Land Preparation: An Integral Part of Farming Systems in the Mid-Hills of Nepal

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Abstract

Land preparation is an integral and, as yet, indispensable component of the farming practices followed by inhabitants of the mid-hills of Nepal. Most farmers continue to follow age-old traditional soil tillage practices using locally fabricated ploughs and hand implements. Farming in the mid-hills involves a huge labour investment due in part to the nature of the land and to the largely manual methods used by the farmers. Recent years have seen substantial increases in land-use intensification in the agricultural sector throughout the mid-hill areas of Nepal. Such intensification is mainly in the form of increased off-season vegetable and horticultural production. The development and adoption of new technologies for increased labour efficiency, reduced costs, and minimised soil tillage and exposure to erosion are required to ensure the sustainability of farming in the middle hills of Nepal. An integrated approach involving soil and water conservation practices, as well as, diversified, carefully managed cropping, soil fertility, organic matter, and weed/pest control systems are needed. This paper provides a preliminary review of existing traditional practices and innovative techniques for land preparation in the mid-hills of Nepal.

Key words: Soil tillage, Sustainable agriculture, Erosion, Land use intensification, Indigenous practices

Introduction

Resource poor hill farmers of the mid-hills of Nepal rely mainly on manual and animal draught techniques for agricultural land preparation. Soil tillage or land preparation of some form is an essential part of low-input hill farming serving to facilitate a variety of functions including water and weed management, pest control, seed-soil contact and seedling germination and establishment. While reduced and minimum tillage alternatives are desirable from an environmental and soil conservation point of view, particularly on sloping lands, their practicability and adoption under the socio-cultural and economic conditions of the mid-hills, however, remains to be seen. This paper provides a preliminary review of existing traditional practices and innovative techniques for land preparation in the mid-hills of Nepal.

Most hill farmers still follow age-old traditional soil tillage practices using locally fabricated ploughs and hand implements. Only subtle variations in these practices can be found in different parts of the country. The vast majority of hill farmers have not adopted many new practices due to a variety of reasons, the most important of which include geographical, economic, financial, risk-avoidance, and socio-cultural factors. Most subsistence-level farmers who struggle to merely grow enough for survival naturally seek to avoid any changes that involve the risk of yield reduction or crop failure. The practices used are often intended to maximise yields over the short-run and minimise the risk of crop failure.

The rugged terrain and steep slopes that exist throughout the Nepal mid-hills severely limit the options available to farmers, and restrict the development of modern, mechanised technologies for farming operations. Successful crop production under these conditions involves labour-intensive and meticulous management of the agricultural land. Increasing population pressures and the recent trend of temporary or seasonal migration of segments of the rural population (i.e., young males) to urban areas for employment, education or due to land fragmentation, tend to create a labour shortage for hill agriculture. This is evidenced by neglected
or abandoned agricultural fields, poorly maintained terraces and irrigation channels, increasing erosion, frequent small landslides, and declining soil fertility (Banskota & Jodha 1992, Shrestha & Katwal 1992).

Over the past decade or so substantial increases in land-use has primarily taken the form of increased off-season vegetable and horticultural production due to the finite nature of productive agricultural land. With expanded road access and irrigation facilities, some pockets of the mid-hills, especially close to urban markets, have seen dramatic increases in production of vegetables, fruits and other cash crops. This is achieved mainly by multiple cropping, both relayed and intercropped, of vegetables along with staple food crops, and in some cases, instead of less profitable food crops like wheat and millet. Such commercial cropping intensification usually involves increased frequency of soil tillage and may not be sustainable due to soil fertility and organic matter status decline (Jodha 1992, Vaidya et al. 1995). For the most part, hill farmers are unable to adequately replenish soil nutrients or organic manure/compost to meet the increased crop demands, thus leading to soil degradation (Shrestha & Katwal, Vaidya et al. 1995). Land-use intensification, therefore, necessitates a careful and integrated approach to soil organic matter and nutrient management (Jodha 1992, Nicholas-Wallis 1997), through such practices as improved composting, mulching, green-manuring, crop rotation management and supplemental fertilisation to overcome deficits.

The information presented in this paper is based on review of the limited available literature related to the topic and informal field survey (RRA) of farmers and local residents in numerous parts of 12 districts in the above three regions of Nepal. In addition, a number of key informants and researchers in several government and non-government organisations were contacted for information regarding new and innovative developments in land preparation techniques. The information has been analysed and categorised into practices that are indigenous/traditional, modern tillage practices and other related practices that are not considered tillage practices in themselves.

