out excessive *bhal* from the field.	The majority of farmers do not use diversion channels to drain out excessive *bhal*.	Explore reasons and research effectiveness of diversion ditches in reducing soil erosion.
3. Terrace riser grasses reduce soil erosion through reduced velocity of *bhal* and trapping of soil particles.	Farmers retain grasses growing naturally on terrace risers, while some farmers also plant new grasses.	Fodder quality of natural grasses is low, they flush late after the dry period, their growing period is short and the majority are non-leguminous.	Possibility for introduction of new grasses and test effectiveness of such grasses in reducing soil erosion.
4. Cultivation of legume crops improves soil quality and increases soil fertility.	Extensive use of legumes for inter-cropping with maize. Planting legumes on sandy and poor fertility soils.	Low and declining yield of many legume varieties.	Introduction of new legumes and/or new legume varieties to increase diversity and yield, and that fit well into the cropping system.
5. Trees on cultivated land cause a reduction of crop yield through competition for light and nutrients.	Farmers minimise the number of trees on cultivated land and trade-off crop production with fodder.	Farmers continue to keep trees on cultivated land and would increase the number if light and nutrient competition can be minimised.	Selection of trees and/or management practices that reduce light and nutrient competition with food crops.
6. Grasses on the edge of terrace risers cause a reduction of crop yield through competition for light and nutrients.	The majority of farmers do not grow grasses on the edge of terraces.	Farmers are interested to grow grasses on the edge of terrace if light and nutrient competition can be minimised.	Selection of grasses and/or management practices that reduce light and nutrient competition with food crops.

Scenario 2: Farmers know but do not practice

Farmers' knowledge	Farmers' practices	Constraints	Intervention options
1. Mulching reduces soil erosion and improves soil quality.	Mulching is practised only on a few cash crops, such as ginger, turmeric, taro and orange trees. It is not practised on food crops.	Shortage of mulching materials and farmers' preference for fodder grasses for livestock feeding.	Farming practices that increase on-farm production of mulching material or provide low-cost mulching materials.
2. Diversion of *bhal* reduces soil erosion through reduced amount and velocity of *bhal*.	The majority of farmers do not use diversion channels to drain out excessive *bhal*.	A network of drainage channels does not exist and the social moral does not allow one to drain out on to another's field.	Ways to mobilise the community to establish drainage outlets at strategic locations and testing the effectiveness of such a system.
3. Exposure of animal manure to air and sun causes a decrease in soil fertility.	The majority of farmers do not incorporate animal manures immediately after they are transported to the field.	Labour shortage during peak planting periods and only few farmers own oxen used for ploughing land.	Quantifying amount of losses due to air and sun exposure and ways to minimise it within the constraints of farmers.
4. Trees and grasses on terrace risers reduce soil erosion.	The majority of farmers keep/grow minimum number/amount of trees/ grasses.	Trees and grasses on terrace risers compete with crops for light and nutrients.	Tress/grasses and/or management practices that reduce light and nutrient competition with crops.
5. Soil erosion is highest during pre-monsoon rain when the soil is well tilled and loose and dusty.	Farmers do not apply any management to minimise the loss.	Climate and farming operations do not allow farmers to grow cover crops and they do not have access to other options.	Identifying niches in crop fields where perennial cover can be established to reduce pre-monsoon soil erosion.

Scenario 3: Farmers do not know and do not practice (Farmers' knowledge gap)

Farmers' knowledge gap	**Farmers' practice**	**Scope for sharing knowledge**	**Intervention options**
1. Movement of rainwater through infiltration is higher than surface runoff.	Farmers focus on surface runoff.	Implications of high infiltration of rainwater.	Means of reducing or retaining infiltration.
2. Nutrients are lost through leaching and this is greater than loss through surface soil erosion.	Farmers focus on nutrient loss through surface soil erosion.	Demonstration of leaching loss and ways to reduce such losses.	Effectiveness of management practices in reducing leaching losses.
3. Soil texture influences nutrient holding capacity (CEC) of soil and thus influences leaching loss.	Manuring and other management practices indifferent to this knowledge.	Visual/diagrammatic demonstration of CEC properties of soils.	Development of management practices which improve soil physical properties (primarily soil O.M. and water-holding capacity).
4. Organic matter increases nutrient holding capacity (CEC) of soil and thus minimises leaching loss.	Farmers apply animal manure and/or organic matters mainly for immediate supply of nutrients.	Visual/diagrammatic demonstration of CEC properties of organic matter.	Enhancing organic matters in soils to reduce leaching losses.

Scenario 4: Farmers do not know but practice (Farmers' knowledge gap)

Farmers' knowledge gap	**Farmers' practice**	**Scope for sharing knowledge**	**Intervention options**
1. The role of deep-rooted plants in nutrient capture and recycling.	Farmers grow surface grasses and fodder trees on terrace risers of cultivated land to meet their fodder requirements.	Visual/diagrammatic demonstration of the process and its importance in minimising leaching losses.	Testing the effectiveness of different grass and tree species in minimising leaching losses of nutrients.
2. The role of legume root nodules and the phenomenon of N-fixation.	Farmers are aware of the role of legumes in improving soil quality and increasing soil fertility (through incorporation of leaves in soil) but inter-crop both with summer and winter crop largely for food.	Visual/diagrammatic demonstration of the process and encouraging farmers to grow legumes more systematically.	Growing legumes under different management practices, and improved varieties of legumes (including perennials). Green manuring.

Scenario 5: Scientists do not know and/or articulate, but farmers' might (Scientists' knowledge gap)

Farmers' knowledge	**Farmers' practice**	**Scope for sharing knowledge**	**Intervention options**
1. Multiple ploughing causes an increase in maize yield. It mixes manure well, and aerates soil and the resulting soil condition provides a good growth environment for seeds and roots.	Farmers prefer and use plough tillage (over spade tillage) and apply 2 to 4 ploughing depending on the availability of oxen and labour.	Sharing farmers' experience of reduced productivity of crops (especially maize) due to the erection of metal sheet around the trial plot – resulting in having to hand plough	Dismantle the metal sheet around the trial plot in winter and allow farmers to use ploughing for tillage, and test intervention option under this system.
2. Farmers have knowledge about *malilopan* and *rukhopan* of fodder trees based on their competition for light and nutrients with crop.	Farmers keep different number and types of fodder trees and trade-off their effect on the food crop with their need for fodder.	Use farmers' knowledge about *rukho* and *malilopan* of fodder trees in the selection and inclusion of such trees in trial design.	Effectiveness of *malilo* and *rukho* trees in trials to reduce nutrient losses from cultivated land.

2.3 Farmer's experimentation

The scientific knowledge was shared with the farmers and the farming community. Village workshops were organised at all the three research sites for this purpose. Farmers (both men and women) were informed of and invited to the workshop through their village leaders. Knowledge on soil and water management was shared with the participating farmers with the help of charts, posters and demonstration equipment prepared by the project team of scientists. A large number of farmers participated in the workshop that lasted for two to three hours (Plate 1). Special emphasis was given to the areas of knowledge which were not well known by the farmers. For example, the concept of leaching loss of nutrients was demonstrated to the farmers by using coloured water pored into locally made glass boxes holding a soil profile, similar to that used by Hagmann *et al.*, (1997) (Plate 2).

Plate 1: Village workshop sharing knowledge

Plate 2: Demonstrating leaching loss of nutrients at the village workshop

The sharing of knowledge led to the realisation that nutrient losses occur through soil erosion *and* leaching and motivated farmers to participate in the technology development process. Farmers and village leaders participating in the village workshop were requested to identify farmers who would undertake research on soil and water interventions suitable for themselves and the community more generally. They selected twelve farmers at each site for this purpose. To facilitate communication and support amongst each other, as well as with the wider farming community and with research scientists, these farmers were called "research farmers" and their group was constituted as a research farmers' committee. The farmers who had been working with Gardner *et al*., continued to maintain those experiments.

2.3.1 Research farmers' exposure visit

The thirty-six new research farmers from all three sites were then taken on a week long study tour to research and demonstration sites in different parts of the country. The places included in the study tour were:

- Paireni research and demonstration site managed by Nepal Agricultural Research Council (NARC) and ICIMOD.
- Majhitar farming community in Dhading district supported by the Nepal Agro-forestry Foundation (NAF).
- Godawari trial and demonstration site managed by ICIMOD.
- Sankhu project site of the Bagmati Integrated Watershed Management Programme (BIWMP) under the Department of Soil Conservation and Watershed Management.

Farmers acquired new knowledge and were able to see a range of new soil and water management practices. They returned to their villages highly motivated to try a number of new soil and water management practices on their own farms. During the visit, the farmers also had an opportunity to discuss and conceptualise ideas about new experiments that they would like to test on their farms.

2.3.2 Identifying and designing new interventions for farmers' experimentation

Meetings of research farmers were called and facilitated by the research scientists to discuss the design of new soil and water management interventions. The meeting started with a review of the knowledge shared in the first village workshop and any insights gained during the study tour to the research and demonstration sites. This helped farmers to conceptualise and identify potential soil and management interventions for their experimentation. The concept of systematic research, including the role of control and replication, was also shared with the research farmers. This helped them to:

- realise that whatever new intervention they would like to experiment with required to be tested for several seasons to draw a meaningful conclusion;
- visualise that the interventions they would experiment with needed to be compared with their current practice to see their effectiveness (the concept of comparison with a control);
- think about the selection of land on which interventions were to be tested to enable suitable comparisons to be made;
- think about methods of observation and indicators for judging the effectiveness of new interventions; and
- realise the need to test the interventions in different environments to judge their robustness or reliability (the concept of replication).

