Analysis of the sustainability of upland farming systems in the Middle Mountains region of Nepal

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This paper examines the sustainability of vegetable production systems as compared with traditional cereal cropping patterns in terms of their ecological suitability, economic profitability, social acceptability and institutional viability. An assessment was carried out using combined quantitative and qualitative data collected from on-farm experimental plots, soil and plant sample analysis, a household survey, focus group discussions and a workshop in Pokhare Khola Watershed of Middle Mountain Nepal. The study showed that adoption of vegetable farming improved the socio-economic condition of the upland farmers, particularly the poor, women and disadvantaged groups, in terms of their food security, farm income, resource accessibility, employment opportunity and social status. These indicators revealed that vegetable-based cropping patterns are economically profitable and socially acceptable and thus contribute somewhat to the sustainability of upland farming. However, such achievement has been made through intensive cultivation practices such as increased use of agrochemicals and hybrid seed, that have led to declining soil fertility and increasing dependency of farmers on external inputs in commercial vegetable production and, therefore, threaten the sustainability of mountain farming in the long run. Additionally, institutional mechanisms for vegetable production and marketing are minimal and do not squarely address problems of upland farming. To ensure environmentally and socially sustainable production, government policy and programmes should promote locally available resources for vegetable production and support market mechanisms which can be competitive in national and international markets.

Keywords: cropping pattern, farm income, food security, local institution, soil quality, sustainability, vegetable production

Introduction

Rapid changes in the social and economic environment together with the deterioration of the natural resource base threatens sustainability of farming systems in many areas of the world (Dogliotti et al., 2004). They are especially acute in the densely populated, underdeveloped and ecologically fragile area of the Hindu Kush Himalayan (HKH) region1 (Rasul & Karki, 2007). As a result of increasing population growth and development of infrastructure in mountain areas in recent decades, subsistence agriculture has been intensified to meet the increasing demand for food and income. Intensification, however, has been applied without
suitable management of uplands, which has accelerated deforestation, soil erosion and environmental degradation. Such agricultural intensification with use of high yielding modern varieties and agrochemicals has many negative implications, particularly for the unique landscape of the mountains where farmers are dependent on the local resources through locally developed technology (Sen et al., 2002). Degradation directly and negatively impacts the lives of some 150 million people living in the HKH region and indirectly affects about 450 million more living downstream (Rasul & Karki, 2007), raising serious concerns about the sustainability of mountain agriculture.

It is expected that change in cropping patterns in upland farming in mountain areas is leading to noticeable change in environmental and socio-economic consequences (Seddon & Adhikari, 2003). The introduction of vegetable production systems in Middle Mountain are important to meet the growing demand for fresh vegetables in urban centres (Kathmandu, Pokhara), including nearby Indian cities offering a comparative advantage over the production systems supported by the hot wet summers in the lowland. Out of these changing practices in upland farming arises an interest in the scientific community to study the sustainability of mountain farming.

There is no universal definition of sustainability of agriculture production systems. Different people have defined and interpreted sustainability based on their experience and local context. Kang et al. (1990) defined sustainability as the ability of a production system to produce stable yield of a crop(s) over a long period of time while minimizing soil degradation. Increased farm productivity and income are important factors for agricultural sustainability that can contribute to increased adoption of natural resource conservation measures to sustain upland production systems (Sajise & Ganapin, 1990; Vorley, 2002). Pretty et al. (2008a) further suggest that resilience and persistence, in addition to economic, social and environmental outcomes need to be considered with respect to sustainability of agriculture systems. However, past studies poorly address the relationship between changes in cropping patterns, and farmers’ socio-economic status and well-being. A better understanding of these changes can have important implications for development of sustainable upland farming. Therefore, this study attempts to examine to what extent the vegetable-based cropping patterns are different from traditional cereal-based cropping patterns in terms of cultivation practices, resource allocation, production and productivity, soil quality, economical viability, and socio-cultural acceptability. The growing interest in changing upland farming is driven by four main concerns of sustainability: (1) Do the changing cropping pattern practices have negative impacts on soil quality and resource use? (2) Are the current cropping practices economically viable? (3) What are the socio-cultural and institutional impacts of farming practices? (4) How can social and environmental vulnerability be minimized to maintain the sustainability of the mountain farming systems? Answers to these related questions require assessment of the complex mountain farming system in view of ecological, social, economic and institutional variables.

Framework for assessing the sustainability of upland farming

Concept of sustainability in upland farming

There has been an ever-growing concern regarding sustainability ever since the publication of the Brundtland Commission’s report in 1987 called ‘Our Common Future’. The report defined sustainability as a ‘development which meets the needs of the present without compromising the ability of future generations to meet their own needs’ (WCED, 1987). Since then more than 70 definitions on sustainability have emerged across the globe (Pretty, 1995). IFAP (International Federation of Agricultural Producers) further defined agricultural sustainability as not only economic sustainability but also environmental, social and ethical sustainability (Vorley, 2002). Additionally, Bos et al. (2007) argued that agricultural sustainability can be quantified from three perspectives: people, planet and profit. Pretty et al. (2008b) also support that agricultural sustainability should be assessed through economic growth, environmental protection and social progress.

There is a growing concern among research scientists and conservationists about the indicators to be used for measuring the sustainability of a farming
ILEIA (1991) suggest indicators like productivity, security, continuity, adaptability, and integrity to measure sustainability. Although large numbers of indicators have been developed by scientists and researchers to assess agriculture sustainability, they do not fully integrate ecological, economical, social and institutional indicators. The precise measurement of sustainability is difficult as it is site-specific and a dynamic concept (Ikerd, 1993). Therefore, the indicators applied in one area may not be applicable to another due to variation in biophysical and socio-economic conditions. For that reason, indicators should be location-specific and considered within the context of the contemporary socio-economic situation (Dumanski & Pieri, 1996; Rasul & Thapa, 2003).

