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# AGRICULTURAL INTENSIFICATION IN A MID-HILL WATERSHED OF NEPAL: SOCIO-ECONOMIC AND ENVIRONMENTAL IMPLICATIONS

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# **Agricultural intensification in a mid-hill watershed of Nepal: socio-economic and environmental implications**

**Philosophiae Doctor (PhD) Thesis**

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## **Abstract**

Agricultural intensification is unavoidable due to the food requirements of a growing population, market availability and access to agro-products, and limited productive agricultural areas in Nepal. A shift from cultivating cereal crops towards vegetables and other cash crops has evolved through the process of agricultural intensification in the hills of the Himalayan region. With increased market access and road links to urban centres, settled agriculture in Nepal is becoming transformed into intensified cropping, especially in peri- and semi- urban areas.

This study reviewed the historic development of intensification, its evolution and adoption by farmers, and its effects on society and the environment in Ansikhola watershed of Kavre district in Nepal. For the historic and socio-economic aspects, personal interviews, discussions with key farmers, specific case studies, and focus group discussions with different wealth and caste groups were conducted. For the environmental aspects, field erosion plots were established to measure the runoff, soil loss and nutrient losses from agricultural lands. The eroded sediment samples and river water samples were analysed for major soil nutrients, chemicals, and aquatic macro-invertebrates. The effect of crop intensification on stream water quality is based on the comparison of two mid-hill watersheds with different degrees of intensification.

The study revealed that intensive agricultural practices diversified the crop production system, shifting it from need-based cereal crops to market-demanded vegetable and cash crops. About 90 per cent of the farmers perceived that this shift has improved their socio-economic condition. Positive changes in wealth and social status, migration from rural to urban areas, and shifts in social division of labour are some of the important impacts. Environmentally, however, intensification has had a number of negative effects. Concentration of nitrate was found to be higher (13-28 mg/L) in stream water adjacent to areas practising intensification. Higher concentrations of sodium (9 mg/L) and potassium (5 mg/L) ions in Ansikhola were thought to be due to soil and nutrient losses from frequent agricultural activities in the watershed. Increases in biomass and abundance with concurrent decrease in species richness of indicative macro-invertebrate species in stream water reflected the impacts of rising agricultural intensification. The study found that intensified agriculture altered water chemistry, microbiology, as well as, aquatic organisms. However, only less than 10 per cent of the farmers were aware of the linkages between intensification and environmental

degradation. Despite soil nutrient loss, erosion, water pollution, and increase in workload of farmers, agricultural intensification is regarded as a viable option for increasing land productivity, diversifying the appropriate crops, increasing farmer's income, and transforming the social structure of the community. The study highlights and recommends an urgent need to address the emerging issues of livelihood and food security in Nepal through a more sustainable agricultural intensification.

**Key words:** agricultural intensification, socio-economic conditions, food security, soil erosion, water quality, sustainable development, Ansikhola

## Contents

### Part I: Extended Summary

Abstract	iii
1. Introduction	1
1.1 Overview of Nepalese agriculture	2
1.2 Agricultural policies and process of intensification	3
1.3 Rational of the study	4
1.4 Agricultural intensification and socio-economic conditions	5
1.5 Intensification and soil/nutrient losses	6
1.6 Watershed water quality in intensive cropping areas	6
1.7 Sustainable agricultural intensification	7
1.8 Objectives of the study	7
1.9 Conceptual framework of the study	8
2. Materials and Methods	10
2.1 Study area	10
2.2 Land use and intensive cropping	11
2.3 Research methods and design	12
2.3.1 Socio-economic conditions of farmers	12
2.3.2 Study on soil erosion and nutrient loss	13
2.3.3 Study on water quality of rivers	13
2.3.4 Review of sustainable agricultural intensification	14
2.3.5 Other data acquisition	14
2.4 Statistical analysis	14
3. Results and Discussion	15
3.1 Impact of intensification on socio-economic conditions of farming communities	15
3.2 Soil erosion and nutrient losses from farm-fields	16
3.3 Water quality assessment in agricultural intensified watersheds	17
3.4 Sustainable agricultural intensification for overall development	18
4. Conclusions and recommendations	19
5. References	21
Appendix	27





## **Part II: List of Papers**

- Paper I. Dahal, B. M., Nyborg, I., Sitaula, B. K., and Bajracharya, R. M. (2009). Agricultural intensification: food insecurity to income security in a mid-hill watershed of Nepal, *International journal of agricultural sustainability*, 7 (4): 249-260.
- Paper II. Dahal, B. M. (2010). Impacts of agricultural intensification on soil and nutrient losses in the mid-hills of Nepal (Manuscript).
- Paper III. Dahal, B. M., Sitaula, B. K., Sharma, S., and Bajracharya, R. M. (2007). Effects of agricultural intensification on the quality of rivers in rural watersheds of Nepal, *Journal of food, agriculture and environment*, 5 (1): 341-347.
- Paper IV. Dahal, B. M., Sitaula, B. K., and Bajracharya, R. M. (2008). Sustainable agricultural intensification for livelihood and food security in Nepal, *Asian journal of water, environment and pollution*, 5 (2): 1-12.



## **Part I: Extended Summary**



## **Part I: Extended Summary**

### **1. Introduction**

Agricultural intensification, an emerging agricultural development process in many developing countries, has several impacts on social and environmental well being of a system. In many cases, the frequency of cropping defines and determines the level of intensification. Intensification is not only defined by crops per land unit but also by cropping patterns, inputs, outputs and other land activities (Boserup, 1965; Turner and Doolittle, 1978; Brookfield, 1984; Netting, 1993; Tiffen et al., 1994; Carswell, 1997; Hunt, 2000). From the literature, it can be inferred that the definition of agricultural intensification is not universal and varies depending on the perspective and the context of the researcher in which it is viewed. In Nepalese context and for the purpose of this study, an increase in the number and types of crops per unit area of land over an annual cropping cycle with concomitant use of agro-chemicals for enhanced crop yield is considered as agricultural intensification. Furthermore, this study also includes a broader concept of intensification in terms of change in socio-economic condition of farmers with an increase in the number of crops per unit area.

Agricultural intensification can be driven by population pressure, access to market, employment opportunity, transport facility, agricultural inputs, institutional development and policies (Binswanger and Ruttan, 1978; Campbell, 1981; Jodha, 1990; Metz, 1991; Carswell, 1997; Templeton and Scherr, 1999; Ojha and Morin, 2001; Ananda and Herath, 2003; Shrestha et al., 2004). Along with these factors, intensification is also affected by the food deficit situation, agricultural trade imbalance, geological condition and national policies in Nepal (Dahal et al., 2008). These factors may enhance crop intensification in isolation or in combination, for example, increasing the demand for food, easing the sale of farm products, and increasing farm income. Lee et al. (2001) considers that the economic growth associated with intensification may be beneficial particularly in the short term. However, the long term relationship between intensification and environmental quality is poorly understood (Lee and Barrett, 2001). Therefore, there is a need to understand how higher agricultural production might be achieved in ways that minimize negative environmental impacts on land and other natural resources.

## 1.1 Overview of Nepalese agriculture

Nepal is an agricultural country with an area of 147 181 square kilometres. Nepal is divided into five ecological zones (Figure 1). Hills and mountains cover about 33 % of the total land area and arable land in midhills is only 25%. Agriculture occupies 18% of total land use in Nepal (Forest 38%, Snow 15%, Pasture 13%, Water 3%, Settlements and roads 1%, and others 12%). Comparing the last 20 years land use data, the per capita land has decreased to 0.64 ha in 1990 from 1.2 ha during 1970 (MoPE, 2000). Similarly, the cultivated land for the same period has declined from 0.7 ha to 0.164 ha. However, more than 80 per cent of the people are still directly dependent upon agriculture, and agriculture contributes to 40% of GDP (MoAC, 2000).

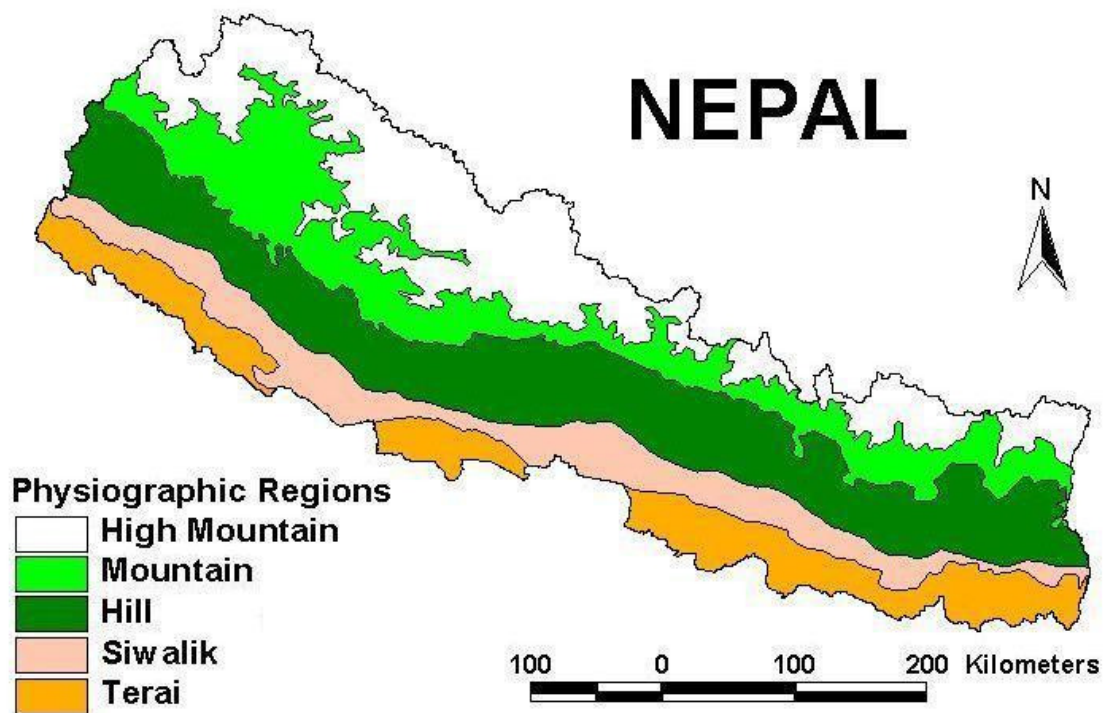


Figure 1. Physiographic regions of Nepal (Data source: NGIIP/Nepal, 1995).

Major cereal crops of Nepal are paddy (*Oriza sativa*), maize (*Zea mays*), millet (*Eleusine coracana*), and wheat (*Triticum aestivum*). Depending upon the ecological regions, different crops can be cultivated. The main crops in Terai and Siwalik regions are rice, wheat, legumes and oilseeds where as in Hills, the major crops are rice, maize, wheat, pulses and oilseeds. Similarly, the crops of Mountains are potato (*Solanum tuberosum*), barley (*Hordeum vulgare*),

buckwheat (*Eriogonum* sps) and *Amaranthus* (Sharma, 2001). Potato and other vegetables crops are being cultivated in these ecological zones both as subsistence farming and/or as a cash crop. The recent trend of increased cultivation of potatoes and other vegetables crops (with high inputs) for an economical benefit is an indicator of agricultural intensification, but has been shown to have negative environmental impacts due to increased soil erosion (Tiwari et al., 2009). In-depth studies taking account of both socio economic and bio-physical factors are needed for a timely and clear understanding of impacts of intensification and for developing strategies to mitigate adverse environmental impacts by promoting sustainable intensive production systems. The sustainable agricultural intensification in this context is similar to FAO (2004) definition, where, agricultural intensification activities do not degrade the natural resources while considering the need to improve the livelihoods of the people who work on land, particularly in developing countries.

Nepalese agricultural is facing the problem of decline in soil quality and soil productivity (MoPE, 2000). In spite of increasing trends of chemical fertilizer use, irrigation and improved seed varieties, the yield rate for cereal crops has not changed significantly. For example, the data of 1975-1995 shows that the yield rate has increased for paddy from 2 to 2.5 metric ton per hectare per year and for wheat from 1.2 to 1.6 metric ton per hectare per year (MoPE, 2000). In a similar manner, the yield rates of maize, barley and millet remained static at 1.8, 1 and 1.1 metric ton per hectare per year respectively. These values are very low compare to the yield rates from other South Asian countries (George, 1994; Saleem, 1994; Alauddin and Quggin, 2005). There is also a trend of shift in cropping pattern in areas with increased access to road network and market.

## **1.2 Agricultural policies and process of intensification**

The national policies and plan of Nepal focus on the reform of agricultural sectors. This can be inferred from the long-term vision of the agricultural sector i.e., to convert subsistence farming system into professional and competitive for the upliftment of living condition through sustainable agricultural development (NPC, 1995). Furthermore, there is a more specific national policy to increase food production per capita from 277 kg to 426 kg by 2017 (NPC, 1995). In line with the national goals, agriculture is gradually transforming toward commercialization from subsistence system (NPC, 2007). Agricultural intensification is a growing trend in certain accessible areas in the mid hills of Nepal. About 44% of the total population lives in middle hill region, which covers 42% of the total land area of Nepal (CBS,



2003). These areas have access to roads, markets, inputs and institutional development and are generally close to the semi- and peri-urban areas.

Since traditional farming practices are unable to fulfill the increasing food demand, and there is little scope for expansion of agricultural land, production must be increased per unit area. Agricultural intensification thus becomes essential to fulfill the increasing food demand and to uplift the living standards of farmers. The global driving factors of intensification are population, income opportunities, access to road and markets, agricultural inputs and support from external organizations (Dahal, et al., 2008). The focuses of agricultural policies of Nepal have also led to intensification (NPC, 2007). The Nepalese farmers have legal right to land ownership and the privileges that go with such private ownership, however, many farmers are merely tenant farmers and do not necessarily own the land they cultivate. However, access to roads, markets, agricultural inputs and land investments may have caused substantial variation in the levels of intensification in different parts of the country.

### **1.3 Rational of the study**

Agricultural intensification is perceived as a major issue in many developing countries, particularly in hill regions of Nepal, due to its multiple positive and negative implications for both human livelihood and environmental quality. Agricultural intensification is practiced in selected areas in the hills (which covers forty two percent of the total area) where forty four percent of the total population live in (CBS, 2003). The areas with access to road, market, inputs and institutional development and generally close to the semi- and peri-urban areas are most potential for agricultural intensification. The traditional farming practices are unable to fulfill the increasing food demand since most of the districts of Nepal are under food deficit condition (CBS, 2003). Agricultural land expansion is an option for food production but there is little scope for expansion of cultivation land (Pingali and Rosegrant, 2001). Therefore, production needs to be increased through sustainable agricultural intensification.

There are socio-economic and environmental aspects of agricultural intensification. For the economic growth, agricultural intensification is beneficial particularly in the short term (Lee et al., 2001) but long run synergies between intensification and environmental quality is not clear (Lee and Barrett, 2001). Some studies (Katwal and Sah, 1992; Matson et al., 1997; Timsina and Upreti, 2002) support intensification due to its contribution towards higher crop

yield and increase in farm income. However, environmental issues of soil loss and decline in soil fertility are raised by numerous studies (Metz, 1991; Subedi and Gurung, 1991; UNEP, 2001; Ananda and Herath, 2003). Soil and nutrient loss eventually affect the crop production and cases of such been reported in (Schreier et al., 1994; Subedi and Gurung, 1991; UNEP, 2001; Thapa and Paudel, 2002; Acharya et al., 2008). However the enhanced anthropogenic (accelerated) erosion in context of Nepal is poorly studied. So far, there have been numerous socio-economic or environmental studies conducted separately. Studies dealing with the nature of intensive farming systems and their impacts on socio-economic status of rural communities and on environmental quality are limited.

In intensive agriculture, the increasing dependence on chemicals is considered to be environmentally problematic (Matson et al., 1997; Miller, 2004). However, Guthman (1997) considers these issues to be of social construction. The social and environmental relationships with agricultural intensification are not adequately understood in Nepal. Hence, there is a distinct research gap in establishing a cause-effect relationship between socio-economic factors and environmental quality, as well as identifying a truly acceptable view on the impacts of intensification from a holistic and interdisciplinary perspective in the middle mountains of Nepal. Whether and how intensification affects the socio-economic condition of farmers, soil and nutrient losses, and water quality are questions, hitherto unanswered, that this study will address. These types of studies are needed for a timely and clear understanding of impacts of intensification and for developing strategies to mitigate adverse environmental impacts, in view of promoting sustainable intensive production systems. The main focus of the study is to establish if there is a relationship between the indicators of agricultural intensification (cropping patterns and inputs) and impacts on socioeconomic conditions (income and living standards) of local communities and on environment (soil and water quality).

#### **1.4 Agricultural intensification and socio-economic conditions**

Agricultural intensification focuses on higher production to raise the economic condition of farmers. However, agricultural intensification involves not only economic aspects but social and environmental aspects as well. Hence, the study of agricultural intensification and its broader impacts is an important issue in farming communities of many countries. Most of the critical studies on intensification focus on the negative environmental aspects of increased soil

erosion, soil fertility loss, biodiversity loss, pollution of soil, water bodies and atmosphere due to intensification (Metz, 1991; Matson et al., 1997; Templeton and Scherr, 1999; Ananda and Herath, 2003). Very few, however, have highlight the impacts on society, in terms of socio-economic conditions, food security and health (Carswell, 1997; Paudel, 2002; Upadhyay, 2004). These issues are very much related. Enhanced soil erosion will affect total production and on-farm income, which will ultimately affect the socio-economic condition of farmers. Agro-chemicals used in intensive agriculture are also the concern of human health, particularly as they infiltrate into the water system and food chain. So far, there have been numerous socio-economic or environmental studies conducted separately. Studies dealing with the nature of intensive farming systems and their impacts on socio-economic status of rural communities and on environmental quality, however are limited. In light with the multiple impacts of intensification, a more detail study on the process and impacts of intensification from historical, social, economical and environmental perspectives was carried out in this study (Paper I).

### **1.5 Intensification and soil/nutrient losses**

The main factors threatening the sustainability, in terms of production and environment, of Nepalese agriculture are soil erosion, decrease of the vital organic matter and losses of other crop essential soil nutrients (Thapa, 1996). Due to high inherent vulnerability (e.g. steep slope, high rainfall), soil erosion from agricultural land is a serious problem in the Himalayan middle mountains. On top of this, agriculture intensification could contribute to even higher soil and nutrient losses in various ways. For example, crop intensification has an implication for crop management factors (C factors) and support practice factor (P factor) defined in Universal Soil Loss Equation (Wischmeier and Smith, 1978; Lal, 2001). Depending upon choice of crop, cropping intensity, and other crop intensification related factors, soil and nutrient losses rate could be higher in the intensified system. Very few studies explore soil and nutrient losses in context of crop intensification despite several studies available in investigating physical soil losses measurements from Nepal (Tiwari et al., 2009). We were able to investigate this through a systematic field experiment in this work (Paper II).

### **1.6 Watershed water quality in intensive cropping areas**

Agricultural intensification requires more nutrients to increase the yield. The changes in cropping patterns are demanding higher amount of chemical fertilizer and pesticides in the

middle mountains of Nepal (Saleem, 1994; Brown and Shrestha, 2000; Atreya, 2007). However, use of agro-chemicals leads to negative impacts on water quality (Singh, 1994). There are worldwide concerns on river water quality but studies on the adverse impacts of intensification on river bodies are limited. Most of the studies on river water quality in Nepal mostly focused on water chemistry (Jenkins et al., 1995; Collins and Jenkins, 1996; Collins and Neal, 1998). Hence our study was carried out to assess the river water quality by comparing agricultural intensive and non-intensive watersheds in terms of water chemistry, microbiological water quality and abundance and biomass of macroinvertebrates in river ecosystems (Paper III).

### **1.7 Sustainable agricultural intensification**

Fulfilling the present needs while also considering the needs of future generations is the sustainable approach (Redclift, 1987) that also applies in the agricultural sector. Though agricultural intensification leads to increased production through efficient use of inputs, positive vs. negative effects of agricultural intensification from natural and social science perspectives are highly debated (FAO, 2004). Statements such as ‘Intensive production can have negative local, regional and global consequences’ (Matson et al., 1997: 504) and ‘intensified production systems are environmentally beneficial, technically appropriate, economically viable, and socially sound’ (World Bank, 2003: 1) are examples of such discussions. For a sustainable agricultural development, productivity, stability, sustainability and equitability are important (Conway, 1985). While there are constraints for the use agricultural technologies, including limited access to inputs, roads, markets and initial cash, Nepalese farmers have started agricultural intensification in some areas. Sustaining the livelihood and food security with this shift is still unclear hence this study focused on reviewing the issues and outcome of agricultural intensification (Paper IV).

## **1.8 Objectives of the study**

The overall objective of this study is to evaluate the effects of agricultural intensification on socio-economic conditions of the local communities and on the biophysical environment, namely soil and water, in Kavre district, Nepal.

The specific objectives are:

1. To examine the socio-economic conditions of rural farmers engaged in intensive and non-intensive agricultural production system (Paper I).
2. To assess the soil and nutrient losses from farms under intensive and non-intensive cropping patterns in the study area (Paper II).
3. To determine the impact of intensive agriculture on stream water quality of the watershed (Paper III).
4. To understand the linkages between the socio-economic and biophysical factors associated with sustainable intensive crop production (Paper IV).