After a thorough discussion, farmers came up with four intervention designs at each of the research sites and, based on their interest in these, divided into four groups of three farmers to experiment with the identified interventions (see Annex 2 of Annex E). These interventions included the use of legume and non-legume forage species, fruit trees and water harvesting structures and crop layout patterns that conserve nutrients and water in the *bari* land. The next day of the meeting, the research scientists visited individual research farmers, made joint observations of the plot selected for establishing the experiments and measured the experiment plots to estimate the planting materials required. Scientists supplied the new planting materials to the research farmers. With technical support from the scientists, the research farmers and their family members planted research materials in the experiment plots as they had agreed in the meeting. At Landruk and Bandipur, with bench terraces, each research farmer allocated two to three terraces to establish experiment plots. Half of each terrace was used to plant research materials as specified in the particular intervention design while the other half was retained as control for comparison. At Nayatola, with sloping terraces, such an arrangement was not possible and so control plots were not established. Comparisons were instead made with the researcher managed trials during the joint monitoring and evaluation exercises (Section 2.4.6). Similar interventions were installed in the researcher managed trials, but the experimental layout was different (Section 2.4).

2.4 Monitoring and evaluation

Detailed investigations were conducted on the researcher managed trials in Landruk and Nayatola. In Landruk, two interventions were investigated: run-on diversion (closed plots), and growing fodder species in the terrace risers. *Setaria anceps* (Setaria) was planted in terrace risers and *Flemingia congesta* was planted on the top of the riser. The *Flemingia congesta* did not perform well in 2000, so in subsequent years only Setaria was planted across the whole riser. The interventions were compared with farmers' practice in which run-on is not controlled and terrace risers were covered by indigenous grasses. At Nayatola, strip crops of maize (*Zea mays*) and ginger (*Zingiber officinale*) and maize and soybean (*Glycine max*) were compared with farmers' practice. At both sites, plots were 20 m x 5 m (long axis down slope) and replicated in 5 blocks. Observations of soil and nutrient losses from different existing farming systems were continued in 6 previous soil erosion research plots (Gardner *et al*., 2000) at Bandipur to determine nutrient dynamics in the system, but no formal measurements were made of any interventions.

2.4.1 Rainfall, runoff, erosion and leaching

Surface runoff volumes and nutrient content were monitored on a weekly basis in standard runoff plots. The experimental plots were enclosed by metal sheets on all sides to prevent lateral water movement (except for the upper border in the open plots at Landruk). The edge of the metal sheet was raised about 0.3 m above and extended 0.2 m below the surface of the soil. A five metre long trough was located at the lower end of the plot and connected with polythene pipe to a drum, in which total runoff from the experimental plot was collected. Eroded sediment was estimated in runoff samples of 0.5 l collected from each drum after vigorous stirring. A sample of clean solution from the last drum containing runoff was also taken for its nutrient analysis. Infiltrated water was collected in lysimeters constructed and inserted in such a way so as to collect leachate from the top 40 cm layer of the soil. They were constructed from polythene pipes of 11 cm diameter and 25 cm length, and filled with soils. A leachate collection cup was fitted in the end of the pipe, and two small, soft tubes of five 5 cm diameter passed out through the pipe, remaining above the soil surface and allowing leachate to be pumped out. These lysimeters were inserted in the runoff plots (3 per plot) 15 cm below the surface of the soil. Rainfall amounts and intensities were recorded over the monsoon period (May – October) using both automated and manual recorders. Selected results are presented here to indicate general trends. The full set of results are presented in Acharya (2003) and Annex D.

At Landruk, diverting run-on resulted in increased infiltration (Figure 6), resulting in higher losses of nitrate–N and exchangeable K compared to farmers' practice (Table 2). More nitrate-N was lost from the closed than the grass planting in terrace riser plots. The loss of nitrate-N was more in mid season and less in early season from all treatments except farmer's practice which lost slightly more in the early season than late season. The closed plots lost more K than farmers' practice, and the plot of grass planting in terrace riser lost least K However, the differences among the treatments for the loss of K in leachate were not significant in any period of the season. K loss in leachate was more in mid season followed by late season and less in early season from all treatments.

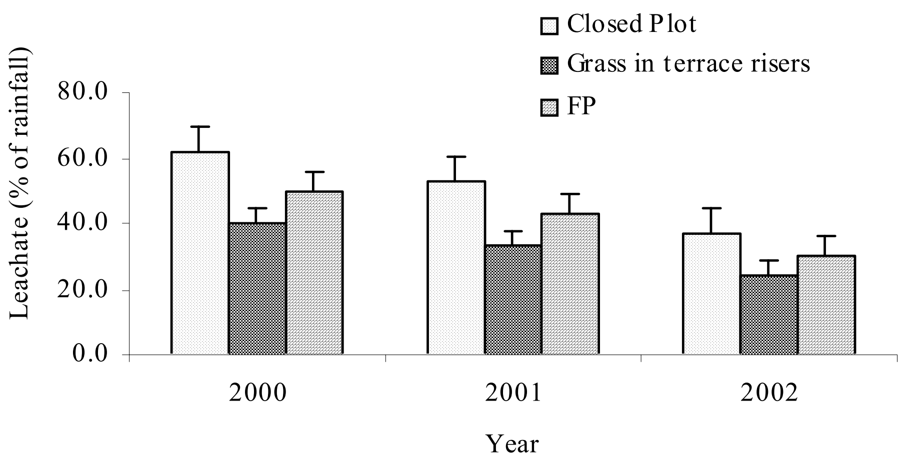
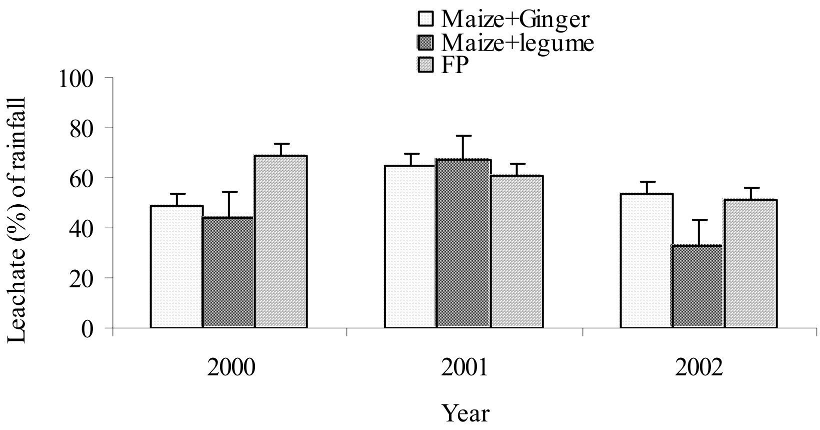


Figure 6. Leachate expressed as a percentage of rainfall at Landruk during 2000-2002

Table 2. Nutrient loss (kg/ha) in leachate at Landruk during 2002

TREATMENT	EARLY SEASON		MID SEASON		LATE SEASON		TOTAL	
	N	K	N	K	N	K	N	K
Closed plot	3.5	3.5	19.9	24.0	6.6	8.8	28.0	35.3
Grass in terrace riser	3.0	2.1	10.8	18.4	6.1	6.6	18.3	26.7
Farmer's practice (FP)	4.2	2.6	11.8	20.7	3.5	7.9	17.3	30.7
P=	0.89	0.61	0.09	0.89	0.57	0.93	0.45	0.91



At Nayatola, differences between the total leachate in the strip cropped plots and control were not significant in any year (Figure 7). Both nitrate-N and exchangeable K leaching losses were slightly higher in maize and ginger strip than that of farmers' practice (Table 3). Losses were reduced in the maize and ginger strip in the mid season because the maize and ginger plants established well and they covered the ground in the mid season. However, it was not so in the farmers' practice. The seasonal distribution of N loss through leaching was the highest in late monsoon period. The seasonal distribution of K loss through leaching was slightly higher in early period followed by mid and late.

Figure 7. Leachate as a percentage of rainfall at Nayatola during 2000-2002

Table 3. Nutrient loss (kg/ha) in leachate at Nayatola during 2002

TREATMENT	EARLY SEASON		MID SEASON		LATE SEASON		TOTAL	
	N	K	N	K	N	K	N	K
Maize+ Ginger	10.9	6.1	10.2	5.7	33.8	4.9	52.9	15.2
Maize + Legume	0.4	2.3	3.5	4.0	16.1	4.5	21.7	10.7
Farmer's practice (FP)	8.2	2.6	4.4	3.6	23.2	4.2	34.8	10.2
P=	0.30	0.20	0.13	0.27	0.63	0.84	0.40	0.35

At Bandipur, lowest losses of both N and K were in the leachate of narrow terrace maize-fallow-fallow (Table 4). The loss of total P in the leachate was less than 1 kg/ha, indicating that the loss of soluble P is negligible in leachate.

Table 4. Nutrient loss (kg/ha) in leachate at Bandipur during 2002

CROPPING SYSTEM	EARLY SEASON		MID SEASON		LATE SEASON		TOTAL	
	N	K	N	K	N	K	N	K
Wide terrace and M-Mi-F	15.9	4.9	12.5	11.5	4.2	7.2	32.6	23.6
Young citrus orchard and inter cropping	19.1	26.6	23.0	5.8	6.8	1.7	48.9	34.1
Narrow terrace and M-Mi-F	12.9	3.7	8.9	9.5	7.6	4.3	29.4	17.5
Narrow terrace and M-Mi-F + grass planting in terrace riser	19.5	3.6	8.4	8.1	11.9	6.5	39.8	18.3
Old citrus orchard	38.7	8.5	12.8	6.9	3.3	1.3	54.9	167

2.4.2 Run-off and eroded sediments

In the high rainfall site of Landruk, the total runoff from closed plots was generally lower than from open plots, but the amount of runoff was very low in all years as compared to rainfall. Consequently, sediment loss (Figure 8) was higher in farmers' practice than closed plots due to the limited area of run-off, where water could not flow freely from the above terraces. A higher sediment loss was observed from grasses grown in the riser plots than farmers' practice during 2001 most probably due to first year planting of grasses in the riser, where roots were not well established to conserve soil. By 2002, the soil loss from closed plot was the lowest, but it was also less in the grass plots than in farmer's practice. Nutrient loss in the eroded sediments was much less, in the order of 20-50%, than in leachate solution (Table 5).