For upland farming, the question thus arises as to how to measure sustainability in this particular context. What are the possible indicators to measure the sustainability of upland farming? In the context of farming systems, sustainability can be examined through economic viability, sustainable use of resources, improved livelihoods of the local people and protection of ecosystems which are influenced by agricultural activities (Dalal et al., 1999). For the Middle Mountain regions of Nepal within this study, ecological, economic, social and institutional aspects were considered in the assessment of sustainability of the upland farming.

**Framework for determining ecological indicators**

Ecological components represent the natural state of environment, which should not be degraded (Yunlong & Smit, 1994) that is, minimal soil erosion; maintenance of soil fertility, crop diversity and water availability. In the context of the study area, ecological sustainability was assessed based on the following indicators.

**Soil and nutrient loss from different cropping patterns at plot level experiment**

On-farm run-off plots were established to measure soil and nutrient losses (SOC, N, P and K) (kg ha\(^{-1}\)) through erosion and run-off as well as crop harvest from two different cropping patterns in outward sloping rain-fed terraces (Bari land) from 2004 to 2007. The slope of the run-off plots terraces ranged from 8 to 12%.

**Soil quality assessment through physical and chemical properties**

Soil quality was assessed based on measured soil properties (bulk density, infiltration rate, soil organic carbon, available nitrogen, available phosphorus and exchangeable potash) collected from farmers’ field plots.

**Soil fertility management**

Soil fertility management was evaluated based on the amount of farmyard manure (FYM)/compost material and chemical fertilizer used in each cropping pattern, and percent of residue left to recycle in each cropping pattern. These data were collected through questionnaire survey at household level.

**Resource use and management**

Forest resources such as leaf litter, fodder and tree branches collected from the farmers to manage their farming were estimated after introducing the vegetable-based cropping pattern. In addition, soil and water conservation practices were also evaluated through field observation and group discussion in the study area.

**Insect and pest management**

Different disease and insect control practices were evaluated in each cropping pattern. Furthermore, frequencies of pesticides application and expenses (NRs) of the pesticides in each cropping pattern were measured.

**Cropping diversification**

This was measured through the index of crop diversification (CDI) following the formula below (Rasul & Thapa, 2004). It is expected that the lower the index value, the higher the diversification and sustainability of the cropping patterns.

\[
CDI = 1/[(R1 + R2 + \cdots Rn)/Nc]
\]

where CDI = index of crop diversification, R1 ratio of sown area under crop 1, R2 ratio of sown area under crop 2, Rn ratio of sown area under crop n, Nc the number of crops.
Framework for determining economic indicators
Economic sustainability requires stability and profitability of farm income. A cropping pattern is sustainable if it has an acceptable level of production of harvested yield which shows a non-declining trend from cropping cycle to cropping cycle over the long term (Izac & Swift, 1994). For economic indicators the following aspects were measured.

Crop yield index
The stability of the crop yield was examined by constructing an index based on farmer's subjective responses to a question related to yield trend in each cropping pattern. It is expected that the higher the yield index, the higher the sustainability of the cropping pattern. The index was constructed based on the following formula (Bhandari & Grant, 2007).

\[
ITY = \left( \frac{fi + fc}{N} \right) + \left( \frac{fd}{N} \right)
\]

where ITY is the index of trend of yield, fi the frequency of responses indicating increasing yield, fc the frequency of responses indicating constant yield, fd the frequency of responses indicating decreasing yield, N the total number of responses.

Net income
Net income from different cropping pattern was estimated using the income from crop production (NRs) minus the cost of external input (NRs) for crop production.

Framework for determining social indicators
Assessment of variables such as equity, food security, risk and uncertainties are highly relevant for agriculture sustainability and livelihood security in rural areas (Pretty, 1995; Rasul & Thapa, 2003). Therefore, social indicators in this study included aspects of equity (including gender equity), work division and specificity of farm activities at inter- and intra-household (HH) level (caste and gender), food security, input self-sufficiency, leadership, and participation from different ethnic groups in local organizations.

Equity
Equity was assessed through subjective judgement based on the access to the farm resources of the different family members, as well as the degree of decision making in the farming and financial activities. It is expected that accessibility to farm resources and involvement in decision making without any gender bias helps to improve sustainability of upland farming.

Farming activities
In rural areas of the mountain regions of Nepal, traditionally certain farm activities are usually assigned based on gender and caste. These assignments are considered a negative indicator of the social sustainability of cropping systems. Gender-wise work division at the household level, and caste-wise activities between households were thus evaluated. In ancient times in the Hindu religion, society was divided into three broad caste systems (Brahmin/Chhetri, Baishaiya and Sudra) according to the profession of people. During that period the Brahmin/Chhetri were the so-called higher caste group specializing in farm activities and decision making in resource management; the Baishaiya (Newar) were placed in the middle caste hierarchy, specializing in business and the Sudra (Damai, Kami, Sarki) were categorized as lower caste (occupational caste/disadvantaged group) specializing in artisanal work and labour activities at higher caste’s farms.

Input self-sufficiency
Input self-sufficiency was estimated on the basis of the ratio of local inputs cost to the total inputs cost. High values of this ratio were regarded to indicate high input self-sufficiency and sustainability.

Food security
Food security was assessed in terms of adequacy of food grain produced as well as the farm household’s ability to purchase food grain required for consumption.

Framework for determining institutional indicators
Institutional indicators assess how different policies, institutions and organizations help to ensure the sustainability of the upland farming. Sustainable agriculture is often associated with farmer participation, group action, and promotion of local institutions (DFID, 2003). Local institutions, including user groups (UGs), forest user groups (FUGs), government organizations (GOs), non-government
organizations (NGOs) and market mechanisms were assessed in terms of their programmes and activities for upland farming.