Traditional Tillage Practices Used by Mid-Hill Farmers

Cultivation Using Ox-drawn Wooden Plough
The most widely used means of soil cultivation practiced by the vast majority of mid-hill farmers involves the use of an ox-drawn wooden plough. Due to the largely marginal, fragile, inaccessible and diverse nature of the Himalayas, draught animal power and manual farming are the most appropriate and economical options available to farmers in this mountain region (Singh 1998). The wood plough is a locally fabricated farm implement often fitted with a strip of metal (20-30 cm long flat iron piece), for reinforcement, along the inner edge to the tip of the pointed plough. The plough is drawn by two oxen and guided from the rear by the farmer who controls the depth and direction using an extended handle connected to the top of the plough. This method is commonly used across the country to cultivate both lowland (khet) and upland (bari) areas. It can be used under both the semi-dry conditions of upland terraces and the flooded, puddled conditions of lowland terraces. For most mid-hills farmers, this method is the most affordable, efficient and practical means of cultivating their fields. The ox-drawn wooden plough is used on uplands with slopes as steep as 50 to 60%, and on terraces that are as narrow as 1.5 to 2 m width (the minimum width required to turn the oxen around; B. Shrestha, B.P. Tripathi, B. Luitel, personal communications). Tillage is done to between 10 and 15 cm depth with this implement.

Manual Cultivation with Hand Hoe
On terraces that are narrower than about 1.5 m, or for those farmers who posses only small parcels of land (less than 0.1 ha) and do not own oxen, cultivation is mostly done by hand-hoe. These come in a number of different blade widths/sizes and handle lengths for use by men and women alike, and for various functions. This manual tillage technique is typically done to depths of less than 10 cm and generally does not involve complete over-turning of the soil. The hand hoe is also used for secondary tillage purposes, clod-breaking and smoothing after ox-ploughing, and post-emergence weeding.

In areas that are predominantly inhabited by Newar communities, the primary method of
cultivation is by means of the Newar hand-plough, which involves over-turning of the soil in lowland and upland paddy fields. This technique is used extensively within the Kathmandu valley, due to religious belief, which does not permit use of oxen (Pandey 1993), and parts of Kabhreplanchok, Lalitpur and Makwanpur districts. It is also used occasionally by non-Newars for purposes such as, terrace side trimming, bund repair, drainage/irrigation ditch work, and for kitchen gardening.

Secondary Tillage Operations

Differences in local traditional tillage practices across the country are found mainly associated with such factors as the number of cultivations, type of implement used for post-tillage clod-breaking, levelling and smoothing of the soil surface, type and use of hand tools, and timing of these operations. The number of cultivations, timing of operations and type of hand tools used depend in large measure upon factors such as, soil type and texture, nature of land, terrace width, irrigation availability, rainfall, cropping pattern and other socio-cultural/religious influences (Turton et al. 1995; Amatya et al. 1997). Clod-breaking, levelling and smoothing operations are done using ox-drawn local wood-harrow and wooden plank in some parts of the country, particularly the lower elevation areas of the Eastern, Central and Western Regions. These are well suited for broad terraces and lowlands with ready access and manoeuvrability of oxen. In other areas, such operations are done mainly by hand hoe or wooden clod-breaker, often by women (Adhikari & Karmacharya 1988, Turton et al. 1995).

Another secondary cultivation practice done mainly on uplands under maize or millet, involves ridging or “earthing-up” (“dohryaune”) of the soil in-between crop rows. This is done by means of the ox-drawn wooden plough or tine-harrow where conditions permit, i.e., when the crop is planted in rows and on fairly broad and flat areas. This tends to serve a dual purpose of weeding and providing support to easily lodged crops like maize (Zea mays). Where it is not possible or practical to perform such ridging by plough or harrow, it is done manually using hand hoes.