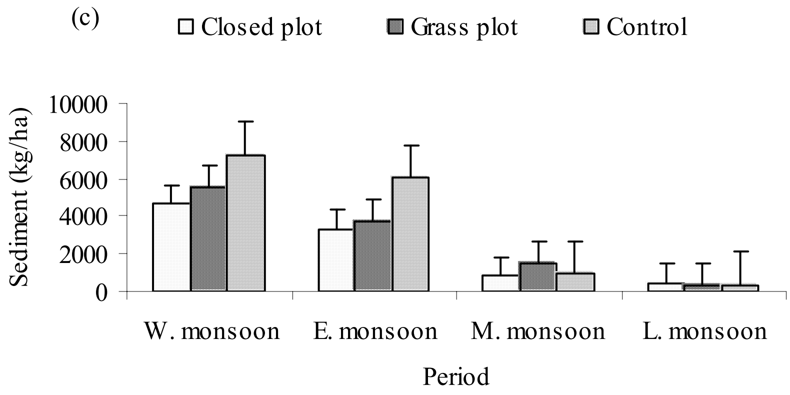


Figure 8. Soil losses at Landruk during 2002

Table 5. Nutrient loss in eroded sediment at Landruk (average of 3 years)

TREATMENT	ORGANIC CARBON (kg/ha)	TOTAL N (kg/ha)	AVAILABLE P (kg/ha)	EXCHANGEABLE K (kg/ha)
Closed plot	55.1	4.7	0.14	0.30
Grass in terrace riser	108.3	8.0	0.26	0.44
Farmer's practice (FP)	114.2	8.4	0.20	0.47

At Nayatola, the total runoff from the strip cropped plots was less than the farmer's practice. The total loss of the sediment was the highest in the farmers' practice followed by maize and soybean strip and maize and ginger strip (Figure 9). Maize and ginger strip is better than maize and soybean as well as farmers' practice for minimizing sediment loss by run-off because in maize and ginger strip, ginger was mulched with locally available materials at planting, which acted as a cover to the soil as well as minimizing the soil run-off. The loss of soil in early season is the largest irrespective of the treatments. Insignificant amounts of soils were lost in mid and late season, however the trend among the treatments was the same as the soil loss in early season. As at Landruk, nutrient loss in the eroded sediments was much less, around 20% less, than in leachate solution (Table 6).

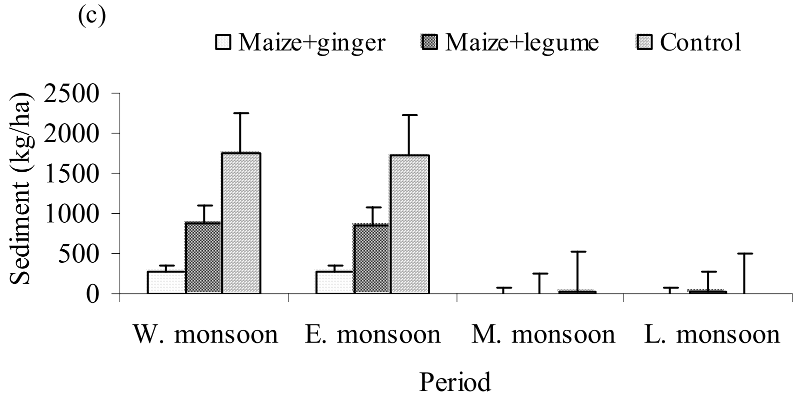


Figure 9. Soil losses at Nayatola during 2002

Table 6. Nutrient loss in eroded sediment at Nayatola (average over 3 years)

TREATMENT	ORGANIC CARBON (kg/ha)	TOTAL N (kg/ha)	AVAILABLE P (kg/ha)	EXCHANGEABLE K (kg/ha)
Maize+ginger strip cropping	6.7	0.2	0.01	0.05
Maize+legume strip cropping	17.2	0.4	0.02	0.10
Farmer’s practice (FP)	22.4	0.5	0.04	0.15

At Bandipur, the highest sediment loss was 1316.3 kg/ha from old citrus orchard and the lowest was 201.8 kg/ha from young citrus orchard in 2000 but the loss was the highest from the plot of narrow terrace maize-fallow-fallow cropping system in 2001. Grass planting in terrace riser had reduced soil loss from narrow terrace maize fellow-fallow cropping system. In 2002, same narrow terrace maize-fallow-fallow system gave more sediment loss and the riser planting with grass did not show the reduction in soil loss. The total loss of soluble nutrients in runoff was not significantly affected by interventions at all sites. However, eroded sediments contain high concentrations of organic matter and phosphorus (Acharya *et al.*, 2001).

2.4.3 Yield and economy

The total productivity of the intervention treatments was compared with farmer’s practice. Interventions did not affect crop productivity at Landruk (Table 7), although there was evidence of improved crop nutrient uptake (Tables 9 and 10) whereas maize and ginger strip cropping provided higher income compared to farmer’s practice at Nayatola (Table 8) because of the higher economic benefit from ginger production.

Table 7. Effect of interventions on crop grain yields (kg/ha) at Landruk

TREATMENT	2000	2001	2002
Closed plot	3929	3381	4778
Plot of grass planting in terrace risers	3715	3866	5248
Control (Farmer's Practice)	3160	3650	4516
P=	0.18	0.76	0.76

Table 8. Income (Rs/ha) from strip cropping at Nayatola

TREATMENT	2000	2001	2002
Maize/Ginger Strip	18110	31868	33647
Maize/ Legume Strip	9236	18820	6420
Control (Farmer's Practice)	15332	21089	9398
P=	0.02	0.04	<0.01

Table 9. NPK uptake by crops at Landruk (2002)

Treatment	N kg/ha	P kg/ha	K kg/ha
Closed plot	144	41	160
Grass plot	140	40	162
Control (Farmers' practice)	104	33	115
Mean	**129.0**	**37.8**	**146.0**
SED	**24.5**	**8.4**	**30.3**

Table 10. NPK uptake by crops at Nayatola (2002)

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)
Maize/ginger strip	48.0	14.6	58.8
Maize/ legume strip	35.2	9.9	43.2
Control (farmers' practice)	45.7	13.4	45.3
Mean	**43.0**	**12.6**	**49.2**
SED	**7.08**	**1.89**	**5.80**

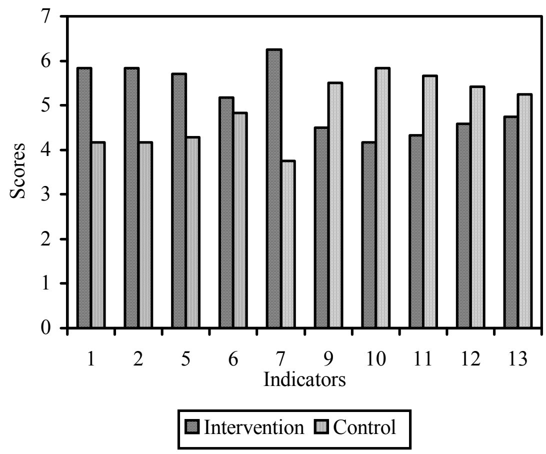
2.4.4 Self-monitoring and evaluation by research farmers

As part of the PTD process, the research farmers were given a leading role in making independent observations and assessments of the effectiveness of the new interventions using their own methods and indicators. The interaction with farmers during knowledge acquisition, and at other times, revealed that they used a number of criteria to assess soil erosion and its effect on soil and crop production. Farmers mentioned 13 indicators of which eight were associated with positive effects and a further five indicative of negative effects to monitor the effectiveness of the new interventions that they were experimenting with (Table 11). The research farmers were requested to make close observations of the effectiveness of the new interventions during the season to obtain systematic feedback. At the end of the rainy reason, each of the research farmers was requested to assess the effectiveness of their interventions by scoring both treatment and control plots for the indicators specified earlier. Maize seeds were used for scoring and farmers were given a maximum of ten seeds for each indicator, the number of these that they allocated indicating the score.

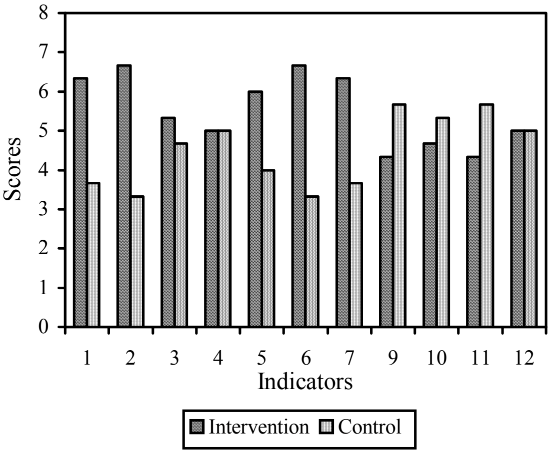
Table 11. Farmers' indicators used for measuring effects of new interventions at the three research sites.