**Local institutions**

Sustainability of local institutions was measured based on membership of farm households in local institutions and their roles in participation, decision making, benefit sharing, and composition of executive committee. Furthermore, programme and services provided by the GOs to the local level was also monitored.

**Leadership**

Leadership was assessed by identifying the different castes and genders to which members holding key posts belonged, such as chairperson, secretary, and other leadership positions or roles in local UG, FUGs and their activities.

**Market mechanism**

Markets for inputs and outputs for different farm products were assessed in terms of (1) price fixing practices for the farm products and (2) percent of price variation from the local market and nearby cities.

**Research design and methods**

**Study area**

To compare the changing cropping patterns in the upland farming and their sustainability, the Pokhare Kola Watershed was selected for this study (Figure 1). It comprises 6 km² located between 27°46’28”–27°48’06”N and 84°53’32”–84°55’11”E in Pida Village Development Committee (VDC), of Dhading District in Central Nepal. The elevation of the watershed ranges from 400 m in the valley bottom to 800 m on the hill slopes. Mean monthly temperature ranges from 13 to 27°C and mean monthly precipitation ranges from 13 to 415 mm with an annual average of 1210 mm. In terms of topography, agricultural production systems, and ongoing changing patterns, resource use, and marketing, the study area is representative of the upland farming system of the Middle Mountain region of Nepal.

The settlements are scattered across the watershed and inhabited by different castes who have adopted different cropping practices and land management practices. The dominant type of land entitlement in Nepal is owner-tiller, with about 85% of the land owner-operated and the remaining 15% is rented. In principal, there is no regulation of land ownership within the caste system, however, access to land is nevertheless limited for poor and lower caste families. The HH survey showed that a majority of the farmers are smallholders having about 10 ropani (0.5 ha) of upland and about 40% area cultivated under vegetable production. They have shifted from maize–millet to vegetable farming in some of their Bari plots since 1997. This study focused primarily on Bari land because of the changes in cropping patterns on this land type, which also make up the primary livelihood and source of income of the poor hill farmers. The watershed is well-linked with the capital city Kathmandu and other parts of the country via the national highway, giving access to markets and potentially contributing to vegetable production.

**Survey and measurements**

This study adopted qualitative and quantitative data collection methods for socio-economic and institutional information and a field experiment for obtaining biophysical data. Data were collected through primary and secondary sources.

**Survey methods**

Out of 378 households in the watershed, nearly 50% (185 households) were interviewed for information on food security, household income, cropping patterns, yield trend, soil nutrient management, farm inputs and outputs, household level decision making and institutional involvement of the family members by gender and caste. Similarly, eight focus group discussions were organized for qualitative information. Field observation methods were also applied to collect primary data on cropping pattern, cropping intensity, use of agrochemicals and input self-sufficiency for different cropping patterns by local farmers.

**Institutional information**

One workshop was organized with key people of the line agencies of the government working at district level (Soil Conservation Officer, Forest Officer and Agriculture Development Officer), lead farmers
and local level NGO representatives. Local farmers participating in the workshop shared their experiences including the benefits and constraints of the government programmes. In addition, several field observations and interactions with local level UGs were held. Similarly, the programmes and constitution of the UGs and FUGs were reviewed to collect information on farmland management. A market survey was also conducted to collect information on price of agricultural produce in local markets and the nearby regional towns, price-fixing policy, farm gate price and retail price to consumers in different time intervals during the field study. Additionally, information on the market price of vegetables in the capital city collected by the Department of Agriculture/Government of Nepal was also collected for analysis.

**Biophysical information**

On-farm run-off plots were established in a completely randomized design with four replications of two treatments, namely: farmer practice (FP) (Zea
mays–Eleusine coracana), and commercial vegetable treatment (CV) (Zea mays–Capsicum sp.). Measurements were done to estimate the soil and major nutrient losses (NPK) and SOC through erosion and runoff as well as crop harvest from two different cropping patterns on Bari land. Eight soil samples from each of the cropping patterns (cereal and vegetable) of farmers’ field plots were collected randomly, composted, and analysed using a standard method to evaluate the soil properties such as bulk density and infiltration rate, SOC, total Nitrogen, available P, and exchangeable K in the soil.

**Statistical analysis**
Data collected from both experimental plots and the household survey were analysed by using the computer software: Statistical Package for Social Science (SPSS) (11.5 version, 2005). Statistical tests such as mean comparison, chi-square and percentage were applied to compare the sustainability of traditional and commercial cropping patterns (CPs).

**Results and discussion**

**Ecological indicators**

**Soil and nutrient losses from different CPs**
Soil and nutrient loss data generated through runoff plots showed relatively high amounts of soil, and major nutrients (NPK) and SOC losses in vegetable-based CPs (CV treatment) compared with cereal-based (FP) treatments. However, the amounts of losses are not significantly different among the treatments (Table 1). The higher amount of soil and nutrient losses from the CV treatment was due to more tillage and lower ground cover than FP treatments. The result indicates that nutrient losses from water erosion were not severe in this area. But nutrient uptake (N and K) from crop harvest were found to be significantly higher in vegetable-based treatments (CV) compared with cereal-based treatments (Figure 2). It indicates high-yielding varieties of vegetable farming required greater amounts of nutrients than other crops. Brown and Shrestha (2000) also reported that commercial vegetable production with high-yielding varieties demanded a high amount of nutrients and increased dependence of farmers on chemical fertilizer and micro-nutrients.