## **1.9 Conceptual framework of the study**

Intensified agriculture in the context of developing nations has socio-economic as well as environmental consequences. In socio-economic terms, intensification has contributed to higher yields, enhanced overall production, and return or income to farmers (Katwal and Sah, 1992; Matson et al., 1997; Timsina and Upreti, 2002). In environmental terms, however, intensification may contribute to soil erosion (Metz, 1991; Ananda and Herath, 2003) and fertility decline (Subedi and Gurung, 1991; UNEP, 2001). Cases of soil fertility decline and crop productivity loss have been reported in numerous studies conducted in Nepal (Subedi and Gurung, 1991; Schreier et al., 1994; UNEP, 2001; Thapa and Paudel, 2002; Bajracharya and Sherchan, 2009). However the enhanced and accelerated anthropogenic erosion in the context of Nepal is poorly studied. Enhanced soil erosion will affect total production and on-farm income, which will ultimately affect the socio-economic condition of farmers. So far, there have been numerous socio-economic or environmental studies conducted separately. Studies dealing with the nature of intensive farming systems and their impacts on both the socio-economic status of rural communities and on environmental quality are limited. Therefore, this interdisciplinary study was proposed with the primary aim to elucidate and improve understanding of the relationship between the indicators of agricultural intensification (cropping patterns and inputs) and impacts on socioeconomic conditions

(income and living standards) of local communities and on environment (soil and water quality). The overall theoretical context and conceptual model for the study are presented in Figure 2.

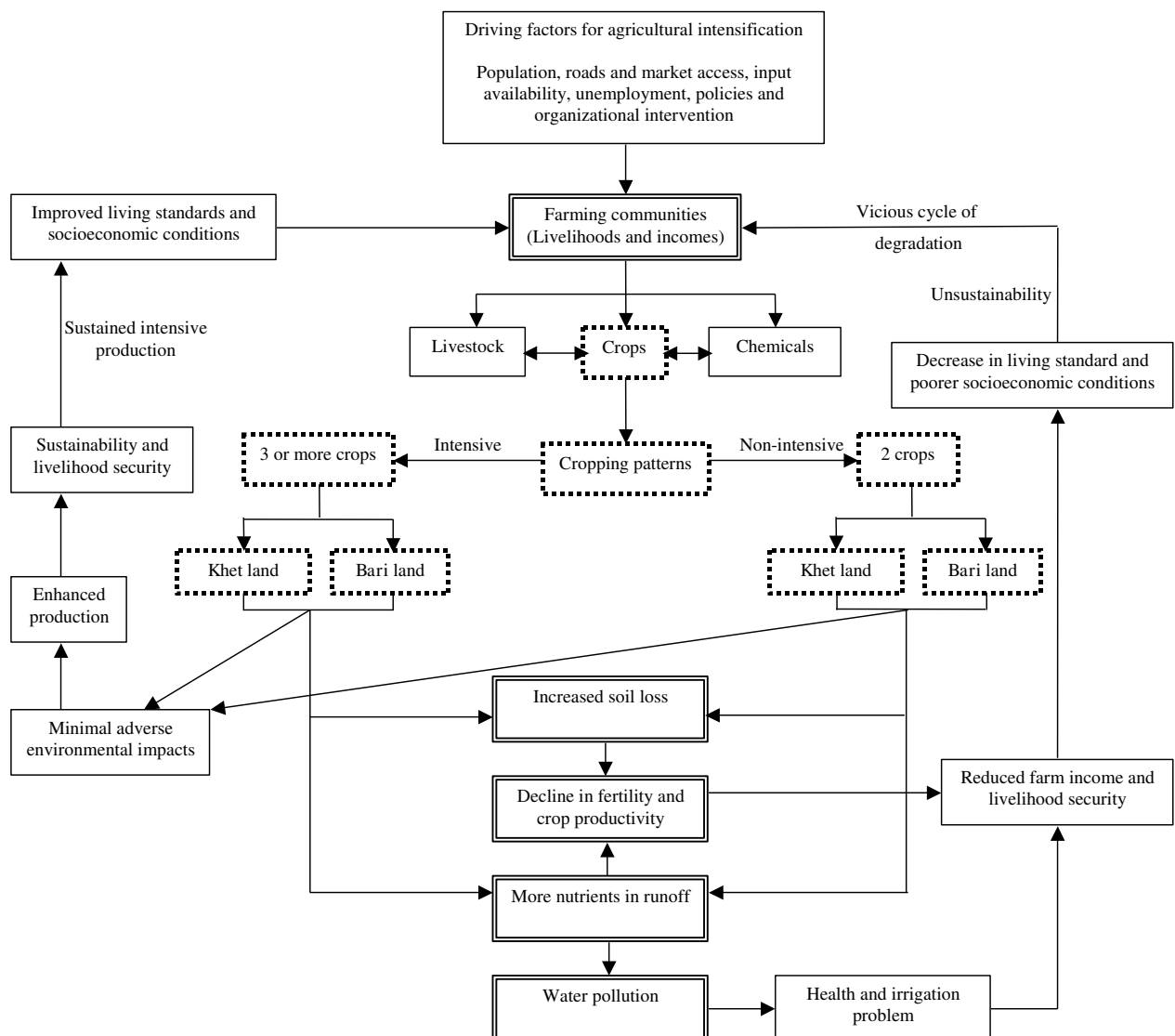


Figure 2. Conceptual model for evaluating the effects of agricultural intensification for this study.

The figure depicts the various factor or driving forces of agricultural intensification and its implications for cropping practices adopted by farmers, which ultimately has a distinct sets of impacts. On the one hand, intensive farming has potential consequences such as increased soil erosion and nutrient losses which affect both agricultural productivity and aquatic environments as well as downstream communities. On the other, intensive agriculture may lead to improved socio-economic status of local communities through enhanced agricultural production and other income generating activities. The latter pathway will require a carefully balanced and sustainable agricultural production approach to intensive agriculture. In the model, the dotted boxes are criteria for intensive and non-intensive conditions to compare

their effects on soil and nutrients losses, water quality, livelihoods and income (shown in double lined boxes). This study could only incorporate the linkages between dotted box and double lined boxes. The Khet lands are the irrigated and essentially flat lands, whereas the Bari lands are rain-fed and sloping terraces in the study watershed.

## **2. Materials and Methods**

The study addresses socio-economic and environmental impacts of agricultural intensification. The socio-economic investigation was carried out through a household survey, group discussions and individual case studies incorporating farmers from different wealth and caste groups practicing both intensive and non-intensive farming. With regard to the environmental studies, the amount of runoff from terraces, soil erosion and nutrient loss from both the intensive and non-intensive cropping system were compared through the establishment of research plots. The detailed methods relating to each specific objective are described in respective paper (see paper 1 – 4). A brief description of the overall materials and methods is given below.

### **2.1 Study area**

The study site, Ansikhola, consists of a small watershed (about 13 square kilometres) in Kavre district of Nepal. It lies between N 27°41' to 27°44' latitude and E 85°31' to 85°37' longitude and the elevation varies from about 800 to 2000 meters above sea level. The watershed lies along the Kathmandu-Melamchi road, about seven kilometres from the Araniko highway. The watershed comprises 1038 households with different (Brahmin and Chhetri, Gurung, Tamang, Rai, Newar, Kami, Damai and Sarki) cast/ethnic groups living together. Based on wealth rankings, households fell into three categories: large-scale, medium-scale and small-scale farmers. The watershed comprises 12 wards within four village development committees (VDC), namely Mahadevsthan (ward numbers one and two), Nayagaon (ward numbers one, five, six, seven, eight and nine), Anaikot (ward numbers six, seven and nine), and Devitar (ward number five) (see Figure 3). Ward is the lowest administrative unit and a VDC consists up to nine wards.

The study area was selected as representative of mid-hill watersheds of Nepal within moderate proximity of urban markets, where agricultural intensification is practiced. The site also represents a heterogeneous socio-economic situation with various caste and wealth status groups involved in agriculture. The area does not, however, represent remote watersheds in

Nepal, such as in the Mid-west and Far-west Regions, which could differ according to socio-economic conditions of farmers, proximity to markets, infrastructure development and inputs in the agricultural sector.

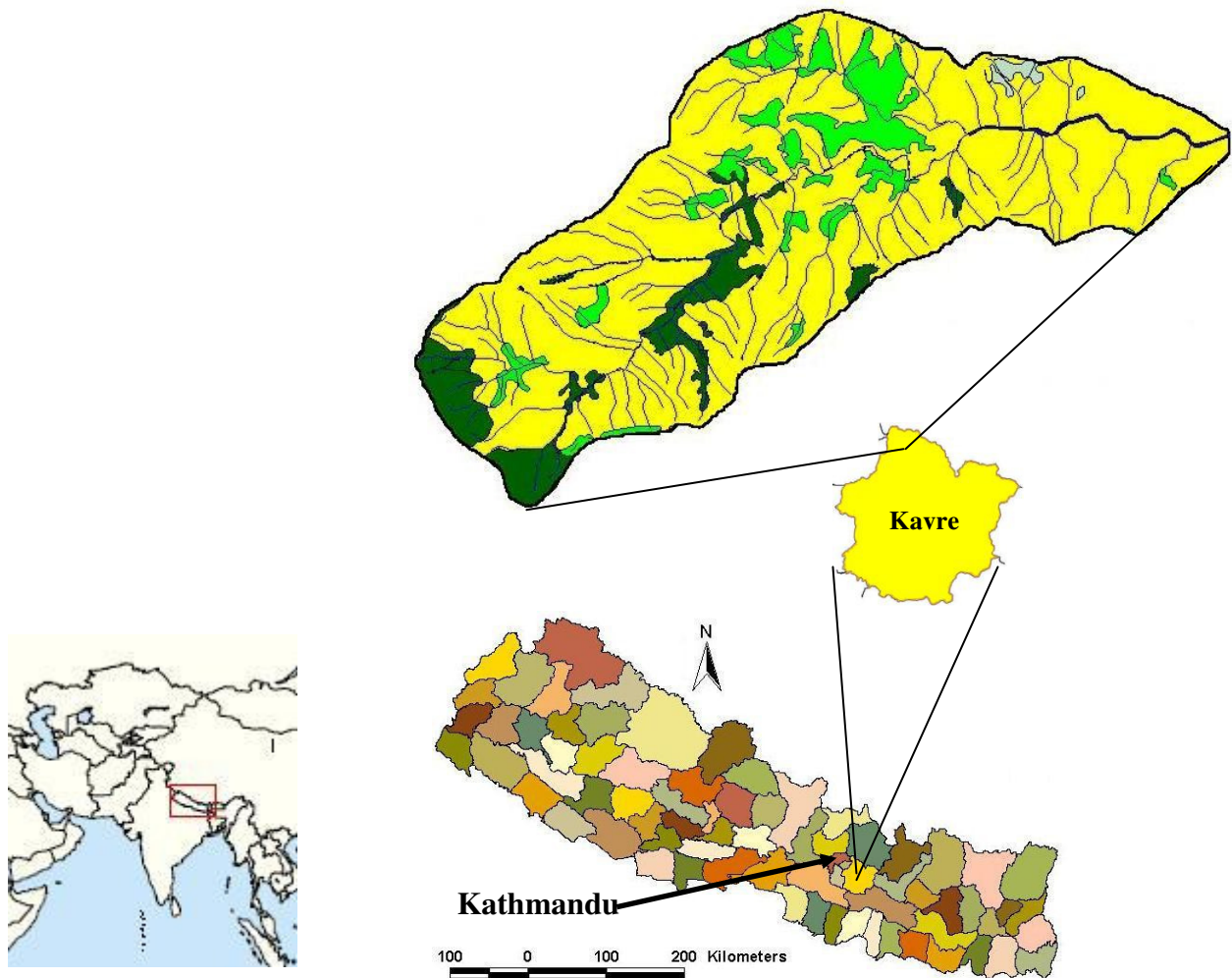


Figure 3. Map showing the study area in Kavre with reference to Nepal and South Asia

## 2.2 Land use and intensive cropping

The study watershed lies in mid-hills of Nepal at an altitude ranging from 800 to 2000 m above sea level. The land area of the watershed is dominated by agriculture (>80% cultivated land), forest (18%) and less than 2% covered by infrastructure and settlements. The majority of farmers have 0.5-1 hectare of land in total. Two types of agricultural lands, irrigated lowlands (Khet) and rain-fed upland terraced lands (Bari) were found in the study area. The crops grown were Paddy (*Oriza sativa*), Maize (*Zea mays*), Wheat (*Triticum aestivum*), Millet (*Eleusine coracana*), Potato (*Solanum tuberosum*), Mustard (*Brassica campestris*), and different vegetables. The major cropping patterns in Khet lands were rice-rice, rice-wheat or rice-maize whereas maize-millet or maize-wheat were grown in Bari lands. Additional



vegetables or potato are grown on both types land. Most of the farmlands supported up to three crops (two paddy and vegetables or potato in Khet and maize-millet or maize-wheat and vegetables or potato in Bari lands). The paddy crop is grown from April to June and the other paddy from July to October in Khet lands. Maize and millet are grown in monsoon and wheat or mustard during the winter months (see Table 2 in Paper I and Table 1 in Paper II). The recent trend of growing more than two crops and shift of cultivating maize-vegetable or potato or vegetable-potato in maize-millet system is sign of intensification in Bari land. Similarly, two paddy crops along with potato or vegetables are grown under intensive cropping in Khet lands. The factors leading to increased agricultural intensification in the study area are roads, market, and input access as it is situated at close proximity to Kathmandu the capital city.

### **2.3 Research methods and design**

The study used both quantitative and qualitative research methods applicable to both socio-economic and environmental studies. The socio-economic study was carried out through household surveys, group discussions and individual case studies to analyze socio-economic conditions of farmers, the processes and development of intensification, and agricultural sustainability. The environmental study focused on the effect of intensification on soil and water qualities which were analyzed through the establishment of research plots to monitor soil and nutrient losses, soil quality, application of nutrients and comparing the amount of soil erosion and nutrient loss from intensive and non-intensive cropping systems.

#### **2.3.1 Socio-economic conditions of farmers**

The socio-economic study was carried out through household survey, group discussions and individual case studies. The total households (1038) of the watershed were stratified based on wealth, caste and gender to study the changes in socio-economic conditions of people as described by Bagchi et al. (1998). Data were collected from 10% of the total households in the structured questionnaire survey, through four group meetings with 20 to 25 male and female participants, four wealth rankings and gender-specific discussions with 45 to 50 total participants. In different group meetings, about one-third participants were women. Personal interviews with total of 35 farmers, both men and women, and discussions with five key informants (long time resident of the area, well experienced on agricultural system, aged, and socially respectable person in the community), were used to evaluate the process of intensification and farmers perception on the effects of intensification (Refer paper I for details on the methods for socio-economic study).

### **2.3.2 Study on soil erosion and nutrient loss**

To monitor the soil and nutrient loss, four research plots in each cropping system (intensive and non-intensive) were established on farmer's fields. Each erosion research plot had two to three terraces (see Figure 2 of Paper II) with total area of about 40-50 m<sup>2</sup> in Bari system and about 100-300 m<sup>2</sup> in Khet system. The nutrients in terms of farm yard manure and inorganic fertilizers applied for each crops in the research plots were recorded. The soil erosion and nutrient losses were monitored regularly from the established plots. Runoff was sampled after each major rainfall event during the year 2005 and 2006 by collecting half to one litre of runoff water from the collection drums. The soil samples (0-15cm and 15-30cm) from the established experimental plots, runoff soil and runoff water samples were analysed in the laboratory for physical and chemical properties using standard methods. The physical properties such as soil texture was determined by Bouyoucous soil hydrometer (Gee and Bauder, 1986) and bulk density (BD) using soil core (Blake and Hartge, 1986). Similarly, soil organic carbon (SOC) by Walkley-Black (Nelson and Sommers, 1982), total nitrogen (N) by Kjeldahl's method (Bremner and Mulvaney, 1982), available phosphorus (P) by modified Olsen's (Olsen and Sommers, 1982), exchangeable potassium (K) by flame photometry (Knudsen et al., 1982) and pH with a digital pH meter with 1:1 soil water ratio (Mclean, 1982).

### **2.3.3 Study on water quality of rivers**

Eight sites (five in Ansikhola and three in Chakhola) were selected based on cropping frequency, accessibility and altitudinal variations for river water quality assessment. Two sites were considered as reference sites based on criteria as described by Hughes (1994) and Reynoldson and Wright (2000). Temperature, pH and conductivity of water were measured using temperature, pH and conductivity probes (WTW-Germany) respectively. Water samples were analysed in lab using Atomic Absorption Spectrophotometer (Thermo Electron Corporation) following standard methods: APHA (1995) for Pb, Cu, Zn, Na, K, orthophosphate, APHA (1989) for Ammonia, and Jenkins and Medsker (1964) for Nitrate. For biological water quality assessment, samples were collected from multiple habitat using different collection techniques such as kick sampling, multi habitat sampling, hand picking, and using a Surber sampler. The biota samples collected were preserved in 75% alcohol (for qualitative samples) and in 5% formalin (for quantitative samples). NEPBIOS (Moog and Sharma, 2001) index is used for the calculation of water quality after sorting and identifying the biota. A Portable Water Testing Kit (OXFAM – DELAGUA, UK) was used for Faecal

coliform (FC) and total coliform (TC) count in 42 drinking water source sites (see Paper III for further details).

#### **2.3.4 Review of sustainable agricultural intensification**

A review of global driving factors on intensification through available literature is carried out to synthesise current knowledge on the impact of agricultural intensification on livelihood, food security and environment of Nepal. The role and linkages of different driving factors of intensification were analysed through available secondary data, till the year 2004 (FAOSTAT, 2004). The review developed a cyclical process of agricultural intensification as presented in Paper IV.

#### **2.3.5 Other data acquisition**

The climatic data (rainfall, temperature and atmospheric pressure) from 2004 to 2007 were measured and recorded daily at three weather stations in Ansikhola and one station in Chakhola watersheds established by Kathmandu University, Nepal. The initial information on household heads, use of agricultural inputs and external interventions in the study area were acquired from local level village development committees, user groups and other organizations working in the study area. The extraction of land use pattern and development of watersheds area map is done from NGIIP/Nepal (1995) data.

#### **2.4 Statistical analysis**

The field and laboratory analysis data were computed in MS excel and statistical tests such as analysis of variance (ANOVA), multiple comparison of means using Student-Newman-Keuls (SNK) at  $<0.05$ , and calculation of range and standard error of means (SE) were done by means of the statistical packages SPSS and SAS. Qualitative information such as progress and process of intensification, decision making process by household members, access and priority use of resources, individual perceptions and experiences were documented through focus group discussions, key informants, and individual interviews. This information was helpful for relating the results of field and laboratory analysis to social context for better understanding of the impacts of sustainable agricultural intensification.

### 3. Results and Discussion

#### 3.1 Impact of intensification on socio-economic conditions of farming communities

The study in Ansikhola watershed showed that an historical shift towards intensified agriculture has diversified the cropping in two ways. The non-productive, pest and disease prone crops with low market value were successively abandoned, where as high demand and high value crops like potato and out-of-season vegetables were systematically introduced. Similarly, change in food habits and social-cultural preferences have led to adoption of crop varieties like tomato, onion, mushrooms in these rural communities (Paper I). Other examples include ginger (*Zingiber officinale*) which has been introduced in Bari lands within the past one or two years. Likewise, potato cultivation has been extended to upper and lower part of the watershed.

Intensification has distinctly affected the social structure in the study area through socio-cultural shifts. The traditional labour-based professions (like lower caste Kami<sup>1</sup>, Damai<sup>2</sup>, and Sarki<sup>3</sup>) were discontinued or transformed to cash-based, rather than kind-based, services in terms of their wages (Paper I). Similar studies (Brown and Kennedy, 2005 in Nepal; Ali, 2007 in Bangladesh) reported such a positive shift in socio-economic condition of farmers through cash or vegetable farming. Similarly, migration within or out of the watershed started due to access or land quality limitations and a desire to buy better land or property elsewhere. Such shifts are recorded by (Kumar and Hotchkiss, 1988; Bhandari, 2004; Tiwari, 2008) in similar watersheds of Nepal.

In comparison with conditions of gender inequity in earlier times, intensification has raised the awareness and level of equity through external interventions. Our study also found that there is an increase in awareness and level of self-decision among Nepalese women. Our findings support earlier gender equity studies of Bhandari (2004) and Upadhyay (2004). However, studies relating such development due to intensification have been limited. This study found that the wealth accumulation, property assets and social status were among the top priorities for the farmers engaged in intensification. However, the impacts or benefits of intensification have not been equal for all the households in the watershed as it has been influenced in response to wealth class, caste group, and proximity/access to road and markets.

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<sup>1</sup> Blaksmith

<sup>2</sup> Tailor and drummer

<sup>3</sup> Shoe maker

The large and medium farmers of high caste benefited most whereas small farmers and lower caste farmers benefited least. The reasons for this difference may be due to existing land size, land condition (lower ridged irrigated land), and capacity for initial investment (seeds, labour, fertilizers) which were more supportive to privilege than marginal farmers. These were also the factors affecting the adoption of agricultural intensification. The farmers who adopt intensification earlier are better off than who adopt later.

Numerous previous studies have emphasized environmental degradation (Mertz, 1991; Matson et al., 1997; Templeton and Scherr, 1999; Ananda and Herath, 2003) as resulting from intensified agriculture, but very few farmers engaged in intensification perceived such negative impacts. In this study, according to most of the farmers surveyed, the linkage between intensification and environmental degradation seemed to be unclear. However, there were also a few farmers who expressed concern over degradation due to intensification. Such a perception might have been due to the level of awareness and knowledge on environmental processes. Environmental degradation is generally not visible or readily expressed in the short-term, which is likely the reason that the farmers did not perceive such a threat in this instance. Such is probably not only the case in this watershed but might be reflected throughout the country or in South Asia where farmers are mainly concerned with maximum profits at present. Hence, sustainable agricultural intensification is an option to uplift the socio-economic condition of subsistence farmers. Practicing intensified agriculture, however, is not a viable option for certain groups of farmers due to their small land holding size, initial investments required, and lack of irrigation. Thus, the farmers who adopt intensification are generally those with better socio-economic status than those not adopting it.