INDICATORS OF CHANGES	LANDRUK	BANDIPUR	NAYATOLA
1. Plant vigour and health	*	*	*
2. Cop yield	*	*	*
3. Growth and vigour orange trees	-	*	-
4. Orange production per tree	-	*	-
5. Forage production on the terrace risers	*	*	-
6. Stabilization of terrace risers	*	*	-
7. Soil softness and ease of tillage	*	*	*
8. Soil moisture	-	-	*
9. Formation of rills on soil surface	*	*	*
10. Exposure of stones on soil surface	*	*	*
11. Exposure of crop roots	*	*	*
12. Surface soil erosion	*	*	*
13. Field-rat infestation	*	-	-

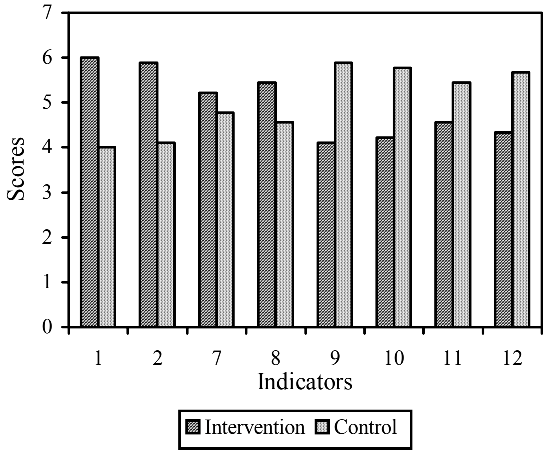
The scores given to each intervention for the different indicators were combined for each intervention for all farmers at the site. The indicators of positive effects were consistently higher for the intervention than control plots after the second year of experimentation (Figure 10), and indicators of negative effects were consistently higher for the control than the intervention plots. The research farmers therefore perceived that the new interventions were effective in reducing soil and nutrient losses, improving soil quality, increasing crop and fruit yield and increasing forage production. In addition to this, farmers' qualitative feedbacks on the performance and adoption and/or adaptation of the new interventions were also collected using an open-ended checklist. The analysis of these feedbacks further confirmed that farmers were positive about the effectiveness of the new interventions, while some of them also indicated modifications to be made in the subsequent season.



(a) Landruk research site



(b) Bandipur research site



(c) Nayatola research site

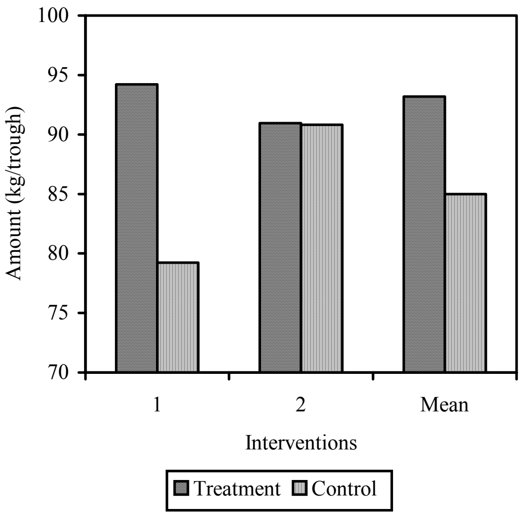
Figure 10. Farmers' scores for indicators used to measure effectiveness of interventions at the three research sites, 2002. The indicators were 1=plant vigour and health; 2=crop yield; 3=growth and vigour of orange trees; 4= Orange production per tree; 5= forage production on terrace risers; 6=stabilization of terrace risers; 7= soil softness and ease of tillage; 8= soil moisture; 9= formation of rills on soil surface; 10= exposure of stones on soil surface; 11= exposure of crop roots; 12= surface soil erosion; 13= field-rat infestation.

2.4.5 Monitoring and evaluation of research farmers trials by scientists

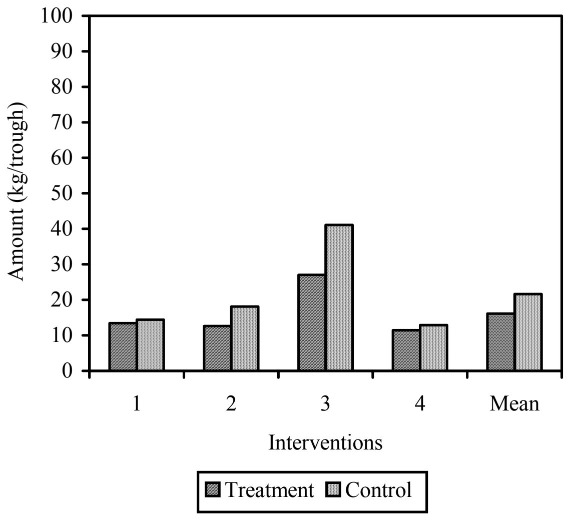
The purpose of monitoring and evaluation of farmers' experiments by scientists was to provide technical feedback to the research farmers about the performance of their experiments and make necessary technical suggestions if required. For this, regular field visits by scientists were made to monitor mortality, growth and health of the plants included in the new interventions. During these visits, scientists also held discussions with the farmers about the performance of the interventions. The assessment also enabled the farmers to quantify their assessment of the changes brought about by the new interventions. Furthermore, a comparison of the broader range of measurements conducted on the farmer managed trials permitted comparison with the more rigorous measurement made on the scientist managed trials, with a view to recommending a suitable suite of indicators which can be simply installed and provide reliable information.

At the Landruk and Bandipur research sites with bench terraces, two measurements were made - one on runoff sediments, to measure changes in soil erosion and another on forage production from the terrace risers, to measure changes in forage supply and nutrient use from the terrace. For this, simple techniques, involving easily made observations manageable under farmers' conditions were used. In the case of soil erosion, this could then be compared with the more rigorously collected data (Annex D) to determine whether more rudimentary measures could serve the same purpose. To measure the changes in runoff sediments, small metal troughs measuring 75 cm in length, 15 cm in width and 10 cm in depth were placed at the base of the terrace risers and sediments collected from the intervention and control plots were regularly monitored and recorded. At the end of the rainy season, the amount of sediment in each trough was calculated to get a quantitative indication of effectiveness of forage species planted on the terrace risers in minimising soil loss from the cultivated terrace. Similarly, to measure changes in forage production, samples of forage produced on the terrace risers of intervention and control plots were collected at regular intervals, and weighed and recorded. At Nayatola with sloping terraces, three measurements were made: soil build up against the hedge, *dhik* (terrace riser) formation and slope angle of the terrace.

The findings of the runoff sediment measurement are presented in Figure 11. The soil erosion as indicated by the amount of runoff sediment was more than three times higher at Landruk than Bandipur, which is consistent with the findings of the researcher-managed trials (Annex D). The difference is attributable to higher total rainfall, and with it the higher cumulative kinetic energy (erosivity) at Landruk. The findings, therefore, suggest that the method can be used to derive an estimate of the extent and pattern of soil erosion and so measure the effectiveness of new interventions. At Landruk, the amount of runoff sediment from intervention plots was more than the non-intervention (control) plots (Figure 11a). This is because of the method of planting of new forage species. The research farmers at Landruk scraped and cleaned local grasses from the terrace risers to increase the survival rate of the new forage species. This obviously exposed more soil to runoff erosion. This finding was contrary to farmers' scoring for soil erosion, as they were observing the terraced area, rather than inputs from the riser. Therefore, in a case like this, where results are not clear at an early stage of experimentation, caution must be exerted in comparing indicators. At Bandipur, however, the planting of new forage species on the terrace risers appeared to trap more sediment than the local practice of just maintaining natural growth of the local species (Figure 11b).



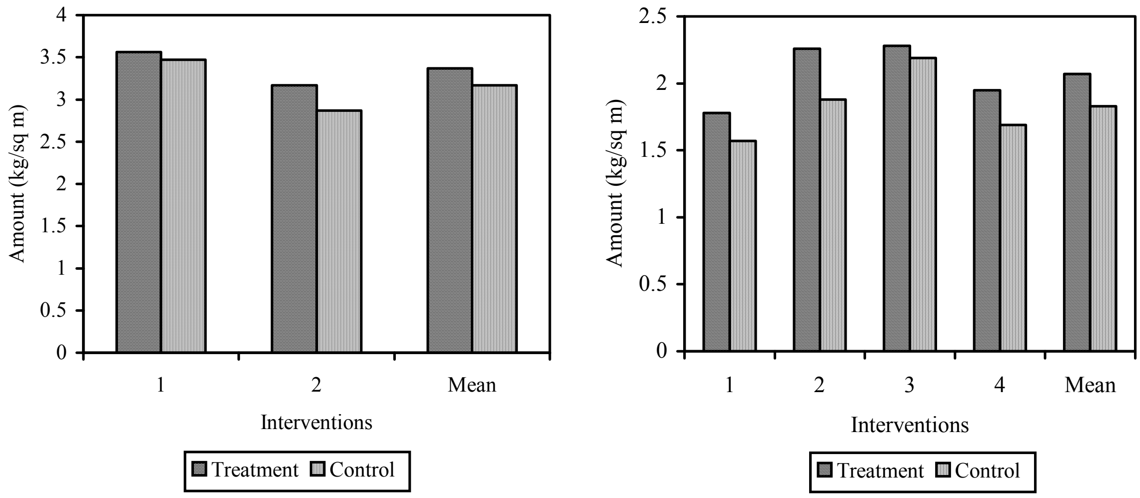
(a) Landruk research site



(b) Bandipur research site

Figure 11. Runoff sediment losses from experiment plots at Landruk and Bandipur, 2002. The interventions at Landruk are: 1=New forage species planted on the terrace risers; 2=New forage species planted on the terrace risers and fruit trees on the edge of terrace. The interventions at Bandipur are: 1=New forage species on terrace risers + tree fodders on the top of terrace risers in young orange orchard intercropped with food crops; 2= New forage species on terrace risers + tree fodders on the top of terrace risers + coffee in old orange orchard; 3= New forage species on terrace risers + tree fodders on the top of terrace risers in the crop field; 4= New forage species on terrace risers + tree fodders on the top of terrace risers + water harvesting pond in the crop field.