**Soil quality assessment**
Soil sample results from different cropping patterns in the study area show lower infiltration rate (IR) and high bulk density (DB) in farm plots with vegetable-based cropping patterns compared to the cereal-based maize–millet system. Similarly, chemical properties such as SOC, and total N were observed as low in vegetable-based cropping patterns compared to the cereal-based maize–millet system (Table 2). The decreasing trend of SOC and total N in the vegetable cultivated land is found due to a high intensity of cultivation (3–4 crops yr\(^{-1}\)), more tillage operation (4–6 times more ploughing and digging yr\(^{-1}\)) and application of high amount (50 : 8 : 8 N : P\(_2\)O\(_5\) : K\(_2\)O kg ha\(^{-1}\)) of chemical fertilizers (Table 3), which resulted in rapid mineralization of SOC under vegetable cultivation. The study indicated that intensive vegetable cultivation practices decrease the soil quality through increased bulk density and more rapid decline in SOC and total N than in traditional cropping patterns. These findings support the argument that agricultural intensification can have negative impacts on soil quality and biodiversity (Matson et al., 1997).

**Table 1** Average annual losses of major nutrients from eroded sediments in two cropping patterns

<table>
<thead>
<tr>
<th>Cropping pattern</th>
<th>(g) m(^{-2}) yr(^{-1})</th>
<th>Major nutrients loss (mg) m(^{-2}) yr(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil loss (\pm) SE</td>
<td>SOC (\pm) SE</td>
</tr>
<tr>
<td>Maize–millet</td>
<td>122.2 (\pm) 45.5</td>
<td>2.40 (\pm) 1.23</td>
</tr>
<tr>
<td>Maize–vegetable</td>
<td>126.5 (\pm) 43.1</td>
<td>2.60 (\pm) 1.14</td>
</tr>
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</table>

Soil fertility management
Farmyard manure (FYM) is the main source and chemical fertilizers are a supplementary source of nutrients for crop production and soil fertility management in the study area. Household data showed nearly equal amounts of FYM \((3.6 \text{ Mg ha}^{-1} \text{yr}^{-1})\) were applied in maize–millet and vegetable-based cropping patterns \((3.3 \text{ Mg ha}^{-1} \text{yr}^{-1} \text{ dry weight basis})\). Whereas, the application of chemical fertilizers was three times higher in the vegetable-based cropping pattern in the study area (Table 3). Local farmers explained that they could not produce profitable yields of vegetables without using chemical fertilizer because they are unable to use high amounts of FYM due to increasing labour costs to produce FYM and decreased use of crop residue to feed the livestock. Crop residues from maize–millet are the primary source of livestock feed for upland farmers which can be stored and supplied during the deficit months. Whereas, in the vegetable-based cropping pattern, residues were difficult to store for long periods and the low biomass production could not provide sufficient food for the livestock. The increasing use of chemical fertilizers and decreasing use of FYM in vegetable-based CP indicates a low level of sustainability in upland farming systems.

Resource use and management
Forest is an integral part of the upland farming system which provides food and bedding materials (tree fodder and grasses) for livestock, compost materials for soil fertility, and fuelwood and timber for household use. Introduction of commercial vegetable production has increased pressure on forest resource collection due to low biomass production from vegetable-based cropping patterns to feed the livestock. Brown and Shrestha (2000) also found increasing pressure on forest resources through increased collection of fodder and leaf litter for vegetable production. Farmers also collected extra tree branches and saplings averaging \(2 \text{ bhari yr}^{-1} \text{HH}^{-1}\) (1 bhari = 25–30 kg) (Figure 3) to grow climbing types of vegetables such as bean, gourd and cucumber. Increasing forest resource use to produce vegetables has thus resulted in negative effects on the sustainability of the upland

Figure 2 Nutrient uptake (nitrogen (N), phosphorus (P), and potash (K) (g) m\(^{-2}\) yr\(^{-1}\))

Table 2 Comparative soil properties (mean and SE) (0–15 cm) in two cropping patterns

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Cropping pattern</th>
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<tbody>
<tr>
<td></td>
<td>Vegetable-based ± SE</td>
</tr>
<tr>
<td>Infiltration (cm hr(^{-1}))</td>
<td>9.00 ± 1.20</td>
</tr>
<tr>
<td>Bd (Mg m(^{-3}))</td>
<td>1.40 ± 0.06</td>
</tr>
<tr>
<td>SOC (g kg(^{-1}))</td>
<td>1.45 ± 0.17</td>
</tr>
<tr>
<td>Total N (g kg(^{-1}))</td>
<td>0.15 ± 0.01</td>
</tr>
<tr>
<td>Available P (mg kg(^{-1}))</td>
<td>27.00 ± 5.50</td>
</tr>
<tr>
<td>Available K (mg kg(^{-1}))</td>
<td>46.00 ± 12.00</td>
</tr>
</tbody>
</table>

Bd = bulk density, SOC = soil organic carbon, Total N = total nitrogen, Available P = available phosphorus, Available K = available potash, SE = standard error.
farming system. However, local farmers are aware of declining forest resources. Consequently they have adopted a community forest management system to meet their growing demand for forest products without degrading the forest resource base. In this endeavour, they have started to plant the perennial grass (*Napier*) and fodder tree species (*Ficus* sp. *Artocarpous lackoocha, Leucaena leucocephala*) in their farmland and degraded sites of the forestland.

Water conservation and utilization for vegetable production was found to improve soil moisture as well as to minimize run-off of excess water. Moisture deficit is a major problem in growing vegetables round the year by upland farmers. It was observed that the farmers are taking initiatives during the monsoon rains to collect run-off water in conservation ponds. The collected water is then distributed to vegetable plots during the dry season through plastic (polyethylene) pipes with a minimum loss.