Shifting Cultivation (“Khoria” and “Bukma” Systems)

Shifting cultivation, also termed slash-and-burn agriculture, is an old practice that is still continued in small pockets of the mid-hills of Nepal, such as in Gorkha, Chitwan, Dhading, Makwanpur, Tanahun, Nawalparasi districts and in the Makalu-Barun area. In the central region of Nepal, the area under shifting or fallow cultivation (“Khoria”) has diminished due to the decline in productivity of the lands. Only very poor landless peasants who, none-the-less, fail to make a successful living from shifting cultivation alone now generally practice it. The practice involves initial clearing of the shrub and tree vegetation on a hillside patch of land and burning of the remaining stubble and residues. The soil is then tilled by hand hoe, incorporating the ash and removing large stones. The land is then planted to maize or finger millet (Eleusine coracana) with some intercropping of beans (soybean, Glycine max; horse gram, Dolichos biflorus; or rice bean) or Niger (Guizotia abyssinica) and sesame (Sesamum orientale). Such a patch of land is cultivated and cropped for a maximum of two or three successive crops (1 to 2 years) and then returned to fallow growth for between three and six years. The ever-decreasing length of fallow period and steep slopes on which the shifting agriculture is practiced renders it an unsustainable and land-degrading practice.

A similar, closely related practice used in the high hills (above 1800 m) is the “Bukma” system or “buk” fertilization method of growing potatoes. This practice is generally found in the north-central and northeastern parts of Nepal (Dhakal 1993). It involves scrapping or slicing layers of sod (soil and grassy vegetation) on natural slopes and piling them in groups of four to eight piles. After drying the piles consisting mostly of dried grass roots and surface vegetation, they are burnt to minimize soil borne diseases. Potatoes (Solanum tuberosum) are then sown into the piles and grown without addition of other manure or fertilizers. Sometimes barley (Hordeum vulgare) is planted in the tilled soil following potato harvest. The land is then left fallow for 4 to 6 years to allow re-growth of the grassy vegetation (mostly Dabo, Cynodon dactylon). As with Khoria, this system, too, faces increasing pressures of population growth and over-grazing, leading to shortened fallow period and declining productivity. Soil erosion is also a major problem with both of these shifting/fallow cultivation
practices, which renders them unsustainable.

**Indigenous Soil and Water Conservation Practices**

A variety of tillage-related practices involving soil manipulation are indigenously used by farmers throughout the middle hills for soil and water conservation purposes, as well as, for enhancing productivity. These include such works as, ditches (both for drainage and soil/water retention), silt traps to conserve soil or prevent loss from fields, and a number of types of bed/furrow systems depending upon moisture requirements of specific crops. Ditches for drainage are constructed along the back walls of terraces with a slight slope to channel water onto lower terraces or waterways. Ditches and bunds along the outward edges of terraces are used to check soil erosion and retain water on outward sloping terraces. Silt traps consisting of stone walls are constructed on lands adjacent to streams and rivers so that sediment-laden flood waters leave behind nutrient-rich silt when waters recede. This type of “soil-harvesting” allows sufficient silt to accumulate over 3 to 4 years enabling crop production (Tamang 1993). Bed and furrow systems are traditionally used to control/regulate moisture for sensitive crops. Sunken beds are used for high moisture demanding crops like cress (*Lepidium sativum*), spinach (*Spinacia oleracea*), garlic (*Allium sativum*), onions (*A. cepa*), coriander (*Coriandrum sativum*), etc. Raised beds are used for crops unable to withstand water logging, such as, cabbage (*Brassica oleracea*), cauliflower (*B. oleracea*), broadleaf mustard (*B. juncea*), potato, radish (*raphnus sativa*), tomato (*Licopersicon esculentum*), etc. (Pandey 1993).

**Other Related Farming Practices**

**Farmyard Manure Application**

Local compost or farmyard manure (FYM) application is a long-standing traditional practice and in the past, was the sole source of plant nutrient and organic matter additions to replenish the soil. Typically, the FYM is comprised of animal wastes, old bedding material from livestock stalls, leaf-litter and twigs collected from nearby forests and otherwise unused plant residues such as weeds and stubble. The traditional composting technique simply involves mixing-up the above materials and allowing decomposition to take place in a heap or pile, preferably located close to the animal stall for ease of incorporating new material. The compost heap is allowed to ripen for periods ranging from just a couple of months to several months with or without occasional mixing. A common disadvantage of this method is the length of time required for adequate decomposition of plant residues, and frequently, the FYM is applied to fields only partially decomposed.

**Mulching**

Mulching is a practice not widely used by hill farmers traditionally, although it is used quite commonly on a small scale for specialty crops and vegetable nursery beds. This may be in part due to the shortage of mulching materials, which are required for other purposes, and also due to the fact that previously farmers have generally not grown crops that require mulching specifically. With a shift in cropping pattern, in recent years, to include more cash and high-value crops such as vegetables and other horticultural crops, the practice of mulching appears to be gaining significance in the mid-hills. Mulching is now done for crops such as ginger (*Zingiber officinale*), colocasia, around fruit trees, and to cover fine nursery seedbeds prepared for vegetable production.