There appeared to be a trend of higher forage production in the intervention plots but differences were small (Figure 12). Nutrient analysis of forage biomass from intervention and control plots was also conducted. The results showed that the amount of nitrogen, phosphorus and potassium per unit area of forage biomass from the intervention plots was higher than that from the control plots (Table 12). The new forage species appeared to trap more soil nutrients and may therefore be efficient in reducing total losses form the system. When considered with the increased crop nutrient uptake also observed (Table 9), it would seem that the intervention plots were effectively increasing nutrient conservation, as a result of the greater agro-diversity.



(a) Landruk (b) Bandipur

Figure 12. Forage production from the terrace risers of experiment plots at Landruk and Bandipur, 2002. The interventions at Landruk are: 1=New forage species planted on the terrace risers; 2=New forage species planted on the terrace risers and fruit trees on the edge of terrace. The interventions at Bandipur are: 1=New forage species on terrace risers + tree fodders on the top of terrace risers in young orange orchard intercropped with food crops; 2= New forage species on terrace risers + tree fodders on the top of terrace risers + coffee in old orange orchard; 3= New forage species on terrace risers + tree fodders on the top of terrace risers in the crop field; 4= New forage species on terrace risers + tree fodders on the top of terrace risers + water harvesting pond in the crop field.

Table 12. Nutrient content of forage produced on the terrace risers of the trial plots.
(a) Landruk, 2002.

INTERVENTIONS	N CONTENT (g m^{-2} FORAGE)			P CONTENT (g m^{-2} FORAGE)			K CONTENT (g m^{-2} FORAGE)		
	Treatment	Control	Diff.	Treatment	Control	Diff.	Treatment	Control	Diff.
1	18.57	15.38	3.19	0.23	0.19	0.04	15.48	12.47	3.01
2	11.91	10.77	1.14	0.18	0.16	0.02	11.09	10.10	0.99
Mean	15.24	13.08	2.17	0.21	0.17	0.03	13.28	11.29	2.00

The interventions at Landruk are: 1=New forage species planted on the terrace risers; 2=New forage species planted on the terrace risers and fruit trees on the edge of terrace.

(b) Bandipur, 2002.

INTERVENTIONS	N CONTENT (g m^{-2} FORAGE)			P CONTENT (g m^{-2} FORAGE)			K CONTENT (g m^{-2} FORAGE)		
	Treatment	Control	Diff.	Treatment	Control	Diff.	Treatment	Control	Diff.
1	5.06	4.89	0.17	0.08	0.06	0.01	6.15	4.89	1.26
2	8.48	6.39	2.09	0.16	0.10	0.07	9.89	4.33	5.56
3	8.55	10.58	-2.03	0.12	0.15	-0.03	10.43	8.72	1.71
4	5.56	5.46	0.10	0.06	0.08	-0.01	8.89	5.19	3.70
Mean	6.91	6.83	0.08	0.11	0.10	0.01	8.84	5.78	3.06

The interventions at Bandipur are: 1=New forage species on terrace risers + tree fodders on the top of terrace risers in young orange orchard intercropped with food crops; 2= New forage species on terrace risers + tree fodders on the top of terrace risers + coffee in old orange orchard; 3= New forage species on terrace risers + tree fodders on the top of terrace risers in the crop field; 4= New forage species on terrace risers + tree fodders on the top of terrace risers + water harvesting pond in the crop field.

At Nayatola, all three types of hedgerow interventions showed some positive effects in minimising soil losses from the sloping *bari* land (Table 13). The difference between the treatments was, however, small. The hedgerow had started to become an effective barrier to soil movement causing soil build up against the hedge. As a result, the slope angle of the terrace was also decreasing. Similarly, soil build up against hedge and tillage down the hedge (tillage erosion) initiated formation of the *dhik* (terrace riser) and it gradually increased over the two years. Hedgerows of forage species alone were showing larger effects on the parameters considered than other hedgerow interventions.

Table 13. Effects of new interventions on soil build up against the hedge, formation of *dhik* (terrace riser) and change in terrace slope at Nayatola, 2002.

INTERVENTION	SOIL BUILD UP AGAINST HEDGE (cm)	*DHIK* HEIGHT (cm)	CHANGE IN TERRACE SLOPE ANGLE$^{\Psi}$ (degrees)
Hedge of forage species	11.14	49.72	-2.17
Hedge of forage species + orange trees	11.56	45.06	-0.94
Hedge of forage species + orange trees + coffee	8.84	44.33	-1.13

$^{\Psi}$Note: Changes from the base year 2001 measured in year 2003. Negative sign shows decrease in slope angle.

2.4.6 Joint monitoring and evaluation

At the end of each rainy season, a joint monitoring programme was organised separately at each research village involving research farmers, scientists, stakeholders from district and central level research and development organizations, and other farmers in the village. The main objective of the joint monitoring was to provide stakeholders and other farmers of the community an opportunity and forum to monitor and evaluate the performance of farmers' experiments; interact with research farmers, scientists and amongst each other; collect their feedback; and assess actual and potential adoption and adaptation of the new interventions.

All the participants were first briefed about the research activities implemented in the village and about the purpose of the monitoring programme. After the introduction with the research farmers and other farmers in the village, the joint monitoring team started a village walk and made observation of all the experiment plots one after another. At each experiment plot, the owner research farmer explained the details of the new intervention to the participants. The participants then questioned the research farmer and acquired feedback on the effectiveness of the new interventions obtained so far. After about four to five hours of village walk and field monitoring a round up meeting was held to discuss what had been observed and how the new interventions were performing. The participants also clarified experimental details and discussed possible modifications in the design of farmers' experiments that could be made in the next season.

2.4.7 Annual review and planning village workshop

At the end of the summer season crop, during which the effect of new interventions was more prominently observable, a village workshop was organised at each research site. Research farmers and scientists shared their experiences of experimenting with new soil and water management interventions with each other and with the farming community at large. Modifications suggested by the research farmers and/or farming community were discussed and the joint research planning for next season was done. The workshop also provided a forum to disseminate the findings of the farmers' experiments to their fellow farmers in the community and motivated others to try the new interventions on their own farms. The workshop was also used as a means to explore and monitor adoption and/or adaptation of the farmers' interventions by the research farmers as well as inside and outside the farming community at each research site.

2.5 Farmer adoption and adaptation

Soil and water management interventions generally have a long gestation period and take a long time to show significant effects. By the end of the second year of farmers' experimentation, it was too early to achieve a full-scale assessment of the adoption and/or adaptation of the new interventions. Attempts, however, were made to monitor farmers' responses and actions that were indicative of their interest in the interventions, and to measure any current or potential adoption and adaptation of the interventions.

2.5.1 Observation of farmers' responses and actions to new interventions

This simply involved observing and recording farmers' responses and actions to the new interventions experimented with at each research site. The observations made were of requests by farmers for planting and other research materials and distribution of such materials, and types of interventions adopted by farmers. Farmers at all the three research sites showed keen interest in the new interventions. Based on this interest, planting materials were supplied to each of the research sites and new farmers joined the farmers' research group in the second year of experimentation (Table 14). This showed that there had been a steady increase in the adoption and adaptation of the new intervention, largely within the research villages. However, it clear that the supply of research materials influences this process and it is more illuminating to observe the more spontaneous uptake resulting from the exchange of materials and information in farmer-to-farmer exchanges (Section 2.5.2).

Table 14. Number of new farmers adopting/adapting new interventions and trial materials distributed at the three research sites.

DESCRIPTION	LANDRUK	BANDIPUR	NAYATOLA
New farmers started adopting/ adapting new interventions in the second year (No.)	15	12	14
Trial materials distributed to farmers (No.)			
Setaria grass slips	6000	7000	6000
Napier grass slips	1000	1000	-
Moth Napier grass slips	-	1000	-
NB-21 grass slips	1000	-	-
Guinea grass slips	500	-	-
Mulberry saplings	-	-	1200
Orange saplings	-	-	688
Lemon saplings	-	-	26
Coffee saplings	-	-	121

At Landruk, community action also emerged from farmers' own initiatives, to construct diversion channels at strategic locations in the village to divert excess runoff water that would otherwise enter *bari* land or the village itself, with an objective of reducing soil erosion and landslides. This indicated that some activities were required to be implemented at landscape scales, beyond the control and management capacity of individual farmers.

2.5.2 Tracer study for tracking flow of information and materials

The flow of information about interventions between farmers is an indication of their interest in these interventions, and can be used as an indicator of the potential for adoption. On the other hand, the flow of materials indicates current adoption of the new interventions. An attempt was therefore made to trace the flow of any information and research materials from research farmers to non-research farmers and from there on to other farmers. Starting from the farmers directly involved in the research (research farmers), each farmer in the chain of information or material flow was traced and any flow of information or materials was recorded, and then mapped to derive a flow network diagram. One example of a flow network diagram from the Landruk research site is shown in Figure 13.