**Insect pest management**

Indiscriminate use of pesticides in vegetable-based cropping patterns was found to be an emerging problem for attaining sustainability in vegetable production. It also has negative impacts on human health which is not fully internalized by farmers in the study area. It was observed that farmers continue to use hazardous chemicals, such as organochlorine and organophosphate pesticides, despite the fact that their use is restricted in developed countries due to adverse affects on human health and aquatic ecosystems. Recent studies in other areas of Nepal show indiscriminate use of broad-spectrum pesticides in vegetable crops during the vegetable growing period (Yadav, 2005). The analysis of input self-sufficiency is also significantly lower (*p* < 0.05) in vegetable-based cropping patterns for insect pest management compared with cereal-based cropping patterns (Table 4). The survey among the farmers who were using pesticides continuously for the last five years showed more than 70% farmers wait less than two weeks between spraying and crop harvest. They applied pesticides five to six times particularly in off-season vegetable production without any precautions. This has led to increased health hazards particularly in urban areas where most of these vegetables are consumed. Shah (2006) reported that different vegetables exhibited different levels of pesticides residue. For example, potato contains (Methyl) 0.006 mg kg$^{-1}$, brinjal contains (Parathion) 0.006 mg kg$^{-1}$ and tomato contains (Cypermethrin) residue 0.84 mg kg$^{-1}$. Tomato exhibited pesticides residue levels higher than maximum residual level

<table>
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<th><strong>Table 3</strong> Farmers’ response on input use of FYM and chemical fertilizers and their nutrients supply in two cropping patterns*</th>
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<tr>
<td><strong>Cropping pattern</strong></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Maize–millet</td>
</tr>
<tr>
<td>Vegetable–vegetable</td>
</tr>
</tbody>
</table>

*Mean value is based on response of 178 farmers’ interviews and nutrient analysis of FYM.*

![Figure 3 Resource collection from the forest (1 Bhari = 25–30 kg)](image-url)
(0.5 mg kg\textsuperscript{-1}) for consumption. On the production front, regular misuse of broad-spectrum pesticides has resulted in resistance to pests, resurgence, and secondary pest outbreaks. Similar observation is reported by Adhikari (2000) on the use of pesticides and insecticides in other parts of Nepal. Farmers also witnessed new types of diseases and pests in recent years which require new chemicals for their control. Safety precautions while mixing and spraying pesticides and the time interval between spraying and sale of produce was inadequate. Moreover, no local institution was involved in raising awareness about pesticide use and its impacts on human health.

### Crop diversification

Household survey data reveals the recent practice of growing short duration vegetables by farmers in their small patch of farmland to sustain the household economy. They grow three to four types of vegetable-based crops either by relay or mixed cropping in a year, based on their experience, available moisture and resources. Moreover, some farmers took initiatives to cultivate another crop in the same plot if one crop failed. Crop diversification indicates increasing numbers of crops or production enterprises per farm (Beets, 1990), which helps insure the crops against various types of risk. In the cereal-based cropping pattern (maize–millet) some farmers cultivate soybean or bean as an intercrop, but continuously cultivate the same crop in the same plot. Calculated crop diversification index (CDI) in vegetable cropping patterns was significantly lower (0.34) as compared with cereal cropping patterns (0.51) which implicitly show high crop diversity in vegetable production (Table 4). Rasul and Thapa (2003) also reported higher CDI in ecological cropping systems due to a higher number of crops cultivated per year than in conventional systems. The lower CDI in vegetable cropping patterns indicates higher insurance against various types of risk such as crop failure, and better crop yield and income than cereal cropping patterns, and represents a positive indicator for sustainability of upland farming.

### Economic indicators

#### Crop yield index (CYI)

The calculated CYI shows higher yield stability in cereal production (CYI = 0.65) but it is not significantly different ($p = <0.05$) compared with vegetable production (CYI = 0.62) (Table 5). This is explained by increased yield in both cropping patterns (41% in cereal-based and 61% vegetable-based) due to adoption of improved varieties and use of chemical fertilizers. The yield stability index of both cropping patterns shows positive indication for sustainability of upland farming.

#### Net income

Net income is found to be significantly high (Table 5, $p < 0.02$) in vegetable production (NRs 1813) as compared with cereal CP (NRs 1271) per ropani (1 ropani = 0.05 ha) area of Bari land. Relatively high income from vegetable production was due to high market price for fresh vegetables, intensive care of vegetable plots by farmers

### Table 4 Index of cropping intensity, crop diversification and input self-sufficiency of the two cropping patterns ($n=178$)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Cereal CP</th>
<th>Vegetable CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropping intensity\textsuperscript{1}</td>
<td>1.8</td>
<td>2.3*</td>
</tr>
<tr>
<td>Crop diversification\textsuperscript{2}</td>
<td>0.51*</td>
<td>0.34</td>
</tr>
<tr>
<td>Input self-sufficiency\textsuperscript{3}</td>
<td>0.75*</td>
<td>0.67</td>
</tr>
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</table>

\*Significant difference of mean ($t$-test, $p < 0.05$) in two cropping patterns (CP).
\textsuperscript{1}The higher the index value, the higher the intensity.
\textsuperscript{2}The lower the index value the higher the diversity.
\textsuperscript{3}The higher the index value, the higher the input self-sufficiency.