**Burning**

Burning is a practice followed sporadically, as needed, in some parts of the middle hills. While burning of entire fields is generally associated with shifting cultivation, it is infrequently done on farm fields that have been left fallow for some years. More common is the practice of burning thick stubble and root mass (as with maize) and other litter (weed residues) including old livestock bedding materials (if available) gathered in to piles. The ashes are subsequently scattered and incorporated into the soil. In some areas, burning of dried weeds and plant residues across the field is done prior to tillage and seedbed preparation for vegetables as a means of sterilizing (for disease and pest control) and nutrient addition to the soil as ash (Budhathoki et al. 1992). From the perspective of OM loss, however, burning is not a useful practice, which could be replaced by other alternatives such as composting and mulching instead.
Terrace-side Slicing
Terrace side slicing is another traditional practice with benefits and some disadvantages. The main reasons for the practice is to improve the quality of the soil through incorporation of fresh soil and grassweed material, to control disease and pests that may be transmitted due to the weed and grass growth on the terrace sides, and for clean/aesthetic appearance. The primary disadvantage is the potential for enhanced soil erosion due to exposure of the soil, particularly during the intense pre-monsoon rains and on sloping terraces.

In-situ Manuring
In-situ manuring involves the grazing of livestock on fallow farm fields, thereby, allowing their droppings to be left dispersed over the field. This is a practice commonly done by farmers across the middle and high hills. It is generally done prior to tillage during the winter months where crops cannot be economically grown and between successive crops both in the spring and autumn (Budhathoki et al. 1992). Where intensive manuring is to be done, farmers occasionally build temporary shelters on farm fields and tether the animals at different spots across the field over a period of 2 to 3 weeks (Subedi et al. 1995). The dung deposited by the animals (sheep, goats or cattle) is subsequently incorporated into the soil through tillage and serves to replace or supplement FYM application for improving the soil nutrient status.

Modern and Innovative Techniques
The rapid growth of human population over the past few centuries has necessitated increasing degrees of intensification of agriculture to meet the food and fibre demands of the world. Yet, land resources are finite and non-renewable and intensive cropping along with exploitation of marginal lands for agriculture lead to soil nutrient depletion, degradation and erosion. Thus, farming systems must evolve towards greater efficiency and sustainability to meet food and fibre requirements into the new millennium (Brady 1990, Lal & Stewart 1995, Nicholas-Wallis 1997). In the context of the mountain ecosystem in general and the Hindu Kush-Himalayan Region in particular, sustainability must be reconciled among policy-level, scientific-level, and the local people's (ethno-cultural) view points, and thinking needs to be scaled temporally, spatially and socio-demographically (Rhoades 1997).

Mechanised Tillage
With the advent of modern technology and mechanisation, agriculture has moved ahead into an input intensive but labour efficient mode through the use of tractors and heavy implements. This trend has, however, met with only limited applicability and adoption among the resource-poor subsistence farmers of Nepal. Due to economic, social and geographic constraints, use of the tractor in farming is limited to areas of the Terai-belt plains region. On the other hand, lesser technologies, such as, the hand tractor, manual seed drill, and bullock-drawn plough/drift (Adhikari & Karmacharya 1988) have some applicability in valleys and level areas of the Middle Mountains Region. Despite this potential, however, their adoption and use by hill farmers have been insignificant owing to socio-cultural, financial and policy constraints. Some small pockets of the mid-hills have adopted the Chinese hand tractor for tillage as with the Newars of Nala, Banepa, due to various socio-economic and cultural/religious reasons. The mould board plough is also used to a limited extent in some flat areas of valleys and plains. Other manually operated, partially mechanised hoes, weeders and planters have been developed but not fully tested and field tried at the farmer level, due largely to policy and institutional weaknesses and research budget constraints.

Zero-Tillage
Zero-till farming is a new area of research and field trials that holds potential for application under certain specific conditions in Nepal. It can be categorised into two approaches; namely direct hand broadcast surface seeding and planting by means of no-till seed drills. This technique is being farmer-adopted, to a limited extent, only in parts of the Terai Region, although it has been successfully tested in the mid-hills (Kathmandu and Kahrlepalanchok districts). Presently, no-till methods are used primarily for wheat (Triticum aestivum) crops following rice (Oriza sativa) in rice-wheat systems, and to a lesser extent for lentil (Lens culinaris) after rice. This practice could potentially be used with
other crops such as rice, maize, millet, buckwheat (*Fagopyrum esculentum*) and sorghum (*Sorghum bicolor*).