### **3.2 Soil erosion and nutrient losses from farm-fields**

The study carried out on four replicate plots in two cropping intensities (2 crops vs. 3 crops) on upland farms showed high soil losses during the early and late seasons rather than during mid-season (July-August) i.e., regardless of the amount of rainfall. Major soil losses took place during the period of initial rainfall (pre-monsoon season) when there was bare or exposed soil with minimal vegetative cover. Correlation analyses indicated that soil loss was correlated with runoff ( $P < 0.01$ ). The soil loss ranged from 0.9 to 8.8 t/ha and 3.4 to 18.7 t/ha for the year 2005 and 2006 for 2 and 3 cropping systems respectively. The nutrient losses ranged from 260 to 280 mg/L for nitrate, 8 to 16 mg/L for phosphate, and 22 to 56 mg/L for ammonia in 2 and 3 cropping systems, respectively. The results suggested that increasing

cropping intensity from 2 crops to 3 crops led to significantly increased soil erosion and nutrient losses from the farm plots due to increased frequency of exposure of bare soil to rain. It was also found that the farmers in intensive cultivation area are using almost twice the amount of fertilizers than recommended by the National Agricultural Research Council.

### **3.3 Water quality assessment in agricultural intensified watersheds**

The physio-chemical parameters of water in many parts of the country show that the rivers or streams flowing through intensively cropped areas are slowly degrading. For example, Collins and Neal (1998) noted that the values of ammonium, nitrate and phosphate in a number of streams in the central mid-hills of Nepal increased over a period of two years compared to an earlier study by Collins and Jenkins (1996) in the same streams. In the present study, the mean concentration of nitrate in the study watersheds (Ansikhola and Chakhola) was more than 10 times higher than the values (<1 mg/L) recorded by Jenkins et al. (1995) in different streams of middle and high Himalayas of Nepal. Similarly, the concentrations of basic cations in the streams in the study watersheds also differed from other similar middle mountain watersheds (Jenkins et al, 1995; Collins and Jenkins, 1996; Collins and Neal, 1998). The higher level of nitrate and phosphate in studied watersheds suggested the use of ever-increasing amounts of inorganic fertilizers by the local farmers practicing intensified cropping.

A comparison of the two adjacent watersheds which had distinctly different levels of intensification, Ansikhola, (intensive) showed almost twice amount of sodium and potassium in the stream water than Chakhola (less intensive). Sodium and potassium in Ansikhola was observed to be 9 and 5 mg/L, respectively, where as it was 6 and 3 mg/L in Chakhola, respectively. Both the streams showed increased biomass and abundance along with the nutrient loading in the rivers. Macroinvertebrate taxa composition was high in Ansikhola compare to Chakhola. Both the rivers showed degrading water quality as they run from source to the lower valley. However, comparing the two streams, the water quality of the less intensive watershed was found to be 'less polluted' (according to the NEPBIOS score) than water quality of intensive watershed reflecting that the intensification of farming activities clearly affects the water quality.

The annual fertilizer application increased in Nepal by about 22% over the last forty years (FAOSTAT, 2004) prevailed by the misconception that high doses of chemical fertilizer

application increases productivity. In reality use of chemical fertilizer deteriorates water quality of the rivers and raises production costs. A very high concentration of nitrate (52.8 mg/l) detected in river water at the time of potato and off season vegetable production in Ansikhola is a clear sign of intensification practice in the watershed. High sodium and potassium concentration detected in river water is an indication of excessive tillage operations, availability of irrigation facility and fertilizer inputs; the three major driving factors leading to agricultural intensification in the region besides the market driven production.

### **3.4 Sustainable agricultural intensification for overall development**

According to the Food and Agriculture Organization of the UN (FAO, 2004: iv), sustainable agricultural intensification is defined as ‘the agricultural practices that do not degrade the natural resource base while also taking into account the need to improve the livelihoods of the millions of people who work the land, particularly in developing countries’. Sustainable agricultural intensification focuses on livelihood enhancement while simultaneously striving to improve the land and environment through intensive cultivation. Such development without environmental damage is a major challenge for the modern day world. Increased agricultural production is an ever-growing requirement to fulfill the food demand and poverty reduction in Nepal (Pyakuryal et al., 2005). But how to achieve this increase in productivity is still a debatable question. Boyd and Slaymaker (2000) have countered the argument that increasing population and intensified agriculture automatically leads to high erosion rates. They claim that it is possible to achieve higher production with less environmental impacts through more careful management under intensified as opposed to non-intensified agriculture. This could be possible even within the Nepalese context. Similarly, Conway (1985) has listed four major themes (productivity, stability, sustainability and equitability) to achieve sustainable agriculture.

Nepal has shifted from being a net food exporter to net importer in the period post-1970. Now-a-days, about half of the districts in Nepal face some sort of food deficit condition. Agricultural intensification is occurring as national policies are in favour of it (NPC, 1995) but as yet this is practiced in only a few locations (Carswell, 1997; Schreier et al., 1997; Gautam et al., 2003) due to unavailability of labour, limited road and market access, lack of fertilizer inputs, lack of irrigation, lack of high value crop varieties, lack of external intervention, and so forth. In some cases, the geology and terrain are not suitable or hamper

agricultural activities, obstruct construction of access road, irrigation canals and other infrastructure required for intensive agriculture. Usually agricultural intensification is conceived as positive process towards livelihood sustainability (Carswell, 1997). It can be an important strategy to increase food production as well as to improve the livelihoods of local farming communities. Agricultural intensification occurring in Nepal has to be in a sustainable manner otherwise rapid economic growth through intensification may increase disparity between well-to-do farmers (large and higher caste farmers in our study) and disadvantage groups (small and lower caste farmers in our study). In Nepal, sustainable agricultural development is possible, for households with access to enough land and other resources, through the selection of appropriate crops, balanced application of nutrients, judicious use of pesticides, irrigation water management, and adoption of appropriate conservation practices. Enhanced farmers awareness and strong government policies are also important for sustainable intensification (Paper IV).

#### **4. Conclusions and Recommendations**

This study has shown that the intensification of agriculture has effects both on the socio-economic conditions of farmers and on the environment. The economic condition of rural farmers was observed to be uplifted with the advent of road access to markets, increased irrigation facilities. Women from all castes became more educated and aware than before in the studied watershed. The impacts of intensification, however, were not observed on equal basis to all the households, as this is influenced by wealth class, caste, and proximity and access to inputs, road and markets. Agricultural intensification thus appears to have number of positive effects on society and need to boost this process in a sustainable basis. The government policies and programs should focus on uplifting rural poor with inadequate access to agricultural resources.

Degradation of river water quality as revealed by high concentration of nitrates indicated clearly that the high doses of inorganic fertilizers input in to the soil environment tends to lead to nutrient loading in streams. High levels of salt ions (sodium and potassium) in one of the studied watersheds is further evidence of the effects of increased tillage and irrigation, the main forms of agricultural intensification. The possible negative effects in terms of soil and nutrient losses should be addressed in a timely manner by various stake holders (farmers, non-governmental and governmental organizations) through proper extension and soil conservation services. The soil and nutrient losses problems could be addressed by



popularising integrated pest management, biodynamics or organic farming, and conservation practices for cultivation of crops that demand high fertilizer and pesticide inputs.

Sloping agricultural terrain, irrigation availability, access to roads, markets and agricultural inputs, and previous national policies are the main factors limiting agricultural intensification in Nepal. Revised agricultural policies aim to transform subsistence farming to commercial, competitive, and sustainable agriculture to uplift the socio-economic condition of people. The vision of the agricultural plan is towards agricultural intensification. Intensification is increasing and it is likely that it will be unavoidable, indeed imperative in the years to come.

The outcomes of agricultural intensification appeared to include improved economic and social conditions for at least some of the farmers who are able to adopt intensification measures, and policies to improve particularly the poor's ability to intensify their production would be an important step towards ensuring food security in Nepal (Paper I). However, the observed environmental impacts in terms of soil erosion and fertility loss (Paper II) and decline in river water quality (Paper III) suggests the need for due consideration of more comprehensive, long term agricultural policy to increase agricultural production on a much more sustainable basis (Paper IV).

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## Appendix

Plates showing land use and other activities in the study area.



1. Bird's eye view of the study watersheds.



2. Terrace farming in the study area.



3. Oxen are used in upland areas.



4. Tractor power is introduced in low land areas.



5. Focus group discussions.



6. Field level interaction and workshop







7. Inter cropping (Maize and Millet)



8. Intensive potato cultivation in the area.



9. River water quality monitoring.



10. Soil sampling.



11. Pesticides application in the crops.



12. Transportation of tomato to the market.



## **Part II: List of Papers**



## **Paper I**

Dahal, B. M., Nyborg, I., Sitaula, B. K., and Bajracharya, R. M. (2009). Agricultural intensification: food insecurity to income security in a mid-hill watershed of Nepal, *International journal of agricultural sustainability*, 7 (4): 249-260.



# Agricultural intensification: food insecurity to income security in a mid-hill watershed of Nepal

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A shift from cultivating cereal crops towards vegetables and other cash crops has evolved through the process of agricultural intensification in the hills of the Himalayan region. Agricultural intensification has attracted the attention of researchers in Nepalese agriculture due to its potential impacts on the environment and socio-economic status of farmers. Nevertheless, socio-economic drivers of agricultural intensification are as yet poorly studied in the Himalayan region. Farmers' perceptions of the effects of agricultural intensification on society and the environment are analysed in the Ansikhola watershed of Kavre district, Nepal. Before the onset of agricultural intensification, food sufficiency was the primary measure of the economic condition of farmers. However, in recent years agricultural income and profits have become key socio-economic measures. This study reveals that intensive agricultural practices shifted need-based cereal farming to market-oriented vegetable-based production systems, thereby improving socio-economic conditions for farmers. Positive changes in wealth and social status, migration from rural to urban areas, and shift in social division of labour are other important impacts.

**Keywords:** caste group, crop intensification, environment, farmers' perceptions, Nepal, socio-economic conditions

## Introduction

The dominant paradigm of agricultural intensification emphasizes production and economic returns, with the assumption that income increases are the only relevant impact for farmers. However, agricultural intensification has other multiple impacts on society as well as on the environment. Hence, it is an important and growing issue in many less developed countries.

Various authors view agricultural intensification from different schools of thought. Some of these viewpoints include: soil fertility implications of intensification (Von Westarp *et al.*, 2004); food scarcity and food insecurity (Bohle & Adhikari, 1998); linking population growth and environment (Boserup, 1965; Lele & Stone, 1989); market influences on intensification (Brown & Shrestha, 2000); poverty alleviation and sustainable livelihoods (Ellis-Jones, 1999; Brown & Kennedy, 2005; Pretty *et al.*, 2008); and technological changes (Upadhyay, 2004) or social changes (Bhandari, 2004). Numerous debates about the effects of agricultural intensification on social, demographic and environmental

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issues have been put forward in a global context, while others have emphasized singular perspectives such as social, economic or environmental.

The purpose of this study was to evaluate the process of intensification and its impact from different perspectives, namely historical, social, economic and environmental, through farmers' viewpoints. Earlier studies viewed agricultural intensification as primarily contributing to negative impacts like increased soil erosion, soil fertility loss, biodiversity loss, pollution of soil, water bodies and atmosphere (Metz, 1991; Matson *et al.*, 1997; Templeton & Scherr, 1999; Ananda & Herath, 2003). However, intensification need not always have negative consequences, but may also lead to positive impacts on society (Carswell, 1997; Paudel, 2002; Upadhyay, 2004). Hence, the question of positive and negative impacts is an important issue in the study of agricultural intensification. This paper focuses on the role of intensification in enabling farming households to shift from a food insufficiency situation to a condition where they can, for example, buy land and experience a variety of social changes.

Although the definition of agricultural intensification is not universal, it is broadly defined as the cropping of any land more frequently than before (Boserup, 1965). In more comprehensively defining intensification, researchers have considered cropping patterns, inputs, outputs and time intervals (Turner & Doolittle, 1978; Carswell, 1997). Hence, a precise definition of agricultural intensification depends on the perspective and context of observation. In the Nepalese context, a practical definition of agricultural intensification is an increase in the number of crops per unit area of land, per cropping season, with concomitant use of agrochemicals for enhanced crop yield.

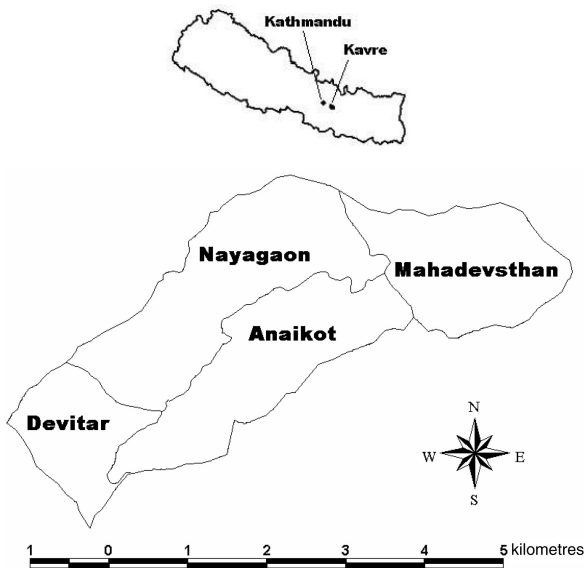
Governments and international organizations have promoted agricultural intensification as a necessary condition for satisfying economic growth, environmental sustainability and poverty alleviation in developing countries (Lee & Barrett, 2001). In Nepal, the livelihoods of hill farming communities are intimately associated with land and water resources (Bohle & Adhikari, 1998; Ellis-Jones, 1999; Pilbeam *et al.*, 1999; Ives, 2004; Brown & Kennedy, 2005). About 44 per cent of the total population live in the middle hill region, covering 42 per cent of the total land area (CBS, 2003). Increased agricultural production could

contribute considerably to economic development, yet at present intensified agriculture is practised only in selected areas of the hills of Nepal. These areas have access to roads, markets, inputs and institutional development and are generally close to urban areas (Thompson *et al.*, 1986; Pilbeam *et al.*, 1999; Brown & Shrestha, 2000; Brown & Kennedy, 2005). While increased yields are sometimes made possible by agricultural extension, the scope for further expansion of cultivated land is minimal in many places (Pingali & Rosegrant, 2001). In this region, increased production per unit area is the only means to meet increasing food demand and raise the living standards of farmers. Hence, increased agricultural growth needs to be achieved from the same land area, without causing deterioration to its condition.

Several factors influence agricultural intensification in Nepal, namely population pressure, access to markets, employment opportunity, transport facilities, agricultural land and inputs, institutional development and policies (Carswell, 1997; Templeton & Scherr, 1999; Blaikie *et al.*, 2002; Ananda & Herath, 2003). These factors may affect crop intensification in isolation or in combination, and in the short or long term. Most of the long-term effects of intensification are regarded as environmental. There are, however, ranges of socio-economic effects of agricultural intensification. To understand the overall impacts of intensification in Nepal, it is vital to analyse its social impact. Therefore, our study deals with the changes in wealth dimensions, social progression, migration, and shifts in payment for services through farmers' perceptions of the historic development of the intensification process at the local level.

## Study site description

The study site, Ansikhola, consists of a small watershed (of 13 km<sup>2</sup>) in Kavre district of Nepal. It lies between N27°41'–27°44' latitude and E85°31'–85°37' longitude and the elevation varies from about 800 to 2000 m.a.s.l. The watershed lies along the Kathmandu–Melamchi road, about 7 km from the Araniko highway. It is comprised of 12 wards within four village development committees (VDC), namely Mahadevsthan, Nayagaon, Anaikot and Devitar (Figure 1).



**Figure 1** Study area showing the four VDCs of the Ansikhola watershed in Kavre

There were 1038 households in the watershed, with 96 per cent being male headed. As in other watersheds in Nepal, people belonging to different caste/ethnic groups live together in the chosen study watershed. According to the legal code (Muluki Ain) of 1854, the present castes of the watersheds fall into three categories. Brahmin and Chhetri are in the higher caste group; Gurung, Tamang, Rai and Newar fall into the middle group; and Kami, Damai and Sarki are lower castes. Based on wealth rankings, households fell into three categories: large-scale, medium-scale and small-scale farmers. These wealth rankings also follow the caste categories, with most of the large-scale farmers being from the Brahmin and Chhetri castes, medium-scale farmers from the Gurung, Tamang, Rai and Newar castes, and small-scale farmers from the Kami, Damai and Sarki castes.

## Methods

The study is based on farmers' interviews and discussions. The total households of the watershed were stratified based on wealth, caste and gender. The livelihood trajectory approach (Bagchi *et al.*, 1998) is used for descriptive analysis and qualitative assessment of changes in the socio-economic conditions of people in the villages. Unlike the single-discipline approach, this study uses a framework based on an

interdisciplinary and triangulated (historical, socio-cultural, economic and environmental) approach. Farmers' perceptions regarding effects of agricultural intensification on society and the environment have been incorporated and analysed.

Informants and participants were selected in a random stratified sampling manner making up 10 per cent of the total number of households in the watershed. Stratification was based on wealth, caste and gender. Wealth ranking was done as described in Bagchi *et al.* (1998). Data was collected through four group meetings and four wealth rankings with 20–25 participants at each meeting. Similarly, two gender-specific discussions with 45–50 participants were organized. Personal interviews and case studies were conducted involving 35 households. Attempts were made to maintain equal representation of households based on different wealth status, caste groups, women and settlement areas. Selected household heads or their representatives in group discussions and personal interviews were aged from 18 to 85 years. From the different group meetings and informal discussions, five key informants were identified and important event-based information was verified through them. The ages of key informants ranged from 50 to 87 years. Analyses of individual case studies, focus group discussions and information from key informants and others were used to evaluate the process of intensification in the watershed.

The study area represented Nepalese mid-hill watersheds within moderate proximity of urban markets, practising intensified agriculture. The site also represents a heterogeneous socio-economic situation with various caste and wealth status groups involved in agriculture. The study findings may apply to other mid-hill watersheds with similar socio-economic situations, castes and wealth status groups. However, the findings might differ in other setups due to socio-economic conditions of farmers, proximity to road and markets, infrastructural development and agricultural inputs.

## Results and discussion

### ***Agricultural intensification and crop diversification***

The watershed shows more dynamic agricultural activities compared to the study of Blaikie *et al.*

(2002) in west central Nepal. This difference could be attributed to the proximity of urban areas, market demand, and other infrastructural development and setups. Discussions with key informants, personal interviews and group discussions indicated that agricultural intensification occurred in the study area mainly due to population pressure, availability of irrigation facility, road network, markets and control of malaria. Prior to the mid-1950s, villagers lived at the upper ridges of the watershed, as the valley was prone to malaria. They used to walk downhill for agricultural activities and return to their homes on a daily basis. According to the group discussions, even the lowlands were cultivated only during the summer season up until the 1960s. The fallow fields were used as grazing land for goats and cattle and raising fields for ducks. Farmers claim that the construction of irrigation canals and the eradication of malaria during the 1950s stand out as the main reasons for the onset of intensified farming in the lower parts of the watershed. Agricultural intensification in lowlands after the eradication of malaria might not be the case for all of the mid-hill watershed of Nepal. However, intensification in Terai also started only after the eradication of malaria (Adhikari & Bhole, 1999; Karki, 2002; Bhandari, 2004). According to the key informants in the study area, the introduction of inorganic fertilizers during the 1970s was another factor leading to the cultivation of spring paddy (along with summer crops). An influential and educated landowner was recognized as one of the key people in initiating the intensification process in the area. Locals agree that he was the first farmer to introduce spring paddy cultivation in 1973.

Farmers stated that crop diversification started in the watershed through a change in food consumption and cultivation patterns. Before the introduction of wheat in the 1970s, it was obtained by barter with maize grown in the watershed. In the western mid-hills, cultivation of wheat also started during early 1970s (Thapa & Paudel, 2002). Finger millet was one of the main crops in non-irrigated lands. Potatoes were first introduced here in 1952 and were exchanged for maize. Not all farmers started cultivating potatoes as soon as they were introduced and due to access to road, market and inputs (fertilizers and pesticides), it took almost 20 years for the commercial production

of potatoes. Nowadays, farmers cultivate potatoes 2–3 times in the same field in a year and it has become one of the major and highly produced cash crops of the watershed. The cultivation of potatoes, tomatoes and vegetables for enhanced income are also reported in similar watersheds elsewhere (Paudel, 2002; Ives, 2004; Brown & Kennedy, 2005; Pretty *et al.*, 2006; Tiwari *et al.*, 2008). Kumar *et al.* (2008) have reported crop intensification and diversification for economic growth in South Asian countries.

In the past, people also used to cultivate tobacco (before 1960) and sugar cane (prior to the 1980s) as cash crops, but later abandoned these crops due to pest problems. Hence, intensification in the study area not only resulted in an increase in the variety of crops grown but has also allowed farmers to discontinue cultivating some crops that had production constraints. Farmers noticed increases of weed, pest and disease problems, requiring higher amounts of inorganic fertilizers and pesticides every year, but expressed their unawareness of the cause. Hence, in spite of the fact that ‘crop choice impacts biodiversity and ecosystem services’ (Pretty *et al.*, 2008), farmers have not perceived this effect in the area and were less concerned about such effects until now. Table 1 presents the historical development of agricultural intensification in the study watershed.