### Table 5 Mean of the Crop yield index and net income from the two cropping patterns ($n=178$).

<table>
<thead>
<tr>
<th></th>
<th>Cereal CP</th>
<th>Vegetable CP</th>
</tr>
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<tbody>
<tr>
<td>Crop yield index</td>
<td>0.65\±</td>
<td>0.62\±</td>
</tr>
<tr>
<td>Net income</td>
<td>1271 \± 70</td>
<td>1813 \± 178*</td>
</tr>
</tbody>
</table>

\*Significant difference of mean ($t$-test, $p < 0.05$) in two cropping patterns (CP).
during their leisure time, use of high-yielding varieties and high doses of chemical fertilizers compared with traditional cereal cropping patterns. Also, high labour input in the vegetable production system was an important factor leading to high income to farmers. It means vegetable production provides better labour productivity in the study area. The net income was calculated assuming zero opportunity costs of household farm labour as well as the use of FYM in both cropping patterns. Niroula and Thapa (2007) also did not account for household labour and FYM in their cost–benefit analysis of farm production in another area in the Middle Mountains of Nepal. Moreover, farmers reported that off-season vegetable production such as tomato during July/August, cauliflower during October/November, and cucumber, pumpkin, gourd species and beans during March/April fetched double the income of normal season vegetable production. Dahal et al. (2006) and Brown and Kennedy (2005) also supported that vegetable-based cash crops increased farm income over cereal crops in the Middle Mountains of Nepal. The higher income from the vegetable-based cropping pattern showed the economic viability and sustainability of upland farming when based on small-scale vegetable production. In addition, increased benefits from vegetable farming discouraged encroachment and cultivation on marginal and forest land which supports the government policy on upland conservation.

Social indicators

Division of labour

In the past, there was a clear division of roles and responsibilities among family members, men, women, productive youth and the elderly. In the traditional cereal-based production system male members were mostly involved in ploughing, digging, threshing, marketing and female members were involved in planting, FYM application and harvesting. The change from cereal-based to commercial vegetable production systems significantly changed the social values at local level, and abolished the existing division of labour between male and female as well as by caste. It was observed that both male and female were involved in land preparation, planting, fertilizer/compost application, and intercultural operations in vegetable production. It was also reported that, previously, men hardly used to help their female counterparts in household chores, but since the earnings from vegetables grew gradually men started helping the women with the domestic chores.

Significant improvement in the involvement of male and female members in farm activities was attributed to being linked to the market for selling their farm produce (vegetables). Both male and female members are involved in marketing their vegetables and buying the inputs for vegetable production as well as daily household consumption materials. These marketing activities helped to empower the local farmers in terms of providing access to price information; awareness about improved farming, increased bargaining power for their farm products as well as the opportunity to share information with other communities. A woman from one disadvantaged group said: ‘If women are involved in the marketing of vegetables they spend some of the money earned from the sale of vegetables on basic household requirements. If male members came to sell their vegetables, they would enter the local restaurant and spend some of the money on alcoholic beverages.’ The new vegetable production system empowered women to come out from their farms and household activities to earn some money selling farm produce in the market and purchase household goods by their own choice.

Caste-based division of labour has also been changed to some extent. Traditionally, so-called higher caste people (Brahmin and Chhetri) did not plough (oxen plough) the land themselves, but hired the occupational caste to plough their land for them. But with the adoption of vegetable farming, higher caste people had to plough their land because of labour shortage. The occupational caste group started to cultivate vegetables in their own farmland as a spillover effect after observing higher caste people. In the present study, it was found that the lower caste people benefited relatively more from vegetable production than the higher caste people, as they stopped ploughing the land of high caste people which give them relatively low returns.

Resource ownership and control

Nepal is a patriarchal society where the overwhelming majority of household decisions are made by
men. Resource ownership is skewed to men and women are considered as subservient. Land registration shows less than 10% of women have land titles in the study area. In vegetable production, even though land may be registered in the male name, the women are equally active in land management and benefit directly from the increased income. Decision making for household expenditure from vegetable income is shared with women for small HH expenditures from the local market, whereas men spend bigger amounts to purchase livestock and agriculture inputs, often at more distant markets. Frequent marketing of fresh vegetables from their farmland gave the poor, women and the disadvantaged access to farm income to purchase household goods of their choice from the market. In addition, women have been able to run a small-scale savings and credit programme (saving Rs 20 to 100 monthly) at village level from their vegetable income. Thus, these activities have increased access to financial resources particularly to the poor, disadvantaged groups and women.

**Decision-making process**

Household level decision-making processes have changed since the introduction of commercial vegetable farming in the study area. Before the introduction of vegetable production, the male household head held the overall decision-making power in the household. The intensive labour demands of vegetable farming, however, required increased labour input from all family members. This led to a process of change in household level decision making, particularly on selection of varieties, adoption of new technology, farm inputs and marketing of farm produces. The unilateral decision-making process by the household head has been changed to a more consensus-based decision making that includes all family members. This led to a process of change in household level decision making, particularly on selection of varieties, adoption of new technology, farm inputs and marketing of farm produces. The unilateral decision-making process by the household head has been changed to a more consensus-based decision making that includes all family members. The sole handling of household income by the male household head also appears to have been changed and the women now handle some of the income earned through the sale of vegetables. The increased access of income to women has not only changed the gender division of labour but has also triggered a shift in power relations between men and women. Therefore, vegetable farming has not only increased the income but has also helped to empower the poor, women and disadvantaged groups (occupational caste) in decision making at HH level and community affairs.

**Input self-sufficiency**

Input self-sufficiency estimated from local input cost divided by total input cost in both production systems showed a significantly higher index (0.75) in cereal cropping patterns compared with vegetable cropping patterns (0.67) at \( p < 0.05 \) (Table 4). Not surprisingly, the higher index in the cereal cropping pattern was due to use of locally available seed, compost, and minimum use of agro-chemicals. Pretty et al. (2008a) suggested that best use of locally available resources increased the sustainability of the agriculture system. On the other hand, farmers used improved seed (hybrid variety), high doses of chemical fertilizer, micro-nutrients and pesticides for commercial vegetable production. Input self-sufficiency indicators showed that the cereal-based cropping pattern is more sustainable than the vegetable-based cropping pattern.