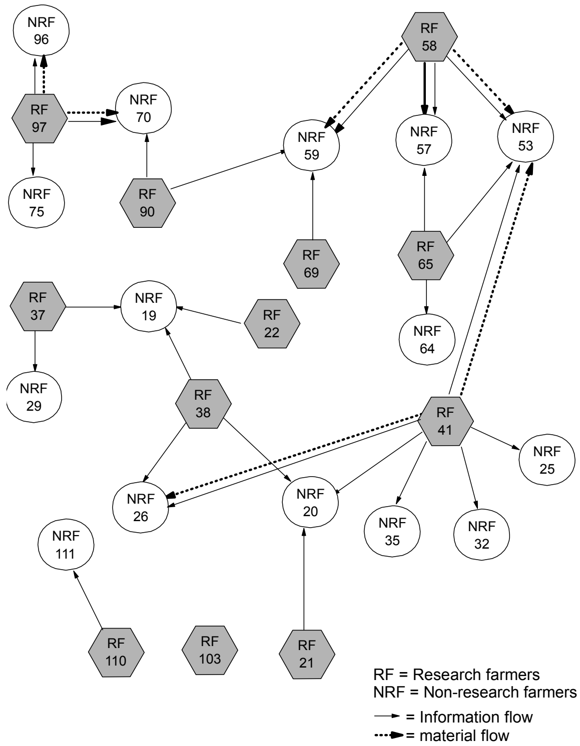


Figure 13. Flow of information and materials from farmer-managed experiments at Landruk, 2002. Nodes are individual farmers and the numbers in them are simply for identification purpose.

The flow network analysis showed that the flow of information among farmers was greater than the flow of materials (Figure 13). This was obvious since the experiment was just in its second year and adequate planting materials were yet to be produced on farm for farmer-to-farmer distribution. With the increase in planting materials within the village in subsequent years, the potential for adoption/ adaptation of the new interventions appears to be high. Another finding from the analysis was that the flow of information and materials from research farmers to non-research farmers was higher from farmer-managed experiments (shown by a large number of inter-connected nodes) compared to the scientist-managed experiments (diagram not shown as there was no flow of information and materials from research farmers). A majority (63%) of the farmers in the flow network were from the BCG (Brahmin, Chhetri, Gharti) ethnic group, followed by MGN (Gurung, Magar, Newar) (25%) and least from KDS (Kami, Damai, Sarki) ethnic groups (12%).

The study indicated that the PTD approach to technology development was more effective in promoting flow of information and materials than researcher managed trials. It was also an indication that non-research farmers in the community were more interested and had higher confidence in what their fellow research farmers were experimenting with. High visibility of farmer experimentation resulting from involvement of farming community in various stages of PTD process also appeared to contribute to the increased flow of information and materials from the research farmers. Farmers from the KDS ethnic group, representing lower castes in the social hierarchy, were weakly linked in the community communication network.

2.5.3. Dissemination of information to the farming community

At the end of the second year of the experimentation with new interventions, that is, at the end of 2002 summer crop, a household survey was conducted to monitor and evaluate the dissemination of information and interventions among the farmers in the community. A systematic sampling procedure was adopted to discern any pattern of such dissemination and to apply statistical tests to measure any significant differences. All the farmers in the community were categorised into the following three groups of farmers.

a. House neighbours of farmers involved in farmer-managed and scientist-managed interventions
b. Field (with experiment) neighbours of farmers involved in farmer-managed and scientist-managed interventions
c. Other farmers of the community selected through random sampling

Two sets of questionnaires were developed - one to get feedback about farmer-managed interventions and another to get feedback about scientist-managed interventions (implemented concurrently to complement each other). The heads of the sample households were individually interviewed using a structured questionnaire and data analysis was done using SPSS computer software. Chi-square statistics were used to test for significant differences in farmers' responses. The data obtained from interviews with farmers sampled with respect to scientist-managed interventions were used as a baseline to evaluate the effectiveness of the farmer-managed PTD approach of technology development. At Bandipur, there were no scientist-managed experiments and therefore no such comparison was possible.

In all three sites, a large proportion of farmers (> 70 %) were aware of the farmer-managed and scientist-managed experiments on soil and water management in the villages (Annex E). At Landruk, farmers' awareness about scientist-managed experiments was even higher. This was mainly because of the visibility of the erosion plots and drums of the scientist-managed experiment plots, and this was evident when farmers were asked about the details of these experiments. However, a higher proportion (57 %) of farmers reported to know the details of the farmer-managed experiments than the scientist-managed experiments (34 %). This showed that the PTD approach to technology development enhanced the flow of information.

The adoption of new interventions by non-research farmers was also high for farmer-managed interventions reported by about 25 % of farmers as against about 7 % for scientist-managed interventions. It indicated that farmer-managed interventions were more readily adopted and adapted by farmers. The difference in adoption was found significant for ethnicity at Landruk, where a significantly higher proportion of farmers from Brahmin, Chhetri and Gharti ethnicity were reported to adopt or adapt new interventions than farmers from other ethnic groups. None of the farmers from Kami, Damai and Sarki, representing low caste and resource-poor ethnic groups, reported adoption or adaptation of any new interventions (Table 15a). For higher ethnic castes and resource rich farmers, a higher awareness about farmer experiments appears to lead to higher adoption of the new interventions but this is less so for lower ethnic castes and resource poor farmers. This is unsurprising as occupational castes have been observed to have lower adoption rates than other castes who are more fully engaged in farming (Floyd *et al.,* 2003). Affirmative action to increase their inclusion in the process and access to resources will help increase their participation and adoption of new soil and water interventions during scaling-up. Younger people tend to be less keen to adopt and this again may require affirmative action, or enquiry in scaling-up stages to understand their constraints. Conversely, older farmers were not directly involved in the early stages of the research, but were the strongest adopters which suggests that their observations and experience result in them taking up technologies when they have sufficient confidence in their efficacy or suitability. The poorer farmers were well-represented in the research process, and both male and female farmers were equally involved.

The effect of farmer types, in terms of their proximity to research farmers and experimental plots, and of farmers' socio-economic factors on the awareness about farmers' experiments, adoption and adaptation of new interventions, and the potential adoption these interventions in the future is presented in Table 15b. A high proportion of field neighbours (89 per cent) and house neighbours (74 per cent) were aware of farmers' experiments at Landruk and Bandipur. At Nayatola, however, other farmers were more aware of the farmers' experiments. Similarly, the awareness of farmers' experiments was significantly higher among male farmers at Bandipur, poor and medium resource farmers at Nayatola, and BCG ethnic farmers and early mid-aged (31-45 years) farmers at Landruk. The awareness among KDS ethnic farmers was consistently low across the research village indicating that these farmers were not well linked in the communication network. More than 30 % of the farmers were willing to adopt or adapt new interventions in the future, giving some idea of the potential for adoption. However, further monitoring of dissemination is required to determine is this level of uptake is actually realized.

Table 15. a) Percentage of farmers; within the community[1], participating in the research[2], aware of the research[3], and adopting the interventions[4] within different categories across the three sites; b) percentage of farmers; aware of farmer experiments[1], adopting the interventions[2], and potential adopters[3] (willing to adopt in the future) within different categories across the three sites. Chi square test: * significant at p=≤0.05; and ** significant at p=≤0.01.

a)

Farmer categories		Landruk				Bandipur				Nayatola				Total			
		Wc[1]	RF[2]	Ae[3]	Ad[4]	Wc[1]	RF[2]	Ae[3]	Ad[4]	Wc[1]	RF[2]	Ae[3]	Ad[4]	Wc[1]	RF[2]	Ae[3]	Ad[4]
Gender	Male	52	58	45	28	38	57	72*	23	47	71	63	30	57	62	59	26
	Female	48	42	59	32	62	43	46	19	53	29	65	25	43	38	54	24
Wealth	Rich	18	17	50	30	32	43	65	31	14	29	14	29	24	30	54	30
	Medium	44	27	43	39	48	50	50	12	44	44	74*	32	40	40	53	27
	Poor	38	58	58	17	20	7	62	19	42	28	72	24	36	30	64	20
Ethnicity	BCG	32	75	74*	63**	34	21	73	27	17	14	56	44	21	35	69*	49**
	MGN	54	25	42	17	36	71	70	30	72	72	69	26	56	58	59	24
	KDS	14	0	29	0	30	30	44	9	11	14	33	0	23	7	41	7
Age groups (years)	<30	12	42	50	0	12	0	63	6	11	36	0	0	11	25	60	5
	31-45	48	42	75*	30	28	36	48	22	20	50	80	40	34	43	65	29
	46-60	28	16	50	28	46	43	74	30	47	14	52	14	34	25	60	24
	>60	12	0	25	35	14	21	43	14	22	0	64	36	21	7	40	32

b)

Farmer categories		Landruk			Bandipur			Nayatola		
		Ae[1]	Ad[2]	Pa[3]	Ae[1]	Ad[2]	Pa[3]	Ae[1]	Ad[2]	Pa[3]
Farmer types♣	HN	61	50	25	74	26	36	58	25	18
	FN	60	20	50	89*	33	33	56	25	46
	OF	41	20	39	47	16	39	74	32	38
Gender	Male	45	28	37	72*	23	46	63	30	44
	Female	59	32	38	46	19	24	65	25	24
Wealth	Rich	50	30	33	65	31	30	14	29	33
	Medium	43	39	36	50	12	39	74*	32	18
	Poor	58	17	40	62	19	33	72	24	53
Ethnicity℘	BCG	74*	63**	60	73	27	22	56	44	29
	MGN	42	17	29	70	30	32	69	26	37
	KDS	29	0	43	44	9	40	33	0	33
Age groups (years)	<30	50	0	50	63	6	40	0	0	0
	31-45	75*	30	67	48	22	29	80	40	50
	46-60	50	28	41	74	30	37	52	14	33
	>60	25	35	87	43	14	33	64	36	22

♣ Farmer types: HN = house neighbours; FN = field neighbours; OF = other farmers.
℘ Ethnicity: BCG = Brahmin/Chhetri/Gharti; MGN = Magar/Gurung/Newar; KDS = Kami/Damai/Sarki.