A Japanese programme introduced commercial vegetable farming in Ansikhola in the early 1980s, before which fresh or dry leaves of rapeseed were the only vegetables produced in the area. Farmers stated that social norms forbid the consumption of onion, tomato and mushroom for the Brahmin caste groups. This could be one of the reasons for the lack of commercial cultivation of such vegetables in the area before 1980. Then tomatoes cost less than 1 rupee/kg, as compared to the current selling price of more than 10 rupees/kg. The cultivation of chilli peppers and bitter gourds started around 2000. Intensive cropping of bitter gourd cultivation resulted from its monetary value, which is 6 times or more than that of rice. Most farmers agree that the cultivation of vegetables and cash crops has raised their economic status, as opposed to cereal crop cultivation which is considered unprofitable. Similar shifts from cereals to cash crops for economic enhancement were documented in other watersheds

**Table 1** Historical development of agricultural intensification in the Ansikhola watershed

<b>Year</b>	<b>Activity</b>	<b>Performance or consequences</b>
1952	Potatoes introduced in the watershed	Initially gradually adopted by farmers, but at present a preferred crop
1954	Irrigation canal at Dhaitar, Mahadevsthan	One of the driving factors for intensification
1955	Cultivation of tobacco	Tobacco abandoned after 1963 due to pest problem
1955	Cultivation of sugar cane	Sugar cane abandoned after 1983 due to pest problem
1958	Eradication of malaria in lowlands	Migration from nearby hills; start of intensification
1965	Introduction of inorganic fertilizers	Another driving factor for intensification
1967	Construction of link road	Easy market access for products
1968	Tomato cultivation started	One of the major products of the area (now highly preferred)
1971	Introduction of spring wheat	Not cultivated in lower elevations after 2000 due to disease and profit
1973	Introduction of a spring paddy	Still in practice
1977	Commercial production of potatoes	The first choice of farmers
1983	Commercial production of tomatoes	Among the first choice of farmers
1998/2000	Commercial production of chilli and bitter gourd	Growing area increasing day by day

Source: Field survey, 2005–2006.

(see Paudel, 2002; Thapa & Paudel, 2002; Ives, 2004).

A shift from upper ridges to lower valleys in the watershed for intensive cultivation was encouraged by access to the road network. It revealed that the eradication of malaria in lowlands, land administration policies and the development of road networks encouraged the establishment of permanent settlements in the lower reaches of the watershed. In earlier days, the nearest market was at Bhaktapur (approximately 20 km away from the study area) and farmers had to walk the whole day, merely to buy salt, spices and vegetable oil. In the early 1970s, people tried to buy and sell local products by establishing a local market within the watershed area. However, it could not be sustained for more than three years, due to the lack of transportation for outside buyers. Now the products are sold in local markets of Bhaktapur and Kathmandu (approximately 40 km).

**Socio-economic conditions**

*Categories of farmers and labour*

Wealth ranking showed that prior to intensification, there were three broad economic categories of farmers, namely those who produced sufficient food crops for the whole year, those who produced enough for only 6 months, and those who produced amounts that last for less than 6 months. Most of the second and third economic class of people worked for daily wages, in addition to working on their own farms. In the past, the daily wages paid to labourers and potters were in kind (paid in local measures of ‘paathi’ – one paathi of wheat being approximately equivalent to 3.7 kg). Besides itinerant daily labourers, farmers with large areas of agricultural land had a tradition of employing a ‘hali’ (ploughman). Note that the hali employment practice in the watershed differs from the bonded labour or ‘Kamaiya’ system that was prevalent in the western part of the country (Karki, 2002). The villagers consider hali as a semi-skilled profession. The ploughman was paid with 1 paathi of cereal for a day’s work. Morning and evening meals were provided for the ploughman, and extra grain was paid on special occasions.

The ploughman system is now obsolete, due to social and political changes in the country. As

claimed by farmers, farmland is divided among sons as inheritance during household division; hence, land fragmentation due to this division among family members has resulted in smaller holdings per household, which made the keeping of a ploughman more expensive than hiring one on a daily basis. Land fragmentation during the division of households continues throughout the country (Adhikari & Bohle, 1999; Caplan, 2000; Bhandari, 2004). Subsequently, people preferred to work for daily wages rather than as ploughmen, as this provided more options for income. Farmers indicated that the exchange of labour between neighbours was also common and still practised in the watershed, but large farmers now hire labour on a daily wage basis. Exchange of labour is an age-old tradition still practised in many agricultural settings (Adhikari & Bohle, 1999; Caplan, 2000). Cereals like paddy, maize, millet and wheat were used for the payment of daily wages and for bartering with household items and spices. During the 1980s, the payment of daily wages shifted entirely from grain to cash.

### *Intensification and migration*

Before the advent of intensification, farmers constantly commuted to the valleys from the upper ridges for agricultural activities. During the journeys, the discussions among the farmers generally revolved around agricultural production as a way to fulfil their daily needs. However, farmers indicated that this trend gradually ceased after permanent settlements, establishment of milk collection centres and local shops emerged in the lower part of the watershed. At present, discussions centre mainly around profit and loss, agrochemicals and pest problems, focusing more on monetary considerations.

The farmers usually value their land based on location/land condition and productivity. The less productive upper ridges and non-irrigated lands have lower market values compared to irrigated and flat lands of the valleys. With an increase in income, farmers who previously had only non-irrigated land have been able to buy irrigated land and shift to the lower reaches of the watershed. Similarly, farmers with irrigated lands who adopted intensification are now in a position to buy land in towns and cities. Hence, intensification has directly affected the migration patterns of

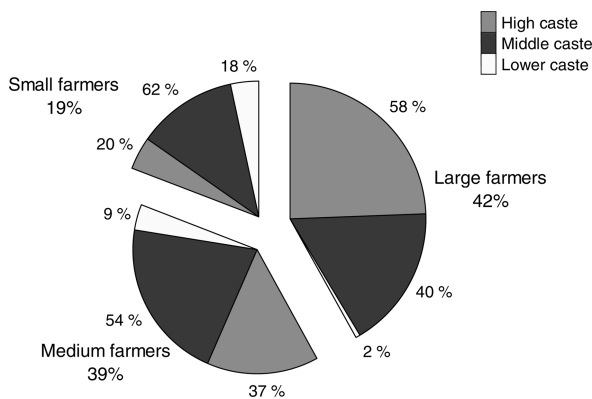
people in the watershed from one location to another. It is more common for people to move from less developed to relatively more developed areas, or from agricultural to non-agricultural areas like cities (Gurung, 1989; Shrestha, 1990; Skeldon, 2002). Rural–urban migration in Nepal was 25.5 per cent in 2001 and is not a recent phenomenon (CBS, 2003). Following the expansion of agricultural intensification, even small-scale farmers were able to generate profit from vegetables and other cash crops. Hence, they also started migrating to semi- or peri-urban areas.

The fixed assets (land/house) of those who migrate from the village are normally bought by other farmers within the watershed or by farmers who have migrated into the watershed from other areas. In his Terai case study, Bhandari (2004) found a higher proportion of migrants within lower caste groups. Other researchers (Gurung, 1989; Shrestha, 1990) claim that poor people migrate in search of or to increase their land holdings. However, our study revealed high migration to cities among the Brahmin and Chhetri caste groups, who are among higher wealth-ranked groups. The migration to cities is mainly for office jobs or business opportunity, good schools for children, hospitals, and other facilities not available in the present study area. Skeldon (2002) supports this phenomenon in the statement – ‘chance of migration is high for the more educated, better-off, innovative members having access to information’. It could be that poor farmers are not in a position to afford the risk and uncertainty of migrating, as pointed out by Skeldon (2002). Over the last 30 years, 15 families from Dhaitar and 40 families from the Mahadevsthan VDC migrated to cities.

### *Wealth accumulation and status*

Agriculture is still the main occupation of all the households living in the watershed. However, some people work in government services, teach in the schools or run small businesses, along with agriculture. The households of the watershed can be categorized into three major wealth groups (large, medium and small farmers), based on the criteria described by the locals during group discussions (see Figure 2).

According to wealth rankings, male-headed households (96 per cent) dominate the watershed.



**Figure 2** Household composition based on wealth ranking and caste groups

Also according to these rankings, 42 per cent of the households are large farmers, 39 per cent medium farmers and 19 per cent small farmers (see Table 2 for details).

We observed that the villagers continued to measure the economic condition of people in terms of food produced for self-consumption over a period of 1 year (Table 3). Agricultural production was also the only criterion of measurement before intensification. Along with intensification,

other measures such as the extent of land holdings became incorporated in the definition of socio-economic status. Farmers having more than 1 ha of agricultural land and sufficient production for their own consumption are now considered as large farmers. Other fixed assets like the number of houses, cattle and their use, are also taken into account in wealth ranking. Profession and level of education are measures of social status, along with economic condition. Although access to markets and the road network helped in the asset accumulation and investment in education, personal interview ranked agricultural intensification as the major contributor. Farmers claim that agricultural intensification has improved the economic conditions of rural communities and they can now afford education for their children. This also led to a shift from the custom of sending only boys to school, to schooling both boys and girls.

Fewer than 20 per cent of the households were considered small farmers, while large and medium farmers dominate the watershed (Figure 2). Large farmers were almost exclusively from the Brahmin and Chhetri caste groups (58 per cent) and medium farmers were mostly Gurungs, Tamangs, Rais and Newars (54 per cent). People from other castes were spread among medium and small farmers. The relationship between wealth ranks and caste groups showed that the Brahmin and Chhetri dominate other castes in terms of economic status. This settlement pattern and trend of socio-economic dominance by Brahmin and Chhetri ethnic groups also exists in many other parts of the country (Adhikari & Bohle, 1999; Caplan, 2000; Upadhyay, 2004). An analysis of wealth ranks within caste groups also supported the finding that there were few Brahmin and Chhetri in the small farmer category (8 per cent). The general impression that ‘the upper caste controls most of the fertile land and other resources in Nepal’ appears to be valid for this study watershed. In the group discussions, most of the farmers agreed that Brahmin and Chhetri were making further (and faster) progress than other castes because of agricultural intensification either through vegetable farming or milk production. The reason for smaller land ownership and lower economic status of other castes could be due to the fact that Kami (blacksmith), Damai (tailors and drummers), Sarki (leather workers) and other groups are involved mainly in their traditional occupations

**Table 2** Caste group and wealth ranking of the total households

Wealth ranking <sup>a</sup>	Caste group <sup>b</sup>			
	High (443) 43%	Middle (517) 50%	Low (78) 7%	Total (1038) 100%
Large (436) 42%	0.1806	0.210	0.0294	0.42
Medium (404) 39%	0.1677	0.195	0.0273	0.39
Small (198) 19%	0.0817	0.095	0.0133	0.19
Total (1038) 100%	0.4300	0.500	0.0700	

<sup>a</sup>Based on the criteria described in Table 3.

<sup>b</sup>Brahmin and Chhetri (high caste); Gurung, Tamang, Rai and Newar (middle caste); Kami, Damai and Sarki (lower caste).

**Table 3** Criteria used by farmers for wealth ranking in the watershed

Criteria	Wealth ranking		
	Large farmers	Medium farmers	Small farmers
Land	Owns more than 1 ha of agricultural land	Owns 0.5–1 ha of agricultural land	Owns less than 0.5 ha of agricultural land, or does not own any land
Property	Owns at least a house and a shed Able to buy seeds and fertilizers to cultivate in time	Owns a house Needs to borrow money from others to buy seeds and fertilizers to cultivate in time	Owns a small house or no house at all Usually not able to buy seeds and fertilizers to cultivate in time
Profession	At least one family member is in government service/teacher/business profession	Service/business is a secondary source of income	Labour or daily wages along with agricultural profession
Education	More than one family member is literate Able to send their children to private school	At least one family member is literate Able to send their children to government, but not private, school	Illiterate family Difficult to send children to school
Cattle	Owns more than one milking cow/buffalo Can sell up to 5 litres of milk per day	Owns at least one milking cow/buffalo	No milking cattle
Production	Agricultural production is more than enough for a year's food requirement Sells paddy, maize, wheat and seasonal products like potatoes, tomatoes and other vegetables	Agricultural production can be sustained for 6 to 12 months	No agricultural production, or that which can be sustained for less than 6 months

Source: Field survey, 2005–2006.

rather than in agriculture. However, within lower-caste group farmers, higher economic status occurred among vegetable producers as compared to traditional, non-intensive farmers.

Before agricultural intensification, there used to be regular service and labour exchange between the Brahmin, Chhetri and other caste groups, which was beneficial and promoted frequent social interactions locally. Groups without agricultural land or non-farmers could earn cereals in exchange for their specific professional skills. Expert blacksmiths, leather workers, tailors and drummers were paid at the rate of 5.4 kg of paddy multiplied by the number of family members in a

household per year by the client farmers. Most of the farmers claim that these practices have now changed and as a result, the skills of the working castes are becoming obsolete. Similarly, the grains-based payment system has changed to cash only.

The Gurung, Tamang and Rai castes settled in non-irrigated, terraced upland areas, whereas the Brahmin and Chhetri were located more often in the flat lowland areas. Numbers of crops cultivated in level bench-terraced areas was high compared to sloping-terraced uplands (Dahal *et al.*, 2007). The higher wealth rankings of Brahmin and Chhetri could be due to settlement and to adoption of intensification earlier than other caste groups.

Yet another reason for the better socio-economic condition of Brahmin and Chhetri is milk production. From historic times, milk was one of the necessities for Brahmin and Chhetri, while other caste groups preferred making and drinking alcohol. Until 1972, milk production was confined to household consumption. With intensification, market-oriented milk production began in the area during the mid-1970s. While each household in the watershed sells an average of 5 litres of milk each day, production is higher within Brahmin and Chhetri castes due to their expertise in raising cattle. There used to be a trend of raising milk and non-milking cattle for the production of farmyard manure until the mid-1960s. Farmers report that this has shifted towards keeping only milking cattle (cows and buffaloes) and plough oxen. Hybrid cattle have replaced most of the local cattle varieties. Land preparation and ploughing was done manually or by oxen until around 1980. An apparent consequence of intensification is the hand-tractor (rotovator), which is gradually replacing ox-drawn ploughs on much of the irrigated lowlands farms. With the use of tractors, farmers claim that working the land has become easier, although productivity and income increases could not be clearly attributed to the use of the rotovator. However, rain-fed upland farmers continue to use the ox-drawn plough.

**Intensification and social division of labour**

The increasing workload has clearly allocated agricultural tasks between man and women. Focus group discussions revealed that household tasks like cooking, washing utensils and fetching water are equally shared among women and men in the Gurung, Tamang and Rai caste groups. Male Brahmin and Chhetri still considered the household tasks like cooking, washing utensils and fetching water as women’s tasks. However, women from these castes are comparatively more educated and aware than those from other caste groups. Therefore, it appears that decision-making levels and access to resources for women are greatly affected by socio-cultural norms and beliefs of the castes. However, the strict labour division of ‘this is a man task and that is a woman task’ is slowly being diluted in this society. The gender-based involvement for different activities is presented in Table 4. Similar social divisions of labour are also

**Table 4** Involvement of men and women in different agricultural activities in the watershed

<b>Agricultural activities and major involvement</b>	
<b>Men</b>	<b>Women</b>
Cash crops production	Cereal crops production
Ploughing of all kinds of land and puddling for rice plantation	Seed bed preparation, breaking the clods with hoes to smooth the land for maize, mustard, finger millet plantation
Terrace maintenance, application of inorganic fertilizer and pesticides	Planting, weeding, harvesting crops and carrying organic manure to field
Grazing, bathing, milking the animals and carrying milk to collection centres	Gathering fodder and bedding material, cleaning sheds and food preparation for animals

recorded in other watersheds (see Adhikari & Bohle, 1999; Upadhyay, 2004).

Since intensification, both men and women are participating equally in new types of agricultural tasks. The workload in terms of hours has actually increased for both men and women; however, tasks are simplified due to the adoption of new technologies in comparison with earlier days.

Historical evidence shows that social norms confined women within households, affecting their literacy, mobility and outdoor participation. However, in recent years, participation of women in the decision-making processes has increased. Most farmers realise that awareness and education have helped to bring women to the forefront of society. Both men and women expressed the fact that women’s involvement in credit and savings tends to be more successful than that of men. Public awareness, education and income savings rose along with the intensification process in the watershed.

**Farmers’ perceptions of intensification**

Farmers’ perceptions of agricultural intensification and its multiple impacts on socio-economic and environmental conditions were analysed through 35 individual case studies. Informants representing different age groups, caste groups and wealth ranks



were selected as mentioned in the Methods section. Individuals were asked mainly open-ended questions about how long they have been/lived in the area, what crops were grown during their childhood, what new crops have been introduced in recent years and so forth. They were also asked how they perceive agricultural intensification, when and why they believed intensification started, what the preferred crops were for intensification, what the benefits/drawbacks of intensification were, and if they noticed any change in socio-economic and water/soil conditions before and after intensification. The following four cases were chosen as reflecting the overall views of the 35 cases studied. The respondent names have been changed for anonymity.

Maize and millet used to be the main crops grown in the area when Bahadur (male, aged 85 years) was a child. Based on his account, only very few farmers cultivated paddy and wheat at that time. Inorganic fertilizers were introduced in his field in 1985 and potato, tomato, maize, paddy, millet and wheat are cultivated at present. He started cultivating potatoes only 5 years ago. According to him, the cultivation of potatoes, tomatoes and other vegetables draws more profit if one can invest in the requisite inorganic fertilizers, pesticides and labour. He did not know about the loss or improvement of soil or overall environmental conditions, but he has experienced a higher income due to intensification (more than three crops instead of the previous two crops).

Simala (female, aged 35 years) believes that intensification is possible in small land areas (up to 0.5 ha of land). According to her, it is difficult to perform intensive cultivation in larger areas due to insufficient fertilizers and a shortage of labour. She confided that tomatoes and potatoes need more pesticides and fertilizers, but the net profit yielded is high (5–6-fold profit) compared to other crops. She claims that cereal crops are now grown only for local consumption. She accepts that after the adoption of intensive cultivation, the socio-economic status of farmers has improved. According to her, income from food production is now sufficient for the whole year while previously the same farmer may have experienced a food deficit for 6 months. However, she claimed that she has experienced some fertility loss in paddy fields over the last 3–5 years.

Lokaya (female, aged 45 years) started cultivating hybrid varieties of maize 2–3 years ago. She eagerly awaits the arrival of irrigation facilities to cultivate vegetables and other cash crops. She believes that intensification is a positive trend to uplift the livelihood of farmers. She felt that raising cattle for milk production could also improve economic conditions. She does not believe that these intensification activities cause soil loss, degradation or other negative impacts on the environment.

Raj (male, aged 49 years) claims that irrigation has enabled the cultivation of more than two crops and has improved the socio-economic condition of farmers like him. According to Raj, farmers are now able to save earnings by selling surplus crops, compared to a food deficit situation earlier. Further, he believes that pest attacks, soil productivity loss, and cost of chemicals increased after the late 1980s. However, he claims that landslides and soil erosion losses have decreased in small terraces with the advent of intensification, due to regular land management and maintenance activities.

From the analysis of 35 cases, including the above examples, regarding the question of ‘impact of intensification on socio-economic condition’, about 90 per cent of farmers (31 out of 35) perceived a general improvement in socio-economic conditions. For them, it is one of the major impacts of agricultural intensification. Studies conducted in other watersheds also found supportive results of positive impacts, such as contribution to higher income and yields (Matson *et al.*, 1997; Tiwari *et al.*, 2008). Kumar *et al.* (2008) also concluded that intensive production could increase the farming economy in Bangladesh, India, Nepal, Pakistan and Sri Lanka. On a global scale, Carswell (1997) makes a strong point regarding the link between increasing quantity (production and incomes) and quality of livelihood of farmers through intensification. Our study supports this link, showing that the practice of agricultural intensification improves the socio-economic condition of farming communities in Nepal. From the individual case studies, it is also evident that all farmers have become more concerned with ‘money’ in terms of higher yield, profit and income, which was not the case prior to intensification. However, with regard to the question of ‘impact of intensification on

environment', only 11 per cent (4 out of 35) of farmers support the proposition that 'intensification process leads to water quality deterioration' (Dahal *et al.*, 2007) and that 'cropping frequency leads to degradation of land' (Templeton & Scherr, 1999). This is despite the fact that such effects have been demonstrated to exist in the area (Dahal *et al.*, 2007). This anomaly could be because farmers are not necessarily introduced to or fully aware of environmental degradation. Hence, farmers should be better informed about resource conserving technologies and practices as they also help to improve farmers' livelihood (Pretty *et al.*, 2006).

## Conclusions

Like the global concept of intensification, the types of crops that farmers are cultivating in the mid-hill field reflect the market-oriented and diversified nature of intensified cropping. The paper analysed the process and impacts of intensification from historical, social, economical and environmental perspectives. The paper concludes that: (1) intensification is an important strategy in agricultural commercialization and uplifting economic conditions of rural farmers; farmers have accepted and are adopting intensification practices in rural watersheds of Nepal; (2) the benefits of intensification are not distributed uniformly across households but vary by caste and proximity/access to road and markets; farmers in the lowlands are getting the maximum benefits of intensification; and (3) few farmers perceived the linkage between intensification and environmental degradation.