While other studies have not specifically analysed input self-sufficiency as an indicator of sustainability as done in this study, they have nevertheless stressed the importance of and ways in which to increase input self-sufficiency. Joshi and Witcombe (2002) reported that good quality seed can be produced in different agro-ecoregions through participatory on-farm seed production. Additionally, integrated pest management was found to be effective to control insect pest management (Neupane, 2003) for vegetable production. Furthermore, Maskey (2000) reported that about 40% of nutrients are lost through various processes in composting and manure application. Nutrient supply for vegetable production can be increased to utilize locally available high N containing plant species (Lantana camera, Adhatoda vasica, Eupatorium adenophorum, Cassia tora, Artemisia vulgaris, Sesbania species) for composting (Tiwari et al., 2006). Therefore, to increase input self-sufficiency for vegetable production, it is necessary to provide training and extension to farmers to utilize locally available plant resources for nutrient supply through more quality and quantity production of compost, selection of locally available good quality seed and adoption of integrated pest management (IPM).

**Food security and household income**

The quest for food security and increased household income are important social determinants for the adoption of vegetable-based cropping patterns in the study area. A change from traditional
cereal-based production to a vegetable-based farming system significantly improved the food security particularly among the poor and disadvantaged groups in the study area. It was reported that about half of the households could meet family food requirements for only half the year when they were relying on cereal-based cropping patterns (Figure 4). In recent years, most of the vegetable growers have increased family income by selling vegetables in nearby markets and thus are able to buy food and other household requirements from the same market due to the higher economic return as compared to cereal crops. Data indicate that over half of the households have increased their income through vegetable sales to avoid a food shortage (Figure 4). Carswell (1997) concluded that cash crop farming enhanced the quantity of food produced and quality of life of the local communities. In addition to improvements in food security, local people were also able to consume more nutritious food in terms of more green vegetables in their diet.

**Employment opportunities**

Vegetable farming also increased the employment opportunities for local people. It opened new avenues of employment in the marketing of the products and agrochemicals. The small landholders with insufficient land to work round the year on their own land opened small shops for marketing of vegetables, chemical fertilizers and pesticides. Some farmers who have relatively large plots of land hired the local people as labour for cultivation of vegetables and to transport the vegetables from their farm to the local market. Labour wages in the study area also increased by 50% during the last five years due to vegetable cultivation round the year, which benefited the poor and disadvantaged groups. Also, the higher incomes from vegetable production and employment opportunity attracted the young generation for vegetable farming and discouraged out-migration.

**Institutional indicators**

**Community-based local institutions**

Implementation of community-based activities through self-initiated local level institutions is gaining momentum in natural resource management in the mountain regions of Nepal. Three types of community-based institutions were involved in natural resource management and community development in the study area: Community Forest User Groups (FUGs) mainly focused on forest resource management, Women Groups (WGs) mainly focused on microfinance and saving among the women, and Conservation and Development Groups (CDGs) focused on integrated farmland and resource management. CDGs are village level institutions where all member households (20–25 members) participate in regular monthly meetings, share their experiences about vegetable farming and the market price of their farm produce, explore new opportunities in farming and encourage women and disadvantaged groups to participate in decision making during the meeting. The income generated from vegetable production increased the amount in their savings in UGs. These activities increased confidence to improve vegetable farming and marketing of their produce at reasonable cost in the market. There could be other benefits from these institutions as well. Local level institutions such as microfinance operated by user groups are not only efficient for
saving and credit activities but also spur the accumulation of social and human capital as well as local participation to achieve genuine sustainable development (Gomez & Santor, 2001).

**Leadership**

Social capital formation in the village by forming User Groups (FUGs, CDGs and WGs) empowered the local farmers, particularly women, disadvantaged groups and poor farmers for leadership development, social mobilization, savings, and credit programmes and commercial vegetable farming as well as natural resource management. This has also changed power relations in the society. One of the UGs was chaired by a man from an occupational caste which was not happening before introduction of commercial vegetable farming. Also, participation of women, minority groups and disadvantaged people has taken pace in Community Forest User Groups (CFUG) as a result of policies of inclusion, as well as an increased awareness among these people of the need for additional inputs in farm production. These community-based activities and the fact that women and disadvantaged farmers have taken leadership positions represent positive social and institutional indicators for the sustainability of upland farming. The fact that the poor, women and occupational caste members were able to be leaders in UGs suggests that the past discrimination based on caste gender has decreased. This is in agreement with the findings of Pretty (1995), whose research revealed that local level community-based institutions helped people know each other, feel more mutual rapport and create opportunities for collective action. The group activities in the study area have positive implications for sustainability of vegetable farming.

**Government institutions**

There are different field level government offices such as Forest Range Post, Agriculture and Livestock Extension offices in nearby Gajuri Bazaar (5 km west). Farmers reported the government services were weak in educating local farmers on new varieties of crops and vegetables, improved farm management technology, insect pest control, pesticide use, resource management and marketing of farm produce. In addition, the government has enacted a law to monitor and control the quality of improved seed, chemical fertilizer and pesticide use, but in practice there was no monitoring mechanism to control the quality of agrochemicals and pesticides use. Poor awareness of the correct use of chemical fertilizer and pesticides as well as weak government extension service mechanisms creates the indiscriminate use of agrochemicals, resulting in negative impact on the sustainability of vegetable farming. Pretty (1998) argued that policy should be enabling and supportive for sustainable development based on locally available resources and local knowledge, which is missing in the study area.