2.5.4 Conditions which foster adoption and adaptation

Our experience suggests that there are several conditions which may foster adoption and adaptation:

1. *Economic benefits*: Economic benefits appeared to be a primary motivation for adoption of new soil and water management interventions. Farmers were interested in interventions that rapidly started generating economic benefits, in terms of increased cash and/or production. At all three research villages, farmers were interested in grasses and forage species not only because there were effective against soil and nutrient losses, but largely because they increased access to and provided quality fodder to their animals. Similarly, inclusion of fruit trees and the incorporation of ginger under mulch in some of the interventions and opting for water harvesting ponds were clear indications of farmers' economic criteria for the adoption of the interventions.

2. *Visibility of farmers' experiments*: Demonstrating the effectiveness of farmers' experiments also motivated other farmers to adopt and adapt the new interventions. This was achieved within the village when the better performance, for example, of new grasses and forage species over the existing ones attracted other farmers in the village. Similarly, the possibility of growing fodder trees and shrubs and fruits as contour hedges without reducing crop production provided a good demonstration of the potential benefits and helped convince even the more sceptical farmers. However, the initial experience gained during field days, exposure visits and knowledge-sharing workshops was extremely important in facilitating group/social learning.

3. *Start-up external support*: External technical and material supports, at least, at the initial stage of the programme, encourages adoption, especially when farmers experimentations involve use of new research materials. Additional planting materials supplied to research villages increased access to such materials and this, in turn, motivated non-research farmers to adapt the new interventions in their own ways increasing overall adoption in each research village. However, production of research materials within the community should be facilitated as quickly as possible to encourage self-reliance (see next point).

4. *Creating village resources*: Supplying research materials from outside is not only costly but is difficult to produce as a timely supply due to poor transportation networks in the rugged terrains of the middle hills of Nepal. Therefore, village nurseries were established with the co-operation of the farming community, and this increased farmers' access to planting materials within their own village. This also encouraged increased adoption of the new soil and water management interventions.

5. *Flexibility*: Giving flexibility to research farmers to modify their experiments (interventions) to suit their needs and farming conditions during the course of their experimentations increased self-confidence and motivated farmers to continue adapting the new interventions. It also motivated non-research farmers to experiment in their own ways to suit their needs and resources.

6. *Involvement of the whole farming community in the PTD processes*: Involvement of the farming community in the various stages of PTD process, e.g. in selection of research farmers, in joint monitoring and evaluation and in annual review and planning village workshops helped establish a good communication linkage between research and non-research farmers. As representatives of their community, research farmers were found to be more willing to share findings of their experiments with their fellow farmers. Similarly, non-research farmers were also interested and curious about experiments of their fellow research farmers and made close observation of the outcomes. This increased interest and communication helped in farmer-to-farmer simultaneous dissemination of information and research materials increasing the adoption and adaptation of the new interventions. There is some evidence, albeit based on a small sample size, that lower caste members are under-represented in the PTD process and affirmative action in future scaling-up activities may be necessary to ensure their involvement.

7. *Involvement of institutional stakeholders*: The involvement of institutional stakeholders, especially district level agricultural development and soil conservation agencies, from the initial stages of the PTD process helped to establish linkages between farmers and these agencies. Direct interaction between development agencies and farmers during the joint monitoring in each research village, helped farmers to secure additional assistance from these agencies leading to increased adoption of the new interventions. At Nayatola, the District Agricultural Development Office assisted farmers to get additional supplies of orange saplings.

Similarly, these institutions also requested farmers to contact them if they needed any further technical support. Establishment of such linkages are important in sustaining the PTD process after the termination of a project.

2.6 Scaling up with GO and NGO extension providers

To facilitate scaling up of new interventions from research villages to wider farming communities, the extension and development agencies working on soil and water conservation in the region were involved in all stages of the PTD process. The participation of these agencies in the joint monitoring and evaluation of research activities at the three research sites was very useful in terms of scaling up of the new interventions. It provided them with an opportunity to obtain information on the new interventions and to make a judgement on whether those interventions could be scaled up to other similar areas. A very good working relationship has now been established between the local project institutions - LI-BIRD and ARS Lumle and the District Agricultural Development Offices (DADO), District Soil Conservation Offices (DSCO) and NGOs working in the region, which is the first important step in the wider scaling up of the new interventions.

In one of the last meetings held with institutional stakeholders, DADO and DSCO in the hill districts of the western development region showed a keen interest in the new interventions and the PTD process and were already planning some activities in their regular annual programmes. However, they strongly pointed out the need for a close collaboration and technical support from the local project team in scaling up of the new interventions and institutionalising the PTD process in those institutions. To start with, the following suggestions were made.

- Use the existing research sites as resource villages for the supply of planting materials and as demonstration sites for farmers of other villages.
- Organise farmers' visits to the three research sites.
- Provide training and orientation to the staff of the extension and development agencies in the region.
- Establish multi-location demonstration sites at a number of strategic locations in the region.
- Dissemination of information about new interventions and the PTD process
- Create conducive environments for wider uptake of new interventions such as, value addition, opening up of markets, introducing other associated enterprises - for example livestock production or silk rearing.

Following these suggestions, a farmer exchange visit was organised to the Nayatola research site for farmers from Syangja, Palpa, Gulmi and Arghakhanchi Districts (Nayatola is a representative site for these districts), and a training cum orientation was given to the field extension workers of DADO and DSCO of these districts. This represented a good start but further commitments from the project team will be required in terms of technical and material support to widen the prospects for scaling up, especially for soil and water management interventions that require long timeframes to achieve the desired results.

Another important consideration to be made is that the scaling up of the products of the research, that is, the new interventions, should be done along with the research process used in generating those products. Often, the products, being tangible and visible, are taken for dissemination leaving behind the process that was used to generate them. This has been one of the main reasons for low adoption of new interventions. The scaling up of new soil and water management interventions should, therefore, be process-led applying the PTD process that includes at least a short cycle of knowledge analysis and sharing, farmers' experimentation and participatory monitoring and evaluation. While this process requires staff resources to implement, it is essential for interventions to remain relevant to farmer circumstances and generally affordable in Nepal where constraints for extension staff lie primarily in lack of operating costs rather than lack of staff time. Demands for additional operating costs can be minimised by re-orienting and rationalising existing development programmes to start from a small number of strategic locations, and gradually expanding from these locations to neighbouring areas by establishing a network for the flow of locally generated materials and information. The farmers involved in the programme can be used as resource persons to support other farmers in the neighbouring areas.

3. Strategies for the development of farmer-oriented natural resource management (NRM) options

This project confirms the findings of the earlier research in that the steep slopes, high rainfall intensities (with associated high kinetic energies), ploughing and intercultural operation of maize crops can cause significant losses of nutrients from the sloping *bari* lands of the hills. Nutrient losses associated with erosion (dissolved in run-off and in eroded sediments) tend to be low in comparison with losses of N and K lost through leaching, although organic matter and available phosphorus losses in eroded sediments may be significant in the long-term. The technologies tested which are accessible to farmers' show promise in their effectiveness to reduce nutrient losses. Although in early stages of establishment, and given that activities during establishment may cause disruption, there is good indication that the technologies can minimise erosion losses on sloping *bari* lands, such as strips of ginger and maize which can also increase income, and in high rainfall areas, diversion of run-on as well as terrace planting with fodder grasses of fast growing species may better conserve soil and nutrients in high rainfall and bench terracing areas. Therefore, the technical effort should be focussed on trapping nutrients which are lost in solution through leaching and the use of barriers to reduce soil movement and nutrient losses in eroded sediments. However, the experiences of this project highlight several key issues that need to be addressed in the development and dissemination of such technologies to smallholder farmers in complex farming systems. The project has provided a vehicle not just to conduct research into new, nutrient-conserving technologies, but also to develop and transfer new generation and diffusion models. Some of the main considerations in this process are:

3.1 Linking knowledge to practice

The findings of the study support the increasingly established view that farmers' local knowledge is dynamic (Thrupp, 1989; Agrawal, 1995; Garforth *et al.*, 1999; Joshi *et al.*, 2003). New knowledge was continuously being generated as farmers faced changes in their production environments and/or when new information and technologies were passed on to them and to their communities. Much of farmers' knowledge about soil and water management is complex due to its conditional nature. Understanding the conditions attached to farmers' knowledge was critical in evaluating such knowledge as failing to do so was likely to either misinterpret knowledge or treat it as a case of inconsistent or contradictory knowledge. This was evident in the case of farmers' knowledge about fertility and productivity of *rato mato* and *kalo mato* soils that depended on the amount of rainfall. Similarly, inconsistency in the water retention capacity of different types of soils was also possible to resolve when conditions attached to farmers' statements were considered. The existence of reasonably sophisticated local explanations about soil processes also has profound implications for what research should be considered relevant to farmers. Where farmers have a detailed understanding of tree–crop interactions fundamental research undertaken on mechanisms of interaction will clearly be perceived as relevant by farmers and thus will be easier to communicate to them. If researchers do not appreciate the complexity of farmers' understanding, it can lead to the erroneous assumption that adaptive research is more relevant to farmers than more fundamental research. Farmers are probably better able than researchers to conduct adaptive research. However, it is difficult for them to tackle more fundamental research issues, because of limits imposed both by the observational techniques available to them and the extent to which they can vary the environment - not least because they have to obtain a living from that environment whilst, at the same time, conducting their research. This realization affects both what type of research is considered useful in support of farmer innovation and the form in which research results are communicated to farmers. Adaptive research tends to lead to prescriptive technology packages, whereas farmers may actually want flexible new knowledge and components that they can adapt to their needs. This requires a shift away from 'extension of prescriptions' towards 'extension of principles'. Enhancing the local knowledge system, through new research identified via analyses of the local knowledge initially held, may build capacity more generally. A richer knowledge system may reduce vulnerability, by ensuring that local communities are better able to cope with any new stresses and problems - including ones which have not been previously anticipated (Joshi *et al.,* 2003; Annex G).