Direct surface seeding of wheat is found to provide economic yields under excessively wet, lowland condition, which normally delay farming operations and sowing of wheat after rice by the conventional method (Giri 1998). The wheat may be relay broadcast prior to rice harvest, or surface seeded immediately following (1-2 days) rice-harvest. Relay surface seeding of wheat 5 to 9 days before rice harvest has the added advantage of early sowing and maturity as compared to sequential cropping (Subedi et al. 1997).

Use of the Chinese no-till seed drill and bullock drawn seed-drill have been successful in providing higher wheat yields than traditional methods on wet lowlands that would otherwise be unproductive due to planting delays (C. Adhikari, G. Shah, personal communications). In three years of field trials at Birganj, yields were 40 to 70% higher through no-till drilling as compared to the traditional farmer practice of ox-drawn ploughing and subsequent sowing of wheat after rice. The overall land preparation costs were calculated to be reduced by 66 to 75%, thereby, offering a net benefit of the Chinese seed-drill to be 1.7 to 1.9 times that of the traditional practice (G. Shah, personal communications). The bullock-drawn seed-drill gave slightly lower yields than the Chinese seed-drill.

**Minimum/Reduced Tillage**

The Chinese hand-tractor with roto-tiller attachment can be adjusted to cultivate only a narrow band of about 10 cm width to a depth of 6 cm. It can, at the same time, be fitted with the seed-drill so that tillage and planting can be completed in a single pass. This offers a means of reduced tillage for minimal disturbance of the soil, yet somewhat better seed germination and seedling establishment than under zero-tillage. The technique is, however, still in the experimental stage of development and requires further field trials and adaptation to determine conditions and cropping patterns under which it may be suitable, particularly for the mid-hills. Other methods of reduced tillage using local traditional implements also need further research and development.

**Bed and Furrow Systems**

Bed or ridge planting is suited to crops that require careful moisture regulation and in lowland areas that are prone to excessive moisture. Ridge planting is commonly practiced for the production of potato, wheat and other winter crops on lowlands where soil remain wet after rice harvest (as in Kathmandu valley) and on some upland areas. Single-row ridges, and in some instances, broad ridges with double rows of potato plants, are found across the middle hills. Bed and furrows are also used for high-value vegetable crops, such as cauliflower, cabbage, tomato, turnip (*Brassica rapa*), spinach and lettuce (*Lactuca sativa*), which are typically seeded in nursery beds with subsequent transplanting of seedlings. Bed or ridge preparation requires fine tillage of the soil.

Broad beds and permanent bed planting are other technologies that may have value for improved soil and water management and agricultural production in gently sloping areas of the mid-hills. The broad bed and furrow system is well suited to conditions of heavy clay soils (Vertisols) and warm-dry climates (semi-arid), but require further research and testing for adaptation to other climatic regions (Virmai et al. 1989). These have generally had limited adoption in Nepal as they are better suited to mechanised agriculture on relatively flat land.

**Contour Bunds, Hedgerows and Agroforestry**

The use of bunds or hedgerows placed along the contour is an effective practice for soil conservation on marginal sloping agricultural land. The bunds should be maintained with grasses or fodder shrub species for effectiveness. Contour hedgerows are created by planting nitrogen fixing trees and shrubs (*Alnus nepalensis*, *Desmodium floribundum*, *D. rensonii*, *Gliricidia sepium*, etc.) in double rows and keeping them severely pruned to a height of 50-60 cm (Partap & Watson 1994). Horticultural, vegetable or even other food crops may be grown between the contour hedgerows using traditional practices.

Farmers in the middle hills frequently follow some form of tree incorporation on agricultural land, particularly, in and around the farmstead where fruit or fodder trees are grown. This type of ‘home garden’ agroforestry is common in villages.
with dwindling nearby forest resources. Species used include *Ficus spp.*, *Sauraria nepalensis*, *Alnus nepalensis* among other fodder and fruit trees (Amatya 1994). The more systematic agroforestry practice of alley cropping is found only in a few parts of the mid-hills. One such practice in Kabhrepalanchok district involves growing food crops between rows of *Luecaena spp.* Another increasingly popular system in eastern Nepal is planting of cardamom in the under story of *Alnus nepalensis* without maintaining rows or alleys (Amatya 1994).