A recent study showed that water quality in the same study watershed has deteriorated with intensification (Dahal *et al.*, 2007). However, only a few farmers perceived that intensification leads to degradation. This could be because farmers are not adequately aware of ideas about degradation and that environmental degradation may not be visible in the short term. This might also be the case for similar farmers of South Asian countries involved in agricultural intensification. Similarly, the increasing demand for inorganic fertilizers and pesticides, coupled with the increasing cost of inputs, have the potential to cause farmers to opt for short cuts and inappropriate management practices, thus adversely affecting soil and water

quality. While there may be reasons for some farmers not to employ agricultural intensification (land holding size, initial investments, irrigation unavailability), this study noted that farmers who adopt agricultural intensification are better off than those who do not. Hence, agricultural intensification needs to be introduced in a sustainable manner in other parts of the country and region to raise the socio-economic condition of subsistence farmers.

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## **Paper II**

Dahal, B. M. (2010). Impacts of agricultural intensification on soil and nutrient losses in the mid-hills of Nepal (Manuscript).



# **Impacts of agricultural intensification on soil and nutrient losses in a mid-hill watershed of Nepal**

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## **Abstract**

Agricultural productivity in Nepal is highly affected by soil and nutrient losses. The national policy to promote the agro-production demanded agricultural intensification likely has put pressure on land and water resources. Thus, soil and nutrients from intensively cultivated lands in mid-hills of Nepal were monitored to analyse the rate of losses from intensive and non-intensive practices. The paper presents water runoff, soil erosion, and nutrient losses measured from multiple terraces in rain-fed and irrigated lands in Ansikhola watershed, in the mid-hills of Nepal during the years 2005 and 2006. The field trials were carried out on four replicate plots in two cropping intensities (2 crops vs. 3 crops) on lowland and upland farms. High soil losses during the early and late seasons and low amounts of soil eroded during mid-season (July-August) were observed regardless of the amount of rainfall. The soil loss ranged from 0.9 to 8.8 t/ha and 3.4 to 18.7 t/ha for the year 2005 and 2006, respectively. The soil nutrient losses ranged from 260 to 280 mg/L for nitrate, 8 to 16 mg/L for phosphate, and 22 to 56 mg/L for ammonia in 2 and 3 cropping systems, respectively. The result suggested that increasing cropping intensity from 2 crops to 3 crops led to significantly increased soil erosion and nutrient losses from the farm plots. This was presumably because of more soil manipulation in intensified cropping than in the less intensive (2 crop) treatments, and timing of farm operations causing the soil surface to be exposed at the critical times (early and late monsoon season). Hence carefully planned crop and soil management practices could mitigate these negative effects of intensification.

## **Keywords**

Agricultural intensification, Ansikhola, mid-hills, Nepal, runoff, soil erosion, terraces

## **Introduction**

Soil erosion from agricultural land is a serious problem in the Himalayan middle mountains of Nepal. Agriculture intensification has an important implications for soil and nutrient losses in various ways. Crop intensification has an implication for crop management factors (C factor) and support practice factor (P factor) defined in the Universal Soil Loss Equation (Wischmeier and Smith, 1978; Lal, 2001). Depending upon choice of crop, number of crops, growing cycles in relation to rainfall intensity and duration, soil and nutrient losses rates vary widely. In the mid-hills of Nepal, soil erosion and nutrient losses have been known to be

higher under intensive cultivation and just before the crop establishment (Sherchan and Gurung, 1992; Tripathi, 1997, Tiwari et. al., 2009).

In this study, the definition of agricultural intensification in Nepal was based upon Boserup (1965) – ‘cropping in a given area of land more frequently than before’. Agricultural intensification is practiced virtually everywhere and in most of the cases involves planting of multiple crops in same plots of land within an annual cropping cycle (Boserup, 1965; Pingali, 1990). National policies of Nepal put emphasis on farmers and land to achieve a high production goal (NPC, 1998). National policies aim to provide easy access to agricultural inputs, road network, marketing and other infrastructure development to achieve the goal. However, thus far, agricultural intensification has been practiced only in few places due to a lack of infrastructures and accessibility (see Dahal et al., 2009).

Farmers started agricultural intensification by increasing cropping frequency and intensity. In 1975, there were only 15 cropping patterns widely used across the entire nation, where as it by 1998 the number reached 26 (Adhikari and Bohle, 1999). Similarly, the cropping intensity increased from 130% in 1975 to 160% in 1998 (Paudel, 2002). Intuitively, crop intensification and forest degradation ultimately contributed to soil and nutrient losses affecting the land productivity.

Soil loss in Nepal was estimated to be 240 million metric tons every year (Jaishy et al., 2001; Thapa and Weber, 1991). Soil erosion in the mid-hills is still severe especially during the pre-monsoon and monsoon period (Gardner and Gerrard, 2003; Acharya et al., 2007; Tiwari et al., 2009). Gardner and Gerrard (2003) reported losses of soil ranging from 3 to 8 tons ha<sup>-1</sup> for 1993 and up to 13 tons ha<sup>-1</sup> for 1992. However, soil erosion rates are not uniform throughout the country or even across the watersheds of mid-hills. For example, in the Likhu Khola watershed, Gardner and Gerrard (2003) reported soil erosion loss of 39 to 316 gram per square meter (equivalent to 3 tons ha<sup>-1</sup>) in a single event. Similarly, Shrestha (2000) reported soil loss of 1 to 20 tons ha<sup>-1</sup> y<sup>-1</sup> from degraded forest and rangeland. The soil losses are found to be different in different land use type and intensity. Values of 70 tons ha<sup>-1</sup> y<sup>-1</sup> in Andhikhola watershed (Pahari, 1993) and 35-41 tons ha<sup>-1</sup> y<sup>-1</sup> in Trijuga (Sah, 1996) from agricultural land have been recorded. Losses of 3-16 tons ha<sup>-1</sup> y<sup>-1</sup> from cultivated terraces and 0.7-8.7 tons ha<sup>-1</sup> y<sup>-1</sup> from grassland were reported in Yarsha Khola, a mid-hill watershed in Dolakha district (DSCWM/PARDYP-ICIMOD, 1998). Obviously the soil losses depend upon the different



factors, such as, slope, land type, land use and frequency of cultivation. Some of these factors such as land use, frequency of cultivation are intimately linked to agricultural intensification. Increasing demand for food production increases the need of maintaining soil fertility worldwide (Wild, 2003; Pilbeam et al., 2005). But intensification by increasing number of crops is contributing to a decline in soil fertility due to nutrient losses (Turton et al., 1995).

This study attempts to relate soil and nutrient losses to degree of agricultural intensification in a mid-hill watershed in Nepal. Specifically, the aim of the study was to describe soil physical and chemical properties, rainfall distribution and analyse the magnitude of soil erosion and nutrient losses in response to 2 vs. 3 crops per year farming systems on upland and lowland areas of Ansikhola watershed within Kavre district of Nepal. It also aims to obtain reasonable estimates of erosion losses in multiple terraces taking account for both run-on and runoff processes.

## **Methods**

### **Study area**

The Ansikhola watershed (27° 41' - 27° 44' N and 85° 31' - 85° 37' E) covers about 13 km<sup>2</sup> in Kavre district of Nepal (see figure 1). The watershed lies in mid-hills of Nepal and altitude ranges from 800-2000 m above sea level. The land area of the watershed is dominated by agriculture (>80% cultivated land), while forest (18%) and land makings only 2% of the land area. The climatic data from 2004 to 2007, measured from three weather stations established in the watershed, shows yearly average maximum and minimum temperatures as 25°C and 18°C respectively. During the same period the watershed received annual rainfall of 1461 mm with maximum of 1708 mm in the year 2006 and 1389 mm as minimum in the year 2004. Detailed description of the study area is given by (Dahal et al., 2007 and Dahal et al., 2009).

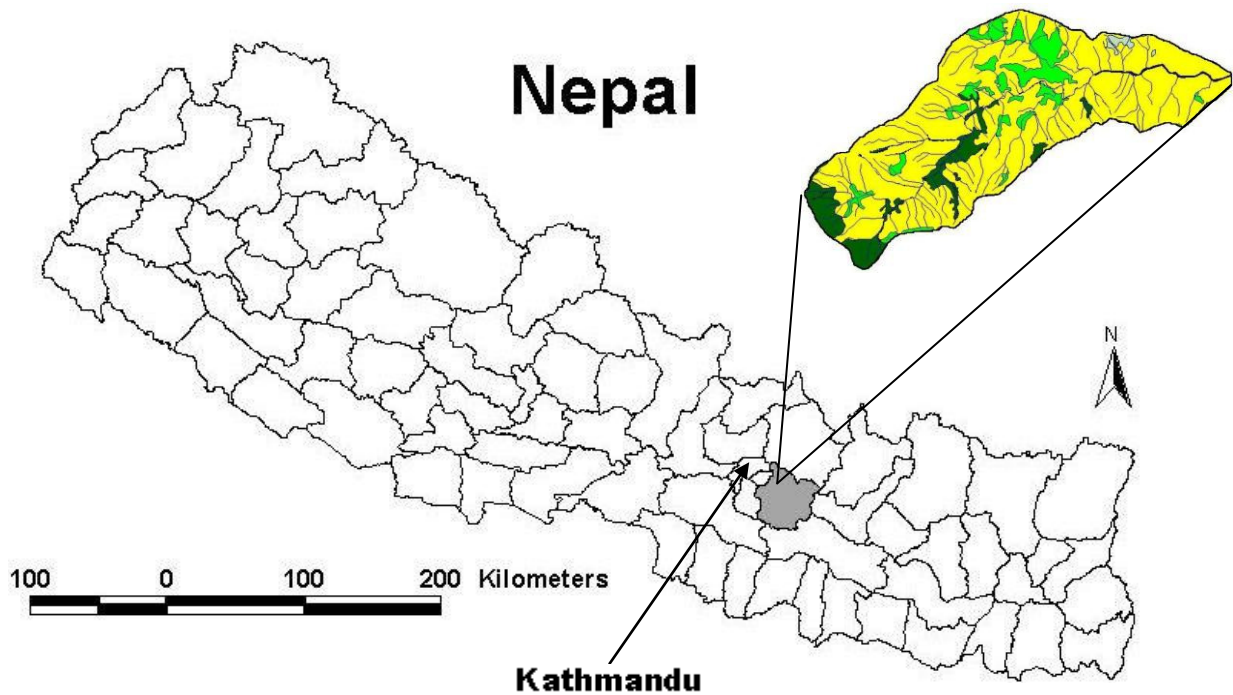


Figure 1. Map of the study area with reference to Nepal.

### Research plots design

The cultivated land in the watershed is divided into two land use systems: levelled irrigated land (Khet land) and rainfed terraced land (Bari land). Based on existing farmer's cropping practices in the watershed, each land system was categorised into two cropping systems representing two and three crops cultivated per year. The crop rotation in the Bari system had maize-millet (two crops) and maize-potato-mustard (three crops). The Khet system had paddy-paddy and paddy-potato-paddy as two and three crops rotation system, respectively (see Table 1). To monitor the soil erosion, four research plots in each cropping systems were established. Each erosion research plot had two to three terraces (see figure 2) with total area of about 40-50 m<sup>2</sup> in Bari system and about 100-300 m<sup>2</sup> in Khet system. While selecting the sites, the representative of different soil types, terrace, and slope were considered so that the four plots of two cropping systems in over all were similar to the four plots of three cropping systems. However, two and three crops rotation farming systems could not be found at the same exact location, which was a constraint to the site selection procedure. The farmers' practice of two or three crops depended upon road/market access, soil quality, and inputs availability.

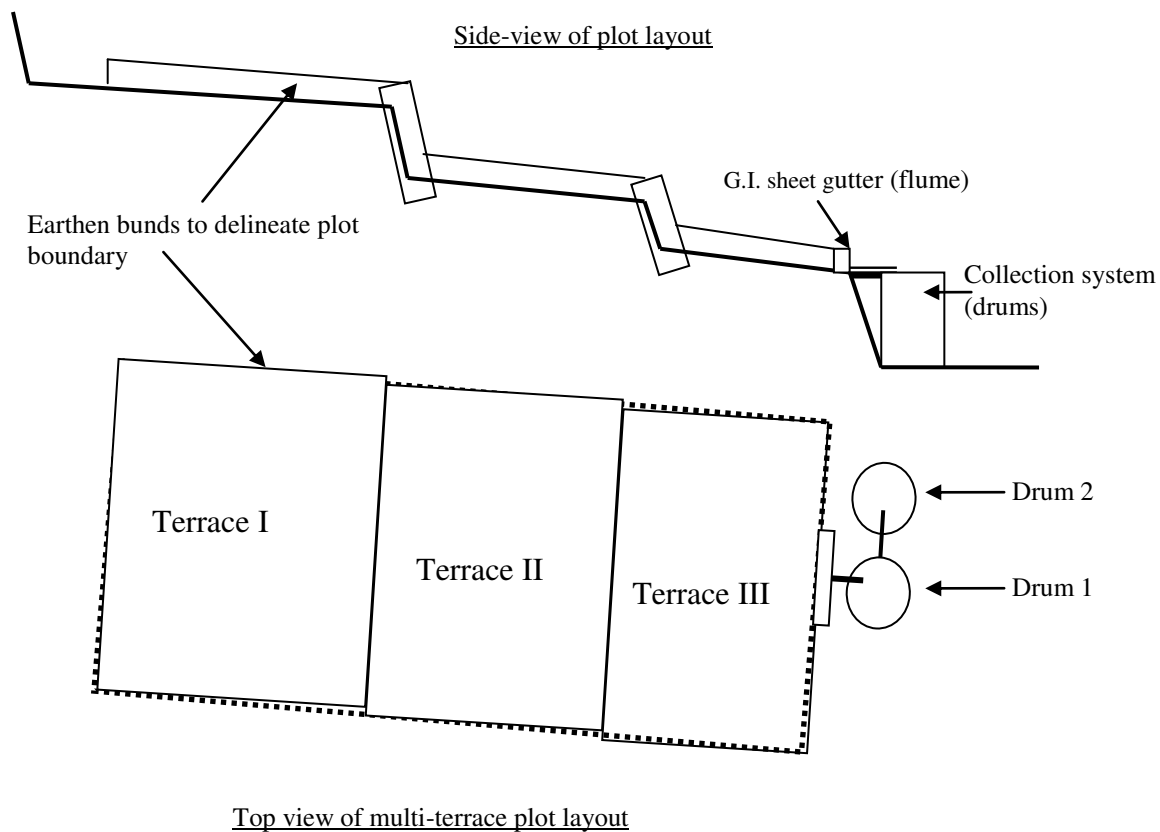


Figure 2. Layout of each erosion plots (two to three terraces) in each crop system.

Table 1. General characteristics and treatments of the study plots.

Land type	Treatments	Cropping systems*	Elevation (m absl)	Slopes of terrain across 2-3 terraces (%)	Major activities months
Bari	2 crops	Maize-Millet	1160	26±4	Feb, Aug
	3 crops	Maize-Potato-Mustard	1880	45±3	Feb, Aug, Oct
Khet	2 crops	Paddy-Paddy	830	11±3	Mar, Jul
	3 crops	Paddy-Potato-Paddy	820	7±2	Mar, Jun, Dec

\*Maize (*Zea mays*); Millet (*Eleusine coracana*); Potato (*Solanum tuberosum*); Mustard (*Brassica compestris*); Paddy (*Oriza sativa*);

### Soil sampling and analysis

The soil erosion and nutrient losses were monitored regularly from the established plots on farmer's fields. Runoff was sampled after each major rainfall event during the year 2005 and 2006 by collecting half to one litre of runoff water from the collection drums. Three weather

stations, two stations representing two and three cropping system in Bari land and one station representing two and three cropping system in Khet land were established to measure the daily temperature, rainfall and atmospheric pressure.

The soil samples (0-15cm and 15-30cm) were collected from the established experimental plots and analysed in the laboratory for physical and chemical properties using standard methods. The physical properties such as soil texture was determined by Bouyoucous soil hydrometer (Gee and Bauder, 1986) and bulk density (BD) using soil core (Blake and Hartge, 1986). Similarly, soil organic carbon (SOC) by Walkley-Black (Nelson and Sommers, 1982), total nitrogen (N) by Kjeldahl's method (Bremner and Mulvaney, 1982), available phosphorus (P) by modified Olsen's (Olsen and Sommers, 1982), exchangeable potassium (K) by flame photometry (Knudsen et al., 1982) and pH with a digital pH meter with 1:1 soil water ratio (Mclean, 1982).

The field and lab analysis data were computed in MS excel and ANOVA tests were performed by SPSS and SAS software for analysis of variance (ANOVA), multiple comparison of means using Student-Newman-Keuls, and variability in soil properties were measured in terms of minimum and maximum range and standard error of means (SE).

## Results

### Soil physical properties

The soil physical properties of the different sites are presented in Table 2. The mean values and standard deviations are based on four sites in each location during the study period. As can be seen from the data, regardless of whether they were in upland or low land areas, the soils were mostly of loam texture with one site having silt loam soil type. The bulk densities of the soils were expectantly low, ranging from 0.9 to 1.3, being recently tilled, cultivated soils.

Table 2. Soil physical properties at different sites expressed as mean±SE.

Treatments	Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Soil texture class	Bulk density (g cm <sup>-3</sup> )
3 crops*	0-15	52±3	34±3	14±2	Loam	0.9±0.04
	15-30	50±4	33±4	17±2	Loam	1.1±0.02
2 crops*	0-15	37±5	41±4	22±5	Loam	1.2±0.09
	15-30	43±6	36±4	21±4	Loam	1.3±0.01

3 crops <sup>#</sup>	0-15	32±4	58±3	10±1	Silt loam	0.9±0.08
	15-30	33±4	54±3	13±3	Silt loam	1.1±0.08
2 crops <sup>#</sup>	0-15	43±3	36±2	21±2	Loam	0.9±0.07
	15-30	44±3	38±2	18±2	Loam	1.0±0.07

\*Rainfed terraced land (Bari land) and <sup>#</sup>levelled irrigated land (Khet land).

### Soil chemical properties

As can be noted from the data in Table 3, the soil chemical properties of different plots/sites were generally of moderate fertility, with medium soil Total Nitrogen (TN), and low to medium soil available Phosphorus (P). The soils were all moderately to strongly acidic with pH values ranging from 4.7 to 5.8. Also, the Soil Organic Carbon (SOC) contents were low to medium and Cation Exchange Capacity (CEC) values generally high.

Table 3. Soil physical properties at different sites expressed as mean±SE (values based on four replications in each location).

Location	Soil depth (cm)	pH	SOC (%)	CEC (me/100gm of soil)	Total N (mg/kg of soil)	P (mg/kg of soil)
3 crops <sup>*</sup>	0-15	4.7±0.1	2.9±0.2	41±4	1247±196	45±8
	15-30	4.7±0.1	2.4±0.3	44±3	1359±156	31±3
2 crops <sup>*</sup>	0-15	5.2±0.1	2.2±0.3	48±3	995±156	22±5
	15-30	5.3±0.1	2.8±0.5	45±5	1168±85	21±4
3 crops <sup>#</sup>	0-15	5.0±0.2	3.1±0.2	52±3	1542±99	79±12
	15-30	5.3±0.2	2.6±0.2	48±8	1261±156	54±14
2 crops <sup>#</sup>	0-15	5.8±0.2	2.4±0.2	44±2	1345±79	29±9
	15-30	5.8±0.2	2.1±0.1	39±1	1443±238	81±24

\*Rainfed terraced land (Bari land) and <sup>#</sup>levelled irrigated land (Khet land).

The results indicated that soil organic carbon and total nitrogen were somewhat higher in the 3 crops (intensified) system compared to the 2 crop system. This was expected due to higher input of FYM and fertilizers in this cropping system (Table 4).

Table 4. Crop wise application of farm yard manure (FYM) and inorganic fertilizers in different locations expressed as mean±SE.

Location	Crops	FYM (t ha <sup>-1</sup> yr <sup>-1</sup> )*	Inorganic fertilizer (kg ha <sup>-1</sup> yr <sup>-1</sup> )		
			Nitrogen	Phosphorus	Potassium
3 crops <sup>*</sup>	Maize	29.5±3.6	332±66	127 <sup>α</sup>	143 <sup>α</sup>
	Potato	29.2±4.7	462±159	258±62	144±21
	Mustard	24.2±3.6	Not applied	Not applied	Not applied
2 crops <sup>*</sup>	Maize	46.5±10.3	245±31	150±21	Not applied
	Millet	Not applied	156±27	Not applied	Not applied
3 crops <sup>#</sup>	Spring paddy	Not applied	125±17	172±22	100±33

	Potato	40.6±5.4	254±42	369±104	101±20
	Winter paddy	Not applied	87±24	127±31	155 <sup>ra</sup>
2 crops <sup>#</sup>	Spring paddy	Not applied	77±17	102±12	26±9
	Winter paddy	17.5±13.5	58±16	145±34	21±13

\*Rainfed terraced land (Bari land) and <sup>#</sup>levelled irrigated land (Khet land). \*\*Value based on 1 'doko' equals 24 kg of compost (Tiwari, et. al., 2004). The moisture content of farmyard manure/compost ranges between 20-30% (Shrestha, et. al., 2006). <sup>ra</sup>One time application only.