Research and development endeavours in NRM should be process-oriented allowing changes to be made as they progress, to enable adaptation of management options to local environments and situations. Resource poor farmers have complex and diverse farming systems, and local adaptation is required to make technologies work. The emphasis in development must be on the product *and* the process in generation and diffusion of technologies that work. Often, the products, being tangible and visible, are taken for dissemination leaving behind the process that was used to generate them. This has been one of the main reasons for low adoption of new interventions. Unlike crop varieties or new seeds, which are either adopted or rejected, soil and water management interventions are management-oriented technologies and, in almost all cases, require adaptation to the new environments. In, for example, the testing of new seed varieties, the farmers do not provide the innovation which has resulted in the improved variety, rather they select the innovation that has been generated by the process (crossing) and experiment with genotype and environment interactions. In the case of soil and water management interventions, PTD is more difficult because the need for invention makes the process les predictable and requires people who are inventive as well as good at selection and promulgation (Douthwaite *et al.,* 2001).

3.2 Combining farmers' and scientists' knowledge

Despite growing interest in, and recognition of, local knowledge in research and development initiatives, it is important not to romanticize it (Joshi *et al.,* 2003; Annex G). This is particularly true with respect to soil processes, since the nature of the soil medium results in limitations in terms of what farmers can observe and hence understand from their own experience. This makes scientific knowledge and the research that generates it, a potentially powerful tool for use in assisting farmers to manage soils more sustainably. It is clear that there is much that farmers still need to know to improve their livelihoods and that there are significant contributions that science can make. The clear example from this research is that, although they know a lot about surface processes (runoff), the hill farmers have little or no understanding of leaching. Sharing of knowledge about leaching losses with farmers has motivated them to experiment with hedgerow-planting deep-rooted crops, and perennial grasses on risers to trap and recycle the leached nutrients, techniques which it had previously been very difficult to convince them to adopt.

3.3 Fulfilling multiple objectives

This experience of PTD in soil and water management strongly suggests that farmers are interested in NRM practices and interventions that rapidly generate generating economic benefit. Therefore, ecosystem services should be tied with productivity enhancement. Farmers' priorities, or highly productive areas with income maximisation potential should be used as entry points for promoting NRM interventions. In the current case, farmers were interested in grasses and forage species not only because these were effective against soil and nutrient losses, but largely because they increased access to and provided quality fodder to their animals. Interventions for natural resource management should be system compatible and harness niche opportunities. In the current work on soil and water management, the hedgerow on the outer boundary of the bench terrace was not preferred by some farmers as it was replacing soybean and beans. Similarly, farmers at the Nayatola research site preferred to integrate orange and coffee along the hedgerow as the site had a good niche for production as well as marketing for these crops. Interventions should be envisaged which result in incremental changes in existing practices. The ginger/maize strip cropping intervention tested at Nayatola proved to be adoptable. Farmers already grow ginger under mulch, and it was a small shift in practice to move this to strips within fields, as opposed to in patches at field edges. Consideration of the scales of operation is equally important. Management of natural resources initiated at farm or farmer level often requires consideration at watershed and/or community level. In the current work on soil and water management, farmers were found to be aware of the potential benefit of diverting runoff from the cultivated land but most of them were not practising it. This required constructing a network of diversion channels at watershed level and community action to initiate and complete the construction. The success of agroecological improvement is not just about appropriate technologies, but about developments which are underpinned by social learning and building of social capital at the local level (Pretty, 1995; Altieri, 2002).

3.4 Comparing farmers' and scientists indicators

The methodology used to monitor nutrient movement in the researcher managed plots is clearly beyond the scope of farmer experimentation. Indeed, there is debate as to the value of using plot-based measurements at all in erosion research, as they isolate the plot from the upper hillside, and can interfere with lateral drainage patterns. However, they provide a realistic means of evaluating relative treatment effects in multivariate studies (Young, 1997; van Noordwijk *et al.*, 1998), as was the case in this project. Given the desirability of evaluating what is clearly a trade-off between relative movement of soil water over the soil surface and percolating through the soil profile, they have provided valuable information, the knowledge of which empowered farmers in their own innovations. There was good comparability between some of the quantitative and qualitative indicators, for example, use of erosion troughs and pins in comparison with runoff plots. Careful siting of such indicators in the landscape will provide an inexpensive means of ongoing monitoring the effectiveness of the interventions over the longer term. Sources of error are considerable, but relative measures of soil changes, which take account of spatial patterns of relative loss and accumulation, and if monitored in a participatory manner with farmers actively involved in the design and implementation of the research, can provide reasonable confidence in the evaluation of the interventions. By explicitly developing indicators with farmers, the PTD process provide a more detailed set of measures to analyse the success of soil conservation measures, and improve the chances of farmers and scientists communicating well. There are several lessons to be drawn from this project. Farmers' evaluation criteria are context-specific and may evolve during the course of a trial; they may also vary according to the season. The indicators adopted by farmers are visible and readily observable, and farmers judge success according to their own direct experience, which often relates specifically to their own fields. The trials were not evaluated solely on the basis of their control of erosion or leaching (even if it could be observed). Farmers are interested in looking at the effect of the technologies on their whole livelihood system, including labour availability, food security and resource flows for priority enterprises such as fodder. As Bunch (1999) has pointed out, rapid returns and economic benefits are more important to poor farmers with a short resource management horizon, than soil erosion *per se*. This is linked to the serious point: that even where soil erosion appears to the outside observer to be severe, it may not be perceived as the principal problem by farmers themselves. Conversely, many of the farmers perceived soil erosion to be a major constraint to productivity, but this was belied by the scientific data generated in the project, which determined that surface erosion was not a significant cause of fertility decline.

The indicators that were developed with the farmers were based on an explicit process facilitated by researchers (McDonald *et al.,* 2003; Annex F). Farmers do not tend to consciously develop indicators, and it is sometimes the case that participatory monitoring and evaluation can place unwarranted demands on farmers, if the results are only of use to the researchers. Nevertheless, by participating in experiments which have a short term incentive, such as fodder production, but which at the same time may reduce soil erosion, farmers may change their perceptions. It is therefore important to pay close attention to the process that is used to develop indicators. Farmers are often unfamiliar with the concept of formal evaluation using indicators, but they are constantly observing change in the environment around them, and will be able to discuss good and bad changes easily. Farmers responding to the researcher-managed trials noted their perceptions of good and bad aspects of the trials. These included observations about labour requirements, soil deposition and changes in crop yield, and provided a starting point for developing indicators. Once the indicators had been used in explicit evaluation and comparison of the interventions, their utility became much more apparent to the participating farmers.

3.5 Inclusion in the research process

Respecting local knowledge by taking the trouble to learn about it, can be an important part of developing a productive participatory relationship with a local community, and may help to empower local articulation of research and extension needs, as well as providing the ‘tools’ for understanding what has been articulated (Joshi *et al.,* 2003). Learning and using local terminology when communicating with farmers will enable communication. Farmer-oriented NRM should consider farmers' local knowledge and practices and incorporate them explicitly into a participatory technology development process that gives farmers a leading role in all stages of decision-making. This, in turn, ensures a process of learning and empowerment. Building on farmers' knowledge and practices, sharing technical knowledge and supporting farmers in their experimentation empowers farmers and the farming community and strengthens their social capital. This is particularly important in achieving sustainable NRM. Consideration of equity issues in NRM is important but should not be imposed from outside. It should be internalised through the involvement of the community. The results were not clear-cut across the sites, but it would appear that lower caste farmers are less involved, but not less aware of the research process. This would suggest that their inclusion is best facilitated at the community level. They may not generally participate in the beginning of a new initiative to minimise their risk, but will join later if they see rapid benefits. However, Floyd *et al.,* (2003) observed in the study area that actually trying a technology was the most constraining step in the adoption process. They also found that awareness of the technologies was affected by extension input levels, i.e. extension was important due to its positive effect on 'awareness' and 'trying'. The early indications from our study are that the involvement of the whole community in the research, which permits 'observation' without 'trying' in initial investigations, may still result in adoption (as was the case with the older farmers at Landruk and Nayatola). Thus, participation in the actual research instills more confidence in non-research farmers in the community in what their fellow research farmers were experimenting with, than the more traditional approach of research followed by extension possibly resulting in adoption. High visibility of farmer experimentation resulting from involvement of the farming community also appeared to contribute to an increased flow of information and materials from the research farmers. It is also probable that the incorporation of farmers' knowledge and perspectives in eth design of the technologies has ensured that the technologies are appropriate and eth 'adoption gap' (Floyd *et al.*, 2003) has been minimized because the adoption of technologies is not hindered by internal constraints. These observations are tenuous given our small sample size and very early stage of adoption, but continued tracing of flows of information and/or research materials from research farmers to non-research farmers and from thereon to other farmers within and outside the research villages will be highly instructive. This view was also expressed during the mid-term review of the project and a recommendation for monitoring post-project impact was made.

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