**Market mechanisms and price fixing practices**

Farmers were unaware of the actual price of their vegetables. In general, the middleman decides the price based on the previous day’s wholesale market price at the capital city and his/her transport cost, tax, and quality of the products as well as profit margin. It was noticed that there was a monopoly market for vegetable products and the middleman got more benefit than the local farmers. Roling and Jiggins (1998) explained that even highly capitalized, large-scale agriculture producers are in a vulnerable position in the market mechanisms vis-à-vis the middlemen. Recently, innovative farmers have begun to collect information on daily vegetable prices in Kathmandu and other city centres from the radio as well as contact with the capital through telephone and have begun to bargain the vegetable price with the middleman if the margin is too high from local markets. It was also observed that the farmers were unaware about the post harvest handling process such as grading, packing and cleaning so that the chance of obtaining the best price for their vegetables was low. In addition, the middlemen also serve as shopkeepers for vegetable growers as well as providing farm inputs and other household goods on credit to small farmers. Therefore, they have been obliged to sell their farm produce to the same middleman to whom they repay their credit. They also reported occasional difficulties in selling their fresh vegetable due to political instability and disturbances such as transport strikes for long periods (2–3 days), which resulted in lost income.

**Price variation between local markets and nearby capital city**

There is seasonal variation in market prices of vegetables. In addition, however, the market price is
just half in local markets compared to the capital city markets in all seasons (Table 6). The higher price in the city was due to price monopoly of the middlemen, transportation cost, tax, and risk of fresh vegetable damage. Lower prices at the local markets was due to poor market information, lack of proper storage, weak bargaining power of the farmers with middlemen, and absence of handling and packing facilities. Price fluctuation also occurred due to transportation strikes, supply of vegetables in the city from other production sites, import/export to India, as well as weather conditions (high rainfall and flooding or drought). It was reported that off-season vegetable production earned significantly more income than seasonal production, mainly due to short supply from other parts of the country.

Table 6 Average monthly price (NRs) variation in the capital city and local vegetable collection centre*

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Kathmandu price</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan</td>
<td>Feb</td>
</tr>
<tr>
<td>Cucumber</td>
<td>18</td>
<td>35</td>
</tr>
<tr>
<td>Cabbage</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Ladysfinger</td>
<td>45</td>
<td>44</td>
</tr>
<tr>
<td>Bittergourd</td>
<td>34</td>
<td>48</td>
</tr>
<tr>
<td>Tomato</td>
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<td>21</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Radish</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Cowpea</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>French bean</td>
<td>22</td>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Local price</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Cabbage</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Ladysfinger</td>
<td>22</td>
<td>20</td>
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<tr>
<td>Bittergourd</td>
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<td>Radish</td>
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<tr>
<td>Cowpea</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>French bean</td>
<td>15</td>
<td>12</td>
</tr>
</tbody>
</table>

*Price information (2006) collection from local collection centre and Marketing Division, Department of Agriculture, Government of Nepal, Kathmandu. Shaded parts in the table are the non-supplying months from the study area.
during the rainy season. Overall, the market mechanism is not favourable to small growers.

Conclusions

The results presented in this study reinforce the importance of integrating ecological, economic, social, and institutional aspects when addressing sustainability issues of upland farming systems. Ecological indicators determined based on soil properties and soil and nutrient losses showed that intensive vegetable production caused soil quality deterioration and higher amounts of nutrient loss compared with cereal crop production. Such production systems also lead to a dependency upon the market for all farm activities, such as agrochemicals, seed and sale of farm products. Nonetheless, farmers preferred the tangible benefits obtained through the use of agrochemicals and HYV, thus they show less concern for soil quality degradation, despite its significance for production in the long run. Economic indicators such as net income from vegetable production showed the economic sustainability of upland farming, albeit under certain cropping patterns. It was estimated that net income from vegetable-based production was about 50% higher than from cereal crop production. Ecological diversity in mountain farming provides farmers with a unique opportunity to provide a wide range of high value agricultural commodities such as seasonal and off-season vegetables to generate higher incomes than cereal crops.

Social indicators such as food security and income generation gave the main positive impacts of the adoption of vegetable-based cropping patterns in the study area. Data indicate over 50% of the households successfully increased their household income and overcame food shortages through vegetable sales. Regular marketing of their vegetable production by both male and female members helped to increase farm income, enhance their access to resources, enable local farmers to improve their farming practices and increase the decision-making power at household and community level. Input self-sufficiency, however, was significantly higher in cereal-based cropping patterns as compared to vegetable-based cropping patterns.

Furthermore, institutional indicators such as community-based user groups (forest user groups, women user groups and community development groups) and their activities in natural resource management, savings and credit programmes, leadership roles for women and farmers from disadvantaged groups showed positive indications for sustainability of upland farming. However, market mechanisms for vegetable production and price variations between local and capital city markets indicated weak institutional arrangements for vegetable production. Government support services were at minimum level and could not help much to improve the sustainability of upland farming. The government needs to elaborate policy and programmes to promote the adoption of organic-based vegetable farming, which combines socio-economic and environmental aspects, and at the same time to support market mechanisms which ensure that this type of production is competitive in national and international markets. The study suggests that key components of sustainable upland farming include institutional strengthening at the local level to make the local communities aware about better use of resources, minimum use of agrochemicals and better prices for farm products. In the long run, sustainable upland farming will not be attractive unless it gives a higher and more stable return to the farmers. Therefore, conservation and management practices should be linked with economic opportunities in order to develop a win–win scenario.

Notes

1. The Hindu Kush Himalayan (HKH) region covers eight countries including Burma, part of China, Bhutan, Nepal, India, Pakistan, Afghanistan and Bangladesh.
2. Vegetable farmers: those farmers who produce vegetables in some of their farm plot for HH income or sold in the local market for their livelihoods are the vegetable farmers in this study.

References