Inputs of nitrogen, phosphorus and potassium nutrients are done through chemical fertilizers, Urea (N=46%), DAP (N=18%, P=46%) and muriate of potash (K=52%), available in the local market. The analysis of total fertilizer application in rain-fed terraced shows that the amount of farm yard manure, nitrogen, phosphorus and potassium fertilizer input was higher in 3 crops than in 2 crops plots. Fertilizer application for the various crops of the study was also found to be higher (almost double) than recommended fertilizer dosages for Nepalese soil (Joshi and Deo, 1976; Joshi, 1997). The recommended amount for hills is 60, 30 and 30 kg per hectare for nitrogen, phosphorus and potash, respectively, and the recommended amount of FYM is 10 ton per hectare (Joshi and Deo, 1976). It was observed that farmers fulfilled the yearly total fertilizer use by dividing the total amount among the number of crops cultivated per year. As a general practice farmers usually do not fertilize the extra crop (mustard) in upland areas, so this crop is dependent upon residual nutrients. Farmers typically did not seek or expect high yield of this extra crop. For levelled irrigated lands, the amounts of fertilizer applied were generally very low. Moreover, farmers applied FYM only for the main (cash crop), such as, potato and winter paddy. But clearly, the farmers applied greater amounts of FYM and/or fertilizers under the intensive (3 crop) farming systems as compared to the non-intensive (2 crop) system.

### **Rainfall, runoff and soil loss from the experimental sites**

Based on the three years of rainfall data, annual rainfall in 3 crops Bari land (Thulichowr), 2 crops Bari land (Kotyang) and 2 and 3 crops Khet land (Dhaitar) was 1692mm, 1262mm and 1429mm, respectively. The mean monthly rainfall distribution in 2005 and 2006 for each of the cropping patterns studies is presented in Figures 3 and 6, respectively. Annual total rainfall amounts in the watershed, taking the average of three weather stations at different locations, was 1389 mm, 1286 mm and 1708 mm, respectively, for the years 2004, 2005 and 2006. The mean annual rainfall for the entire watershed was thus calculated to be 1461 mm. The year 2005 received 12% less rainfall where as the year 2006 received 17% more rain compared to the annual average rainfall for the watershed.

Monsoon rainfall (June-September) accounted for 76% and 73% of the total rainfall in the watershed in 2005 and 2006 respectively, where as pre-monsoon rainfall (March-May) accounted for 10% and 23% in 2005 and 2006, respectively. Pre-monsoon and monsoon season is sensitive for soil erosion in the watershed as more than 90% of the rainfall occurs during this period. The rainfall amounts and distribution across the watershed was noted to be different for each of the years studied (Figure 3 and 6). For example, the rainfall in the year 2005 was less by 7% compare to rainfall of the year 2004 where as the rainfall of year 2006 was high by 33% than of the year 2005. Hence the amount of runoff, soil loss and nutrient losses may also be expected to vary considerably each year.

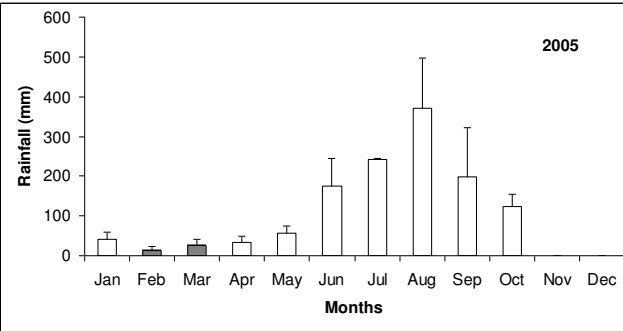


Figure 3. Monthly average rainfall for the year 2005.

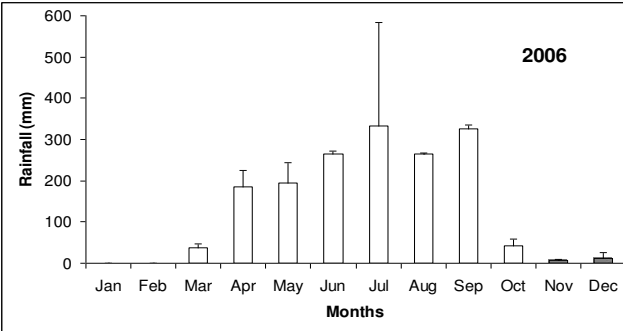


Figure 6. Monthly average rainfall for the year 2006.

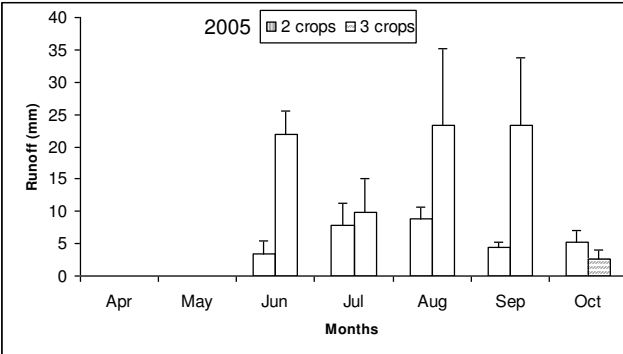


Figure 4. Average monthly runoff losses from 2 and 3 crops system of Bari land in the year 2005.

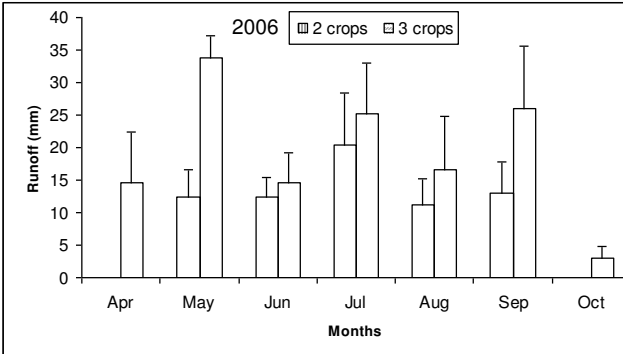


Figure 7. Average monthly runoff from 2 and 3 crops system of Bari land in the year 2006.

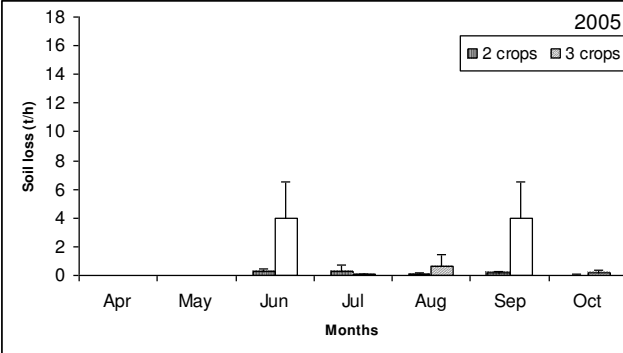


Figure 5. Average monthly soil loss from 2 and 3 crops system of Bari land in the year 2005.

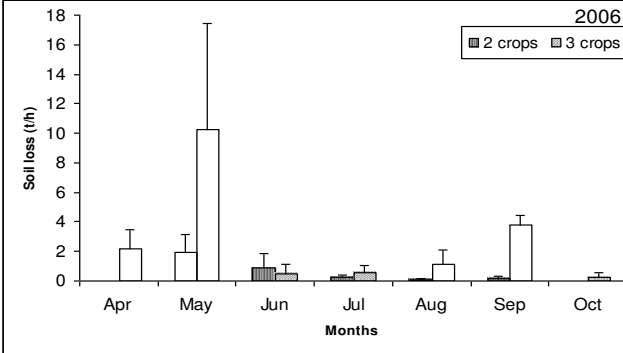


Figure 8. Average monthly soil loss from 2 and 3 crops system of Bari land in the year 2006.

The monthly trends of runoff and soil loss from the upland (Bari) plots are graphically shown in figures 4-8. A general trend of high soil losses during the early (March-May) and late seasons (September-November), and low amounts of soil eroded during mid-season (July-August), regardless of the amount of runoff was, observed. Higher soil losses during pre-monsoon were also observed by numerous researchers in other parts of Nepal (Gardner and Gerrard, 2003; Acharya et al., 2007; Tiwari et al., 2009). The highest soil loss (9 t/ha) for a single day was recorded from the 3 crop rotation system on Bari land in Thulichowr. Correspondingly, the maximum runoff (9.7 mm) on 6 September, 2005, was also recorded from same area. Analysis of variance (Table 5) showed that soil erosion was highly significantly different according to cropping intensity treatment (i.e., between 2 and 3 crops treatments). However, it was only weakly significant by year (2005 vs. 2006). The erosion rates reported in this study are generally lower than the rates of soil loss that have been reported in other studies (Pahari, 1993; Sah, 1996; DSCWM/PARDYP-ICIMOD, 1998; Shrestha, 2000; Gardner and Gerrard, 2003) from mid-hills of Nepal. This is likely due to the fact that the present study adopted a multiple terrace erosion plot approach, while other studies measured soil loss from single terraces. The multiple terraces account not only for soil removed from a plot by runoff, but also for sediment brought onto the terrace by run-on from the adjacent upper terrace.

As with soil loss, runoff amount from farm plots were highly significantly different between both cropping treatments and between years (Table 5). Student-Newman-Keuls test (pair-wise means comparison) also showed that the 2 crops and 3 crops treatments in Bari (upland sloping terrace) systems are significantly different in terms of runoff, erosion,  $\text{NH}_3\text{-N}$  and  $\text{PO}_4$  losses (Table 6). Thus, it could be inferred that increasing cropping intensity from 2 crops to 3 crops led to high water runoff and soil erosion from the farm plots. This is likely due to the fact that in intensive cropping systems there was a greater degree of soil manipulation than in the less intensive (2 crop) treatments, and timing of farm operations may have led to soil surface being exposed at the critical times (early and late monsoon season). As can be seen from the figures 4-8, for most months runoff and soil losses were greater in the 3 crops treatments i.e., in the intensively cropped plots. Similar trends of soil loss due to intensification of cropping have been reported by other researchers (Brown et al., 1999; Gardner and Gerrard, 2003; Shrestha et al., 2004; Tiwari, 2009).



Correlation analyses indicated that soil loss was correlated with runoff ( $P < 0.01$ ). We have noted that major soil losses took place during the period when there was bare or exposed soil with minimal vegetative cover. Such critical exposure periods are likely to increase with increasing levels of cropping intensification due to greater number of farm operations such as tillage, weeding, and harvesting.

Other parameters, namely, losses of nutrients (nitrate, phosphate and ammonia) were only weakly or non-significantly correlated with runoff or soil erosion. In spite of higher amount of fertilizer use in the crops, the nutrient loss through runoff or soil erosion was low. Soil nutrient losses are not primarily due to soil erosion (Gardner et al., 2000; Gardner and Gerrard, 2003; Pilbeam et al., 2004) and amount of soluble nutrients in runoff are only a small fraction compare to the lost through leachate (Acharya et al., 2007). Therefore a high proportion of the nutrients could also be lost through leaching rather than through erosion. This is also supported by the amount of nutrients and salts in river water of the same watershed (Dahal et al., 2007).

Table 5. Combined ANOVA for measured parameters (by year and treatments) with their F-test values and level of significance for Bari land system.

Source	Runoff	Erosion	NH <sub>3</sub> -N	NO <sub>3</sub> -N	PO <sub>4</sub>
Year	33.18 <sup>**</sup>	3.64 <sup>+</sup>	0.74 <sup>NS</sup>	2.74 <sup>+</sup>	0.98 <sup>NS</sup>
Treatment	68.62 <sup>**</sup>	24.34 <sup>**</sup>	4.08 <sup>*</sup>	0.03 <sup>NS</sup>	5.21 <sup>*</sup>
Year*Treatment	9.07 <sup>**</sup>	0 <sup>NS</sup>	0.69 <sup>NS</sup>	0.28 <sup>NS</sup>	0.29 <sup>NS</sup>

Significant difference of mean (<sup>+</sup>:  $p < 0.1$ ; <sup>\*</sup>:  $p < 0.05$ ; <sup>\*\*</sup>:  $P < 0.01$ ; <sup>NS</sup>: Not significant)

Table 6. Means for pair-wise comparison (Student-Newman-Keuls test) of different measured variables for Bari land system.

Variables	Mean (No. of observations in parenthesis)	
	2 crops	3 crops
Runoff (mm)	78.168 (224)A	126.849 (251)B
Erosion (t/ha)	0.076 (224)A	0.439 (250)B
NH <sub>3</sub> -N (g/L)	0.022 (32)A	0.056 (63)B
NO <sub>3</sub> -N (g/L)	0.264 (32)A	0.281 (63)A
PO <sub>4</sub> (g/L)	0.008 (32)A	0.016 (63)B

Means with the same letter across rows are not significantly different from each other at  $p < 0.05$ .

The results of this study should be interpreted with caution due to the facts that the 2 and 3 treatments site had some differences in site characteristics (Table 2). Therefore, the results should be taken as indicative of the studied watershed and may not represent general phenomenon across the entire mid-hills region. Despite the higher soil organic carbon in the 3 cropping (intensified) system (Table 3), higher erosion rates were observed (Table 6) which may be a result of frequent mechanical manipulation and soil exposure during rainfall events. Given the reality of watershed and existing farming practices, it was difficult to obtain 3 and 2 cropping practices in the same locations of the study watershed. More extensive study with greater numbers of replications is recommended before the results could be generalized to other parts of the Himalayan mid-hills.

## **Conclusions**

Higher soil losses were observed during pre-monsoon period (March-May) in the watershed. From assessments of soil erosion, researchers have reported similar observations in other watersheds of the country, none-the-less, three cropping i.e., intensified systems exhibited higher soil and nutrient losses despite the fact that it contained higher soil organic carbon. The more pronounced positive correlations between runoff and soil losses in 3 cropping system reflects that 3 crops systems are more frequently tilled and exposed to erosive forces. The heavy pre-monsoon rainfall and intensive cropping (more than 2 crops) can have negative effects on soil and nutrients losses. Rainfall is unavoidable, and indeed desirable, sustainable approaches to agricultural intensification need to be adopted to minimize soil and nutrient losses. Some such sustainable approaches could be choice of cropping pattern in accordance with the rainfall pattern, crop management operations throughout the year, water management and soil conservation practices especially during the initial (early monsoon and peak) periods.

## **Acknowledgement**

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## **Paper III**

Dahal, B. M., Sitaula, B. K., Sharma, S., and Bajracharya, R. M. (2007). Effects of agricultural intensification on the quality of rivers in rural watersheds of Nepal, *Journal of food, agriculture and environment*, 5 (1): 341-347.





## Effects of agricultural intensification on the quality of rivers in rural watersheds of Nepal

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### Abstract

The impact of agricultural intensification on surface water quality is an issue of global concern. The effects of crop intensification on stream water quality in Midhill watersheds of Nepal were studied. Variations in anion (NH<sub>3</sub>, NO<sub>3</sub>, PO<sub>4</sub>) and cation (Na, K, Pb, Zn, Cu) concentrations, composition of stream macroinvertebrate communities and level of faecal coliform contamination in public drinking water sources were assessed for two rural streams (Ansikhola and Chakhola) of Nepal. Both qualitative and quantitative samples of macroinvertebrate communities were sampled to determine biomass and abundance. Samples were collected from Chakhola and Ansikhola during July (rainy season) and November (dry season) in the year 2004. Both watersheds had similar biophysical conditions but differed in the degree of agricultural intensification, which was higher in Ansikhola compared to Chakhola in terms of number of crops per year. Concentrations of NH<sub>3</sub> and NO<sub>3</sub> were higher in sites of Chakhola compared to Ansikhola. Sodium was the dominant cation at all sites in both streams. Most of the drinking water sources were found contaminated with faecal coliforms during the rainy season. Biomass and abundance of macroinvertebrate communities increased with increasing agricultural intensification, although species richness decreased. Hydropsychidae were more common in agricultural sites, whereas Baetidae dominated forest sites. Hence, increased agricultural intensification alters water chemistry, microbiology, as well as benthic faunal diversity and biomass.

**Key words:** Agricultural intensification, water quality, faecal coliform bacteria, macroinvertebrate.

### Introduction

Agricultural intensification is defined as cropping a given area of land more frequently than before<sup>3</sup>. The increasing demand for agricultural intensification in Nepal is due to high rate of population growth, 2.25% per annum<sup>6</sup>, declining fertility of existing agricultural lands, and insufficient agricultural production. To overcome the food insufficiency, national policy of Nepal aims to increase per capita food production from 277 kg to 426 kg by 2017<sup>18</sup>, which will require agricultural intensification. The shift from subsistence production to market driven cash crop production<sup>5,19</sup> is one example of agricultural intensification in the middle mountains of Nepal. With increased market access, traditional crops (such as rice-maize or maize-millet in case of hills in Nepal) are being replaced by high-value cash crops<sup>20</sup>. Along with high value crops, the number of crops per year has also increased. The typical two food crops per year has increased to two crops of rice and additional maize and/or vegetables such as potato and tomato, reflecting agricultural intensification in the study area.

The change in cropping pattern has already led to increased use of agrochemicals in the middle mountains of Nepal<sup>5,22</sup>. Brown and Shrestha<sup>5</sup> further elucidate soil fertility decline with agricultural intensification. Hence, to maintain soil fertility and high productivity, farmers need increasing doses of organic and inorganic fertilizers. However, negative impacts on soil and water quality are likely to occur with injudicious use of chemical fertilizers and pesticides<sup>25</sup>. Intensification can have negative local consequences, such as increased erosion, lower soil fertility and

reduced biodiversity; negative regional consequences, such as pollution of ground water and eutrophication of rivers and lakes; and negative global consequences, including impacts on atmospheric constituents and climate<sup>13,24</sup>.

Agricultural intensification not only affects the quality but also the quantity of water as most of the river water is diverted to agricultural fields and this water returns back to river with pollutants through surface and subsurface transport. Farmers claimed inadequate water supply for crops like potato and wheat during the winter and pre-monsoon period. In contrast to insufficient water during dry conditions (winter), the water becomes practically unsuitable for drinking and has high health risk during summer, due to sewage and other pollutants wash down into river system<sup>14</sup>. River water fluctuations also affect benthic invertebrates<sup>4</sup>.

The adverse impacts of intensified agriculture on river water quality are an issue of concern worldwide, but studies on the effects of agriculture on river water quality in Middle Mountains Region of Nepal are limited and mostly focused on water chemistry. The studies carried out thus have been in conclusion whether river water quality is changing due to natural geological processes, agricultural practices, and/or cumulative effects of natural and human actions. Jenkins *et al.*<sup>11</sup> have pointed out the need of comparing pristine and agricultural catchments of similar geology to draw specific conclusions regarding land use impacts on water quality. Furthermore, Brewin *et al.*<sup>4</sup> was also unclear on the exact



mechanisms of land use effects on stream biota in the Himalayas. Therefore, this study was conducted in two watersheds with similar geology but different levels of agricultural intensification, to assess its effects on river water quality through chemical, microbial and biological indicators.

Impact of agriculture on river water quality may be studied through chemical analysis of the water and correlation with the biota present in and around the river <sup>26</sup>. This method may be applied either to simple chemicals such as metals, plant nutrients and dissolved gases or complex organic compounds such as chlorinated hydrocarbons <sup>15</sup>. Relative frequency and diversity indices of living communities may also be used to monitor water contamination, assess ecosystem integrity, and for environmental bioremediation <sup>9</sup>. Since pollution level and chemical changes in water are reflected by the species richness of aquatic biota; bio-monitoring along with chemical analysis was used in this study. The specific objectives of this study were to compare agricultural intensive and non-intensive watersheds in terms of water chemistry, microbiological water quality and abundance and biomass of macroinvertebrates in river ecosystems.

### Materials and Methods

**Study sites:** The adjacent watersheds of Ansikhola and Chakhola, lie between N27°41' and 27°44' latitude and E85°31' to 85°37' longitude in Kavre district, Nepal (Fig. 1). They have a dramatic elevation difference from about 800 m at the streambed to nearly 2000 m at the source. The main factors increasing agricultural intensification of the area are road access and market in the capital city, Kathmandu.

Both Chakhola and Ansikhola watersheds have similar biophysical conditions with no industrial effects, the main difference being degree of cropping intensification (Table 1). Two major crops (maize-millet or wheat in *Bari* and rice-rice, rice-wheat or rice-maize in *Khet* land) and additional vegetables or potato are cultivated in Ansikhola watershed. However, in Chakhola watershed, vegetables or potato cultivation was minor crop compared to Ansikhola. Therefore, the two watersheds were considered different in terms of number of major crops grown. There were three major crops per year in Ansikhola and only two major crops per year in Chakhola watershed. However, most of the cultivated lands adjacent to the rivers, i.e., level terraces (*Khet*), were at the valley bottom in both watersheds. In most of the areas, the lower reaches of the valley were supporting up to three crops (two of paddy and the third vegetables or potato). Of the two rice crops, the first is grown from April to June and second from July to October (Table 2). The rain fed terrace (*Bari*) supports maize and millet in monsoon season and wheat or mustard during the winter months.

**Table 1.** Area, climate and land use of Ansikhola and Chakhola watersheds.

	Ansikhola	Chakhola
Watershed area (km <sup>2</sup> )**	13	25
Annual rainfall (mm)*	1389	1713
Annual max. temperature (°C)*	25	23
Annual min. temperature (°C)*	17	14
Annual relative humidity (%)*	74	82
Dominant land use types**	8.4% forest, 9.9% bush, 80.6% cultivation	5.7% forest, 11.1% bush, 81.6% cultivation

\* Data of the year 2004 and based on weather stations, three in Ansikhola and one in Chakhola, by Kathmandu University.

\*\* Based on NGHIP/Nepal <sup>17</sup>.

**Table 2.** Major cropping pattern in Ansikhola and Chakhola watersheds.

Cropping pattern	Cropping season			
	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec
1. <i>Bari</i> land				
Mustard*	■			
Vegetables*		■		
Wheat			■	
Potato				■
Maize and millet			■	
2. <i>Khet</i> land				
Vegetables*	■			■
Rice variety 1*		■		
Maize			■	
Rice variety 2			■	

\* When irrigation available. Data Source: Baseline survey of the watersheds during 2004.