**Kitchen Gardening**

The maintenance of kitchen gardens on tiny plots of land adjacent to rural dwellings is another from of intensive cropping that is gaining attention and popularity due to vigorous promotion by numerous NGOs, INGOs and government agencies. Through meticulous soil, water and nutrient management and proper choice of vegetable, spice and leguminous crops, this could be sustainable practice, which also supplements household nutrition and income (Adhikari *et al.* 1996). Khatiwada *et al.* (1998) reported the possibility of year-round production of some 28 different vegetable and spice crops, yielding on average 1.5 to 2.0 kg/day from a plot of 110 sq. m area. Nutrient management is, however, critical under such intensive production.

**Improved Composting Technologies**

Under the conditions of low input agriculture as is practiced in the middle hills of Nepal, improved composting/manuring techniques are critical. Although the final nutrient composition appears to be more a function of the composting materials, the time required for adequate decomposition and ripening of the compost can be reduced with improved techniques (Subedi *et al.* 1995). The type of pit structure or enclosure, proper aeration, and inoculating with various bacteria, fungi, yeasts and actinomycetes (effective microorganisms, EM) can speed up the composting process, as well as, enhancing the quality of the soil and efficacy of the compost (S. P. Thapa, ICIMOD; R. B. Yadav, RARC-Parwanipur; personal communications). Compost/FYM has been observed to be particularly beneficial in maintaining the overall soil nutritional, physical and chemical status of the soil. Its application in combination with inorganic fertilizers, has also been noted to give the highest yields and residual benefits under both maize-millet and rice-wheat systems (Scherchan *et al.* 1997, Scherchan & Gurung 1998, Tripathi 1998, Pilbeam *et al.* 1999).

**Green Manuring/Cover Crops**

Green manuring is a practice that has been used sporadically in indigenous farming systems throughout the country, but has failed to be systematically incorporated into the traditional practices of most hill farmers. This is due mainly to the fact that most farmers tend to avoid sacrificing a potential crop or hindering sowing/transplanting of their primary crops. Hence inclusion of green manures or cover crops in the cropping cycle would require species that can be planted early and mature quickly within the 1 to 2 month “safe window of opportunity” between harvesting and planting dates, i.e., typically a few weeks between April and July, depending on location and elevation. Some introduced species that have potential in this regard include: *Vicia faba*, *V. villosa*, *V. sativa*, *Lupinus mutabilis*, and *Trifolium resupinatum* (Keatinge *et al.* 1999). The use of green manures has been observed to significantly increase rice yields under rice-wheat and maize-rice systems. A number of indigenous species that are effective for this purpose include: *Adhatoda vasica*, *Melia azedarach*, *Eupatorium antidysenterica*, *Sesbania aculeata*, *Guizotia abyssinica*, *Vigna umbellata*, *Albizzia spp.*, *Artemisia vulgaris* (Subedi *et al.* 1995; Gurung & Sherchan 1997).

Nonetheless, farmers are reluctant to adopt this practice, particularly on upland areas where maize is planted, as they do not wish to sacrifice or risk losses of the main crop.

**Conclusion**

Land preparation is an indispensable part of local farming practices in the mid-hills of Nepal. Soil working is generally a very labour intensive and time consuming component of hill farming done mostly manually or using animal draught power.

The development and adoption of new technologies for increased labour efficiency, reduced costs, and minimised soil tillage and exposure to erosion are required to ensure the
sustainability of farming in the middle hills of Nepal. An integrated approach involving soil and water conservation practices, as well as, diversified, carefully managed cropping, soil fertility, organic matter, and weed/pest control systems are needed. Some areas for research, development and training include: a) modification of present soil tillage practices to incorporate better soil and water conservation, thus enhancing production and environmental compatibility; b) adoption of reduced or minimum tillage options, where appropriate, thereby, decreasing soil exposure, erosion and organic matter/nutrient depletion; c) improvement of local compost/FYM techniques enabling maintenance of soil nutrient status with minimal chemical fertiliser inputs; d) determining socio-economic and site specific conditions for suitability of mulching, green manuring and cover crops for better soil, organic matter and nutrient conservation; e) application of zero-tillage and direct surface seeding techniques for a variety of crops (wheat, rice, maize, lentils, millet, sorghum) to determine areas and conditions under which these practices may be economically and socio-culturally viable; f) adoption of other soil and water conserving practices, such as, contour-hedge rows, strip-cropping, ridge/furrow systems, and agroforestry on marginal lands; and g) establishment of productive kitchen gardens, where appropriate, through bio-intensive gardening.

References