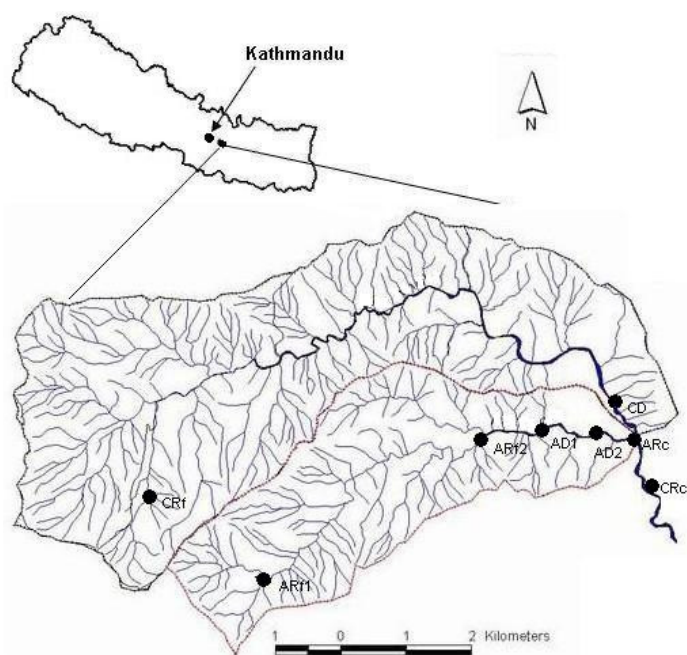
**Site selection:** Eight sites were selected based on cropping frequency, accessibility and altitudinal variations. Five sites in Ansikhola and three in Chakhola were designated as reference (Rf), disturbed (D) and recovery (Rc) sites respectively. Sites at Ansikhola were denoted the letter 'A' and Chakhola with 'C' for each reference, disturbed and recovery sites. (For point location of the sampling sites in both watersheds see Fig. 1). Selection of reference sites was based on criteria as described by Hughes <sup>10</sup> and Reynoldson and Wright <sup>21</sup>, and factors included for this study were land use practices and settlements. In this study, reference sites have low settlement and less crop intensity; disturbed sites had visible impact to aquatic ecosystem, and recovery sites were taken 0.5 to 1 km downstream of the impacted areas.

**Sampling methodology:** Seasonal samples of stream water were collected from different sites of both watersheds (see Fig. 1) in mid summer 2004 and mid winter 2004 encompassing one wet and one dry season. Temperature, pH and conductivity were measured using temperature, pH and conductivity probes (WTW-Germany) respectively. Water samples for ammonia, nitrate and orthophosphate were collected using HACH test kits in field. The samples were transported to the laboratory in Aquatic Ecology Centre, Kathmandu University, within 24 h of collection in an icebox for spectrophotometric analysis of ammonia <sup>1</sup>, orthophosphate <sup>2</sup> and nitrate <sup>12</sup>. Separate samples preserved in 1-2 ml concentrated nitric acid were also transported to the laboratory for analysis of Pb, Cu, Zn, Na and K using atomic absorption spectrophotometry (Thermo Electron Corporation) as described by APHA <sup>2</sup>.

In case of the biological water quality studies, both qualitative and quantitative sampling was performed in the months of August 2004 and January 2005. Qualitative samples were collected from multiple habitats using different collection techniques such as kick sampling, multi habitat sampling and also hand net collection. Surber sampler was used for quantitative sampling. The biota samples collected were preserved in 75% alcohol (for qualitative samples) and in 5% formalin (for quantitative samples). After sorting the samples in the laboratory, biota were identified and enumerated (in quantitative samples) for calculation of water quality index.

A Portable Water Testing Kit (OXFAM – DELAGUA, UK) was used for microbiological testing of drinking water sources. In total, 42 sites were sampled, of which 31% were *kuwas* (spring-fed and slow flowing source), 31% springs, 24% taps and 14% tanks. During the months of April to June 2004, samples for microbiological analysis were collected in sterilized plastic bottles, stored in an icebox, and brought to the lab within 24 hours. Faecal coliforms (FC) and total coliforms (TC) were analysed to determine the level of contamination of drinking water sources due to runoff from crop intensive areas.

Statistical analysis was carried out using SAS software<sup>23</sup>. The level of anions, cations and abundance and biomass of macro-invertebrates in river water were analysed by general linear model procedures. Multiple comparison of means for each class variable were carried out using a Student–Newman–Keuls (SNK) test at  $p < 0.05$ .



**Figure 1.** Study watersheds and location of sampling sites (up Chakhola, down Ansikhola).

## Results and Discussion

**Physico-chemical analysis:** From the sampling sites at Chakhola and Ansikhola, there were no significant differences in terms of temperature, pH and conductivity between the streams of two watersheds (Fig. 2). However, there was a significant difference in conductivity within the sites of Ansikhola and Chakhola (Table 3a and 3b).

**Table 3a.** Comparison of the physical parameters (mean±SE) at different sites of Ansikhola.

Parameter	Sample ID <sup>§</sup>				
	ARf1	ARf2	AD1	AD2	ARc
Temperature (°C)	20±3	23±5	26±6	24±5	23±5
pH	7.2±0.05	8.1±0.21	7.8±0.27	8.1±0.63	7.6±0.87
Conductivity (µS/cm)	280 C ±5	291 C ±5	395 A ±7	323 B ±10	307 BC ±5

<sup>§</sup>ARf1, ARf2, AD1, AD2, and ARc: First reference site, second reference site, first disturbed site, second disturbed site, and recovery site at Ansikhola respectively. Means with the same letter are not significantly different from each other at  $p < 0.01$ .

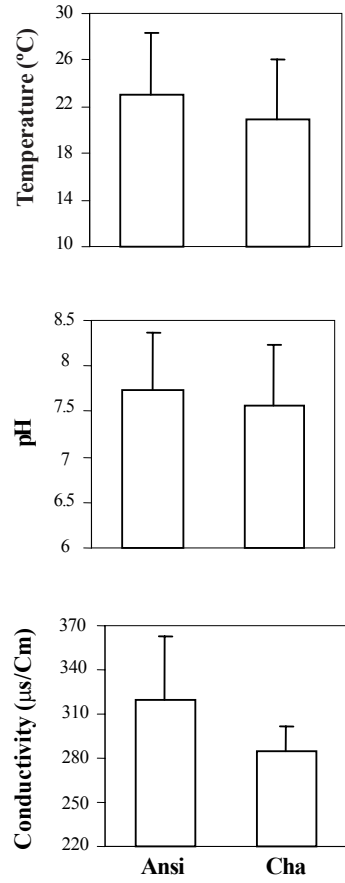
**Table 3b.** Comparison of the physical parameters (mean±SE) at different sites of Chakhola.

Parameter	Sample ID <sup>§</sup>		
	CRf	CD	CRc
Temperature (°C)	23±3	18±6	20±3
pH	8.1±0.11	6.9±0.44	7.6±0.52
Conductivity (µS/cm)	268 B±3	288 AB±3	300 A±9

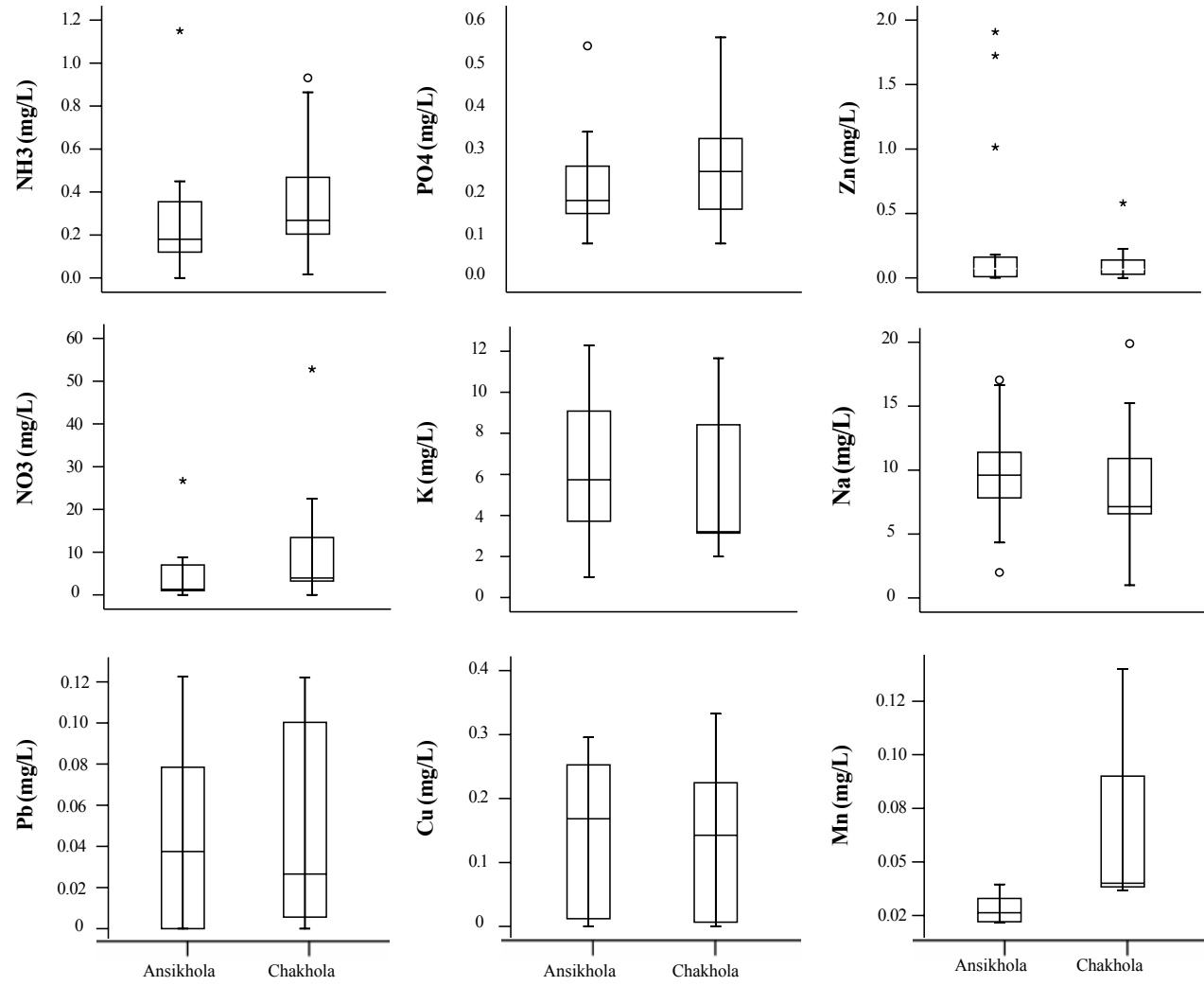
<sup>§</sup>CRf, CD, and CRc: reference site, disturbed site and recovery site at Chakhola respectively. Means with the same letter are not significantly different from each other at  $p < 0.05$ .

Ansikhola and Chakhola did not show significant differences in the chemical parameters measured in the study (Fig. 3). However, mean concentration of nitrate in Ansikhola and Chakhola was 13 and 28 mg/L respectively, which were considerably higher than the values recorded by Jenkins *et al.*<sup>11</sup> ( $< 1$  mg/L) in different streams of middle and high Himalayas of Nepal. Moreover, the concentrations of basic cations of Ansikhola and Chakhola were also different from the findings of other researchers<sup>7,8,11</sup> in similar middle mountain watersheds of Nepal. Contrary to the findings of Collins and Jenkins<sup>7</sup>, concentrations of ammonium, nitrate and phosphate were higher in this study (Fig. 2). This could be due to an increase in agricultural intensification during the period from 1996 to 2004. Collins and Neal<sup>8</sup> in 1998 also found higher values in the same watersheds examined by Collins and Jenkins<sup>7</sup> in 1996. After the confluence of Chakhola and Ansikhola, highest concentration of nitrate (52.8 mg/L) was recorded, which clearly reflects increased crop intensification with high levels of mineral-nitrogen and organic fertilizer applied to farmland for potato and off-season vegetables in Ansikhola. Usually,  $PO_4$  is absorbed in soil or used by biota and little is detected in the stream but high concentrations of  $PO_4$  (0.5 mg/L) measured in both streams suggested that fertilizer application was a major source of  $PO_4$  in stream water (Fig. 2).

Though there was no significant difference in terms of chemical parameters, Ansikhola distinctly showed higher mean concentration of sodium and potassium than Chakhola. Average concentration of sodium and potassium in Ansikhola was 9 and 5 mg/L, respectively, where as sodium and potassium at Chakhola was 6 and 3 mg/L, respectively. The higher concentration of dissolved Na and K in stream water was presumably due to agricultural activities like tillage, irrigation and fertilizer applications. Fertilizers and land management practices, both in agriculture and forestry, have altered these values considerably. In addition, tomatoes and potatoes require higher levels of N and  $P_2O_5$  than rice or wheat<sup>5</sup> and vegetables and potatoes were among the main crops grown in Ansikhola. Lack of differentiation of the two rivers on the basis of water chemistry may have been due in part to the number and location of sampling sites, particularly for Chakhola.



**Figure 2.** The comparison of physical parameters between the two rivers. Error bars are the standard deviation for all the observations.



**Figure 3.** The box plot comparison of different chemical parameters between the rivers of the watersheds. Outliers in the sample are expressed with \* and o symbols.

**Microbiological contamination:** Faecal coliform contamination at all sources during the rainy season was observed to be higher (more than 300 colonies per 100 ml of water sample) than during the dry season. Water springs were found to be virtually free from contamination during the dry seasons. Merz *et al.*<sup>14</sup> also reported similar results in a nearby agriculturally intensified watershed, Jhikhukhola watershed. The higher microbial contamination of drinking water sources during the rainy season was likely due to high runoff and direct wash down of wastes and pollutants as mentioned by Merz *et al.*<sup>14</sup>. Spring being a constantly flowing ground water source showed less contamination compared to water storing type sources (kuwa and tank). None the less, a clear relationship between agricultural intensification and microbial contamination of drinking water sources could not be established from this study.

### Stream biology

**Habitat attributes:** Ansikhola is a tributary of Chakhola, hence, the length and discharge of Chakhola is higher than Ansikhola. Other differences among the two streams were also found, such as width, level of aquatic vegetation, substrate type and depth among the two streams. Differences in habitat attributes of sampling sites in both Chakhola and Ansikhola are shown in Table 4.

**Table 4.** Habitat condition of the sampling sites at Ansikhola and Chakhola.

Variable↓ Sample ID→	Ansikhola					Chakhola		
	ARf2	ARf1	AD1	AD2	ARc	CRf	CD	CRc
Substrate type (%)								
Rocks	10	75	65	25	-	70	-	-
Boulders	15	10	10	25	10	5	10	5
Cobbles	15	10	15	35	70	10	70	75
Pebbles	20	5	5	10	15	2	5	15
Gravels	25	-	5	5	5	3	5	5
Sand, silt and clay	15	-	-	-	-	10	10	-
Maximum width(m)	6	10	20	10	8	10	10	12
Maximum depth(m)	0.5	0.3	0.3	0.5	0.3	1.5	0.3	0.5
Plant cover (%)	90	5	0	0	-	95	0	0
Vegetation (%)	10	4	25	5	4	40	0	35

Due to differences in river morphology, size and other habitat attributes, presence and abundance of macroinvertebrates differed between Ansikhola and Chakhola sites. Perlidae, Simuliidae and Baetidae were more abundant in dense vegetation areas of both rivers. Similarly, Hepatogeniidae and Hydropsychiidae were recorded higher in sites having a higher proportion of boulders. The existence of Ephemeroptera, Plecoptera and Trichoptera differed with overall substrate type.

**Taxa composition and biomass:** The total numbers of benthic macroinvertebrate taxa recorded in Ansikhola during August 2004 and January 2005 were 30 and 37 families respectively. In Chakhola, fewer total numbers of families (23 and 33) were recorded during both sampling periods. A total of 18,063 macroinvertebrates representing 40 different taxa were collected over the study period quantitatively using the Surber sampler. The four groups that composed the majority of macroinvertebrate communities were: Ephemeroptera (Baetidae), Trichoptera (Hydropsychidae and Psychomyiidae), Diptera (Simuliidae and Psychodidae) and Gastropoda (Physidae).

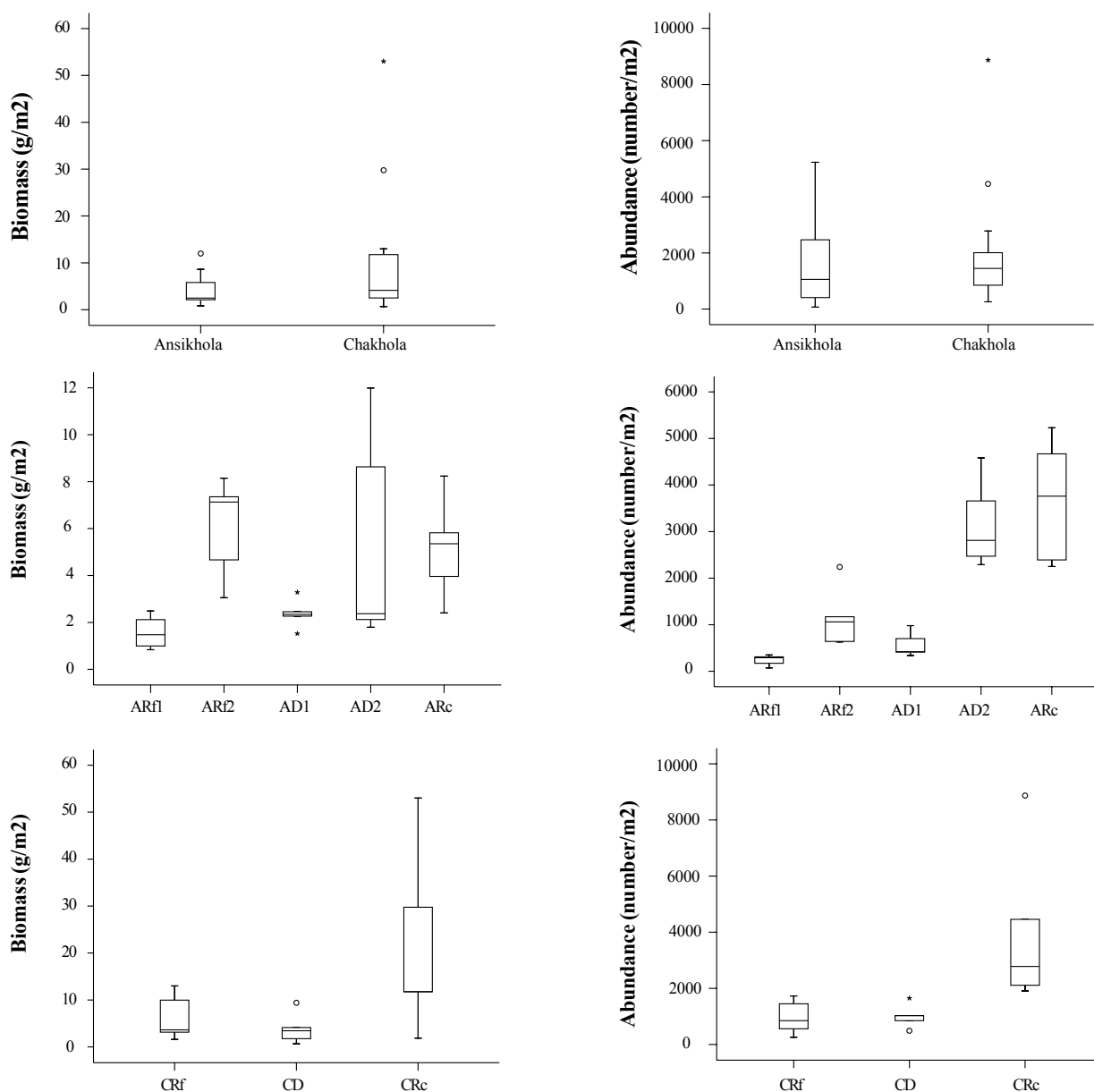
Ansikhola and Chakhola were found to be significantly different ( $p < 0.05$ ) in total biomass of fauna but not in their abundance (Fig. 4). None the less, for both rivers, biomass and abundance of macroinvertebrate communities showed an increasing trend with increase in the flow of water from upper reaches to lower reaches (Fig. 4). Upper sites had the lowest mean biomass and abundances compared to lower sites. The lower reaches of the watersheds were under intense agricultural land use. Hence, the increase in biomass and abundance of macroinvertebrates reflected the increased nutrient loading at the lower reaches of rivers. On the other hand, lower biomass and abundances in disturbed sites (Fig. 4, sites AD1 and CD) could be due to recent and extreme disturbances in the habitat conditions, such as sand and rock extraction. Moreover, CRc site and ARc sites were not, in actuality, recovery sites as expected according to the site selection process.

The dominant macroinvertebrate communities in the study were Baetidae, Hydropsychidae, Physidae and Chironomidae. Similarly, Hydropsychidae was observed to be dominant in the lower reaches and along the dominant terraced land use. Brewin *et al.*<sup>4</sup> also recorded about 90% dominance by these invertebrates in similar terraced agriculture of Likhu Khola watershed in Nepal. Hence, the distribution and dominance of these macroinvertebrates also reflected the existence of agricultural intensification in this study. Biomass and abundance of the macroinvertebrate communities are presented in Table 5a and 5b.

**Bio-assessment of water quality:** Fifty-six families of macroinvertebrate communities are identified and used to assess the water quality through water quality index, NEPBIOS<sup>16</sup>. Based on the water quality index, Chakhola was found to be less polluted compared to Ansikhola. Water quality started degrading downstream from the headwaters to lower reaches (Table 6). The water quality classes of sites in Ansikhola were seen to differ with season, where as no change was noted in Chakhola for both seasons. The water quality classes clearly 'indicated' that Chakhola had fewer disturbances, and processes of water quality degradation were higher in Ansikhola compared to Chakhola.

### Conclusions

This study revealed that physical parameters like temperature and pH are less sensitive to agricultural land use due to their inconsistency. However, conductivity was found to be a good indicator since it was closely related with intensity of agriculture. Agricultural processes influence variations in the concentrations of nitrogen, phosphorus, potassium and some metals. High values of nitrate and phosphorus in rivers are due to higher amount of chemical fertilizer application for intensive production of crops like potato and off-season vegetables. High value of nitrogen and phosphorus mainly at site CRc of Chakhola (Fig. 3) is due to water discharged from Ansikhola. It could also be due to the cumulative wash down of nutrients from both Chakhola and Ansikhola. Na and K were the dominate cations at all sites in both the streams indicating land disturbances throughout the year. Drinking water sources of Ansikhola watershed were most contaminated with faecal coliform bacteria. Though agricultural intensification may not have direct effect on the faecal contamination of water, it may have an indirect influence through increased number of inhabitants, labourers and cattle in the watersheds.



**Figure 4.** The box plot comparison of two rivers and their sampling sites based on biomass and abundance of macroinvertebrates. Outliers in the sample are expressed with ★ and o symbols.

**Table 5a.** Biomass and abundance of individual macroinvertebrate (mean±SE) communities at different sampling sites of Ansikhola.

Parameter	Sample ID <sup>§</sup>				
	ARf1	ARf2	AD1	AD2	ARc
Biomass (g/m <sup>2</sup> )	1.6±0.3	6.1±0.9	2.4±0.3	5.4±2.1	5.2±0.9
Abundance (no/m <sup>2</sup> )	238 B±52	1148 B±294	570 B±120	3162 A±426	3660 A±596

<sup>§</sup>ARf1, ARf2, AD1, AD2, and ARc: first reference site, second reference site, first disturbed site, second disturbed site, and recovery site at Ansikhola respectively. Means with the same letter are not significantly different from each other at p<0.01.

**Table 5b.** Biomass and abundance of individual macroinvertebrate (mean±SE) communities at different sampling sites of Chakhola.

Parameter	Sample ID <sup>§</sup>		
	CRf	CD	CRc
Biomass (g/m <sup>2</sup> )	6.3±2.2	3.9±1.5	21.6±9.1
Abundance (no/m <sup>2</sup> )	970 B±273	1010 B±188	4026 A±1291

<sup>§</sup>CRf, CD, and CRc: Reference site, Disturbed site and Recovery site at Chakhola respectively. Means with the same letter are not significantly different from each other at p<0.01.

**Table 6.** Water quality classes of Ansikhola and Chakhola.

Site	ARf1	ARf2	AD1	AD2	ARc	CRf	CD	CRc
Rainy season	II	II	II	II-III	II-III	I-II	II-III	II-III
Dry season	II	II	II-III	III	II-III	I-II	II-III	II-III

\* Based on NEPBIOS. (I- None to slightly polluted; I-II Slightly polluted; II Moderately polluted; II-III Critically polluted; III Extremely polluted; III-IV Heavily polluted; IV Very heavily polluted).

The statistically significant differences in biomass of macroinvertebrates in two rivers clearly indicated that Ansikhola and Chakhola had different watershed characteristics and dynamics. Water quality classes of the two streams (Table 6) also suggested that Ansikhola was comparatively more polluted than Chakhola. Similarly, a seasonal variation in water quality classes was observed (from II-III to III) in Ansikhola. Therefore, Ansikhola was influenced more by agricultural activities compared to Chakhola. Furthermore, water discharged from Ansikhola influenced the biota at the presumed recovery site, CRc. The higher alternation in water chemistry and benthic macroinvertebrates at Ansikhola may be due to agricultural disturbances. This finding is also supportive of Brewin *et al.*<sup>4</sup> in Likhu Khola where they found significantly higher turnover in benthic composition along the agricultural lands compared to other land areas. Therefore, this study suggested the conclusion that higher agricultural intensification leads to greater effects on aquatic biodiversity reflecting overall river environment. The change in river water quality may also affect the farming and livelihood activities of the watersheds indirectly influencing the health and well-being of farming communities in long run.

### Acknowledgements

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## **Paper IV**

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# Sustainable Agricultural Intensification for Livelihood and Food Security in Nepal

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**Abstract:** With increased market access and road links to urban centres, settled agriculture in Nepal is becoming transformed into intensified cropping, especially in peri- and semi-urban areas. On a global scale, major driving factors for intensification are: population growth, lack of alternate employment, profit motive, market access, road links, availability of agricultural inputs and organizational cooperation. However, in Nepal the main driving factor is necessity due to lack of other income opportunities. The outcomes of agricultural intensification, namely, improved economic condition of farmers with higher production and good market price are intended to address the developmental challenges of high population growth, food deficit, agricultural trade modalities, fragile ecology, and national policies. In spite of soil fertility loss, erosion, workload and pollution, agricultural intensification is found to be a viable option for better livelihood in developing countries. This review paper discusses the global driving factors of intensification in the local context highlighting their positive and negative impacts.

**Key words:** Cropping intensification, food deficit, Nepal, peri-urban, semi-urban, sustainable development.

## Introduction

Over the centuries subsistence farming has been practiced throughout the country and the well being of people was related to agricultural production in the past. Those farmers who were able to grow enough crops to supply year- round food for their families were considered 'self sufficient' and who could not were regarded as 'deficit' farming households. In recent years cash crops and livestock have gained importance within agricultural system. In urban and peri-urban areas of Nepal, vegetables grown as cash crops dominate agricultural production.

The fragile geological set up and sensitive environmental conditions in Nepal hinder the construction of roads, irrigation facilities, use of modern

tools and technologies as well as other infrastructure development required for increasing growth in the agricultural sector. The distribution and storage of agricultural produce is another major challenge due to transportation and market constraints. For instance, most cereal crops fetch a low price at harvest time due to inadequate storage facilities, while at other times they are imported at higher price. Moreover, the liberalization policy of the government has also led to increased import of food grains from India because of lower prices there as compared to Nepal. These factors are affecting the agricultural production and growth, contributing both to poor economic condition of the farmers and food insecurity.

In spite of government prioritizing the agricultural sector and marginal improvement in irrigation facilities, hybrid seed varieties and a shift towards commercial farming, the Nepalese agriculture is unable to alleviate

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poverty and food insecurity. Intensified production has potential to be a viable option but some authors (Ananda and Herath, 2003; Metz, 1991; UNEP, 2001) argue against it on environmental grounds. The question of 'how to achieve higher agricultural production with minimal negative impacts?' continues to haunt Nepalese agriculture. The 'more people less erosion' hypothesis of Boyd and Slaymaker (2000) offers a possible answer to this question.

The aim of this paper is to review and synthesise literature on agricultural intensification and its impacts on farm production, livelihood, food security, and environment in Nepal. The figures and statistics in this study are associated with Nepal unless otherwise specified. It is argued that intensification of agriculture need not be detrimental to the environment, but in fact, may be beneficial for socioeconomic uplifting of rural communities. As agricultural intensification is still localised and practiced mainly in 'pocket' areas, conclusions drawn on the basis of only a few cases must be interpreted with caution.

### **Agricultural Intensification and Sustainable Development**

The literature contains many definitions of agricultural intensification (see Boserup, 1965; Brookfield, 1984; Carswell, 1997; Turner and Doolittle, 1978). In the Nepalese context, agricultural intensification is best defined as the cultivation of new types and numbers of crops to increase production from same land area. Greater use of chemical fertilisers, pesticides and labour inputs are also characteristics of agricultural intensification in Nepal. The aim in Nepalese agriculture has been to raise the agricultural production; therefore, whatever means are applied to increase production from the same amount of land can be regarded as intensification.

World Commission on Environment and Development in 1987 defined sustainable development as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. Future generations must inherit an improved capital stock and better technology that will equip them to substitute resources and overcome scarcity (Redclift, 1987). If we consider sustainable development as an alternative to unsustainable development, it should imply a break with the linear model of growth and accumulation that ultimately undermines the planet's life support systems (Redclift, 1987).

Sustainable agricultural intensification could be a viable option to meet the food need and minimise the environmental consequences. 'Sustainable agricultural intensification' in this context has similar meaning to that highlighted by FAO (2004) – the agricultural practices that do not degrade the natural resource base while also taking into account the need to improve the livelihoods of the millions of people who till the land, particularly in developing countries. Therefore, sustainable agricultural intensification has two goals: intensive cultivation for enhanced livelihoods and to improve the land and environment. The World Bank (2003) has also emphasised intensive sustainable agriculture by the statement 'intensified and sustainable production systems are environmentally beneficial, technically appropriate, economically viable, and socially sound'. The present agricultural practice in Nepal is not adequate to fulfil the country's food needs and as stated by Gips (1987), intensive production without considering geological conditions and environmental issues will not be sustainable. Therefore, this paper emphasises the balanced approach of 'sustainable agricultural intensification' to improve the livelihoods and economic conditions of farmers as well as food security in Nepal.

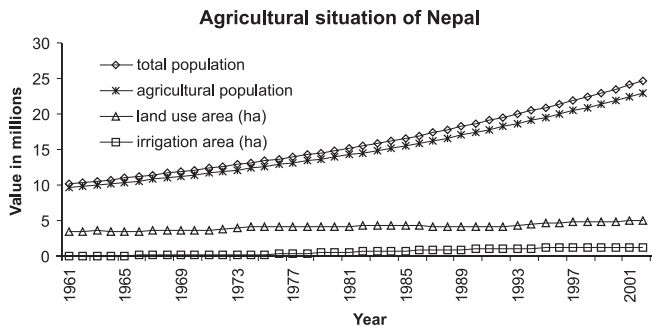
### **Need of Agricultural Intensification to Secure Livelihoods in Nepal**

The meaning of livelihood security is elucidated by Chambers (1988) who points out that livelihoods are secure when households have secure ownership of, or access to, resources and income earning activities, including reserves and assets, to off-set risk, ease shocks, and meet contingencies. Similarly, Adhikari (2002) in Nepalese context defines livelihood security as the capacity of the individual or household to improve their various assets (physical, financial, human, social and political). When the household has adequate and sustainable access to income and resource to meet basic needs, the livelihoods of its members can be considered secure. As a large proportion (>40%) of the people in Nepal are living below the international poverty line and still struggling for basic needs, livelihood insecurity predominates.

Population growth rates, the food deficit situation, imbalance of agricultural trade, land/geological conditions, and national policies are found to be the major factors affecting agricultural intensification in Nepal. The relationships of these factors are discussed individually in the following sections.

## Population Growth

Agricultural productivity is important for livelihood security in Nepal as more than 80% of the people's livelihoods are based upon it. However, despite being an agrarian society, Nepal's agricultural production has always been suppressed (FAO, 2003; World Bank, 1998) by the higher population growth rate (2.3%) (CBS, 2003). See Figure 1 for the trend of population growth in last forty years.



**Figure 1: Unequal growth of population and agricultural land area.**

Data source: FAOSTAT data, 2004.

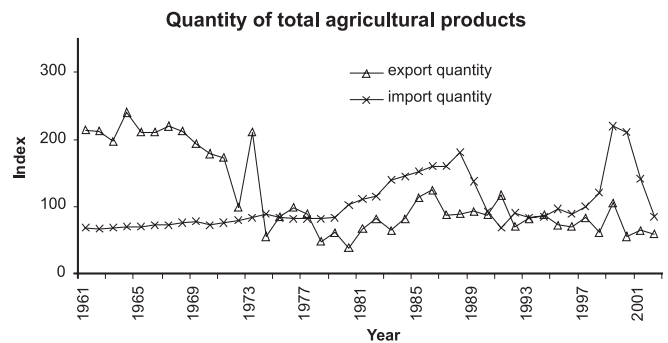
Agricultural intensification is in large part a consequence of increased food demands of a growing population. In Nepal, an imbalance in the growth rate of the population (2.3%) compared to agricultural land (0.8%) indicates that fulfilling the increasing food demand will have to be met by alternate means (Figure 1). People began migrating from villages to towns, especially in Terai, for employment and food production during the 1950s and a food deficit situation began to persist from the 1970s. Food and nutritional security are subsets of livelihood security, and the provision of food is indeed a central issue within society since so much in human life depends on the ability to find enough to eat (Sen, 1989). It is perhaps for this reason that there are many places in Nepal where farmers grow crops according to annual food requirements.

## Food Deficit

Annual food deficit condition is another reason for the need of agricultural intensification. It is estimated that out of the 75 districts, 43 are food deficit in Nepal and most of these districts are in hills and mountains (Bohle and Adhikari, 1998). Here, 54 per cent of households have only sufficient food for less than six months out of the year. The per capita food grain production has decreased and the average food deficit is 47 kg per capita in mountain region and 32 kg in the hills (Pyakuryal et al., 2005). Nepal Living Standard Survey report estimated

that 40 per cent of the people were living below the poverty line (CBS, 1996). This figure is believed to have increased since.

Nepal went from being a net exporter to becoming a net importer during the late 1970s reflecting a problem in agricultural sector of Nepal (see Figure 2). Between 1975 and 1983, paddy and maize yields declined from 2.6 to 2.0 and 1.8 to 1.4 t/ha respectively in Gorkha, Syangja and Tanahun districts (Kumar and Hotchkiss, 1988). At this stage, the food demand was growing faster than the internal food supply; hence Nepal started importing foods (Pyakuryal et al., 2005). Therefore, in order to balance the food import and export situation, crop production needs to be increased.

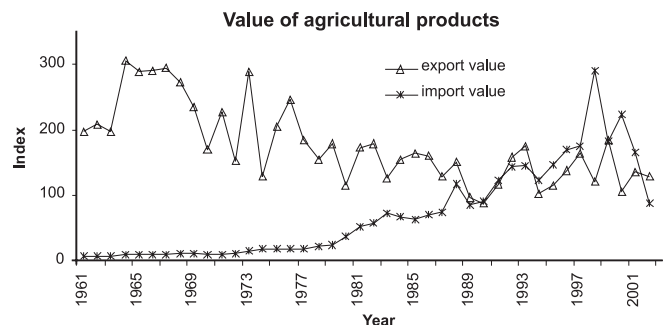


**Figure 2: Index of imported and exported quantities of food.**

Data source: FAOSTAT data, 2004.

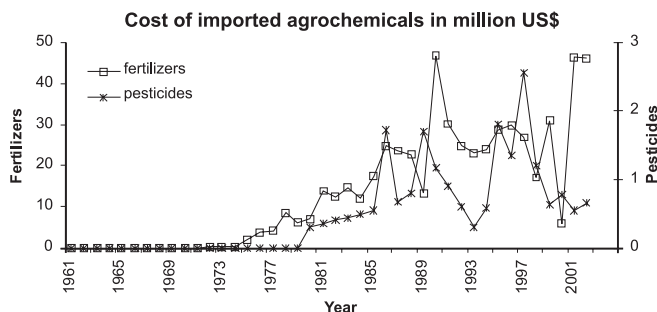
## Agricultural Trade

The total income from exports of agricultural income is not balanced. The import value is increasing whereas export value is decreasing (Figure 3). If this situation persists, the sustainability of agricultural production is doubtful. Furthermore, the cost and import of agro-chemicals is always increasing (see Figure 4). This imbalance also reflects the increase of agricultural inputs



**Figure 3: Imbalance of export and import of agricultural products.**

Data source: FAOSTAT data, 2004.



**Figure 4: Increasing cost of fertilizer and pesticides.**

Data source: FAOSTAT data, 2004.

without increasing the productivity to boost the export value. Under such conditions, farmers are becoming poorer; hence, the need of intensive farm production.

### Geology

The dramatic increase in farm production through agricultural modernization (mechanization, chemical fertilisers, hybrid varieties and pest control) marking the green revolution in advanced nations is a lesson for the development of poor countries (Redclift, 1987). Intensified agriculture had been a key development strategy to enhance food security and economic growth (Lee et al., 2001). But Nepal has less suitable agricultural land due to geologic and natural conditions. The agricultural land area increased from about 24% of total land area in 1961 to 34% in 2002 and has since essentially stabilized (FAOSTAT data, 2004). In fact, some of the previously prime agricultural land is being lost to urban expansion. Furthermore, the landholdings are small and fragmented (40 percent of landholdings are less than 0.5 hectare and 70 percent are less than one hectare), fertiliser use is low, agricultural road networks are inadequate and, in spite of extensive river systems, irrigation does not reach all arable land (UN, 1999). Only about 22 percent of the total cultivated areas receive year-round irrigation. Without improving the irrigation facility and modern inputs, it will be difficult to increase production. Distribution and transportation of agricultural products are also major hurdles to progress resulting from a lack of infrastructure development in the country.

### National Policies

Nepalese agriculture focusses on intensive production to overcome the food deficit situation and to improve socio-economic condition. The national agricultural policy has also stressed the need of agricultural intensification i.e., to increase per capita food production

from 277 kg to 426 kg by 2017 (NPC, 1995). It is possible to achieve this goal through inputs and supports to farmers. Here, the statement of Boserup (1965) on intensification is very relevant – ‘previously the regions under forest fallow could support only a couple of families per square kilometre; however at present, supports hundreds of families in the same area by means of intensive cultivation’. She has further highlighted that intensification is needed in every part of the world. Therefore, to support a growing population, meet the national target, overcome the food deficit problem, balance the economy of the country, and improve the living standard of people, despite the extreme geological and natural conditions, intensification is needed.

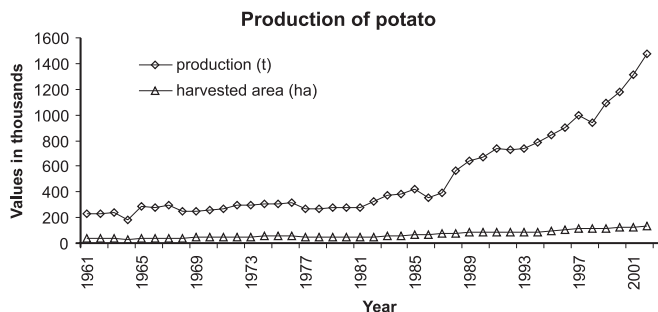
### Signs of Intensification Practices in Nepal

Agricultural intensification is now practiced in some areas of Nepal having access to roads and markets, irrigation facilities, and input/support from external organizations. Though intensification exists in a few pocket areas of Nepal (Carswell, 1997; Schreier et al., 1997), they supply a large proportion of the agricultural produce to nearby urban centres. GIS analysis between 1976 and 2000 (Gautam et al., 2003) also indicates that intensification exists in Nepalese agriculture. However, the farmers have only been able to capitalize upon a few products to intensify farming, namely, high value crops (in terms of market value and production), fertilisers, and cropping pattern. These parameters are considered as the main indicators of intensification in Nepal.

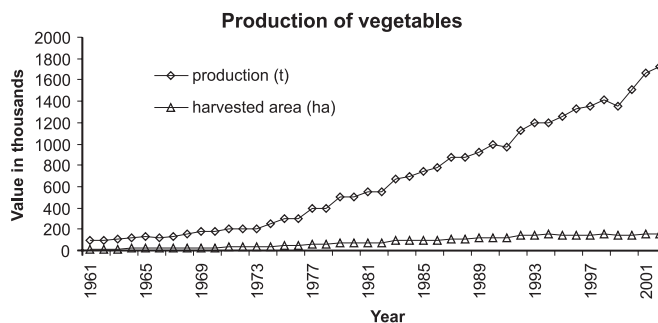
### High Value Crops

The most common crops used as high value crops are out-of-season vegetables, potatoes, and tomatoes in hilly areas. The recent trend of cultivating these cash crops instead of cereal crops is an indication of agricultural intensification in Nepal. The main reason for cultivating these crops is due not only to the higher price, but also because of higher yields. For example, on an average, the price of paddy, potato and tomato per kg is nearly the same; however, the yields of the latter are higher than that of rice. See Figures 5 and 6 where production has increased from nearly the same harvested area for the last four decades.

Over the past forty years, the rate of cereal production has remained nearly constant at 3%, while total fruit and vegetable production increased to 19%. Similarly, the production of cash crops like tea, coffee, tobacco and

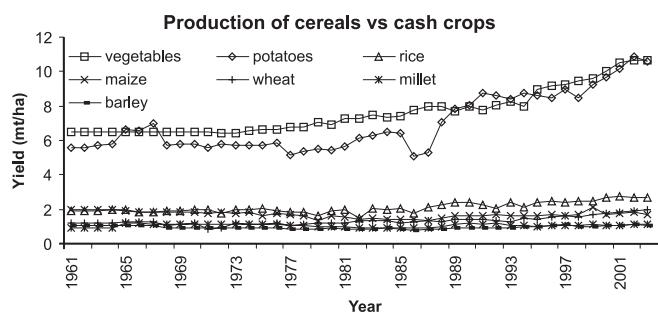


**Figure 5: Increase of production from approximately same harvested area of potato.**  
Data source: FAOSTAT data, 2004.



**Figure 6: Increase of production from approximately same harvested area of vegetables.**  
Data source: FAOSTAT data, 2004.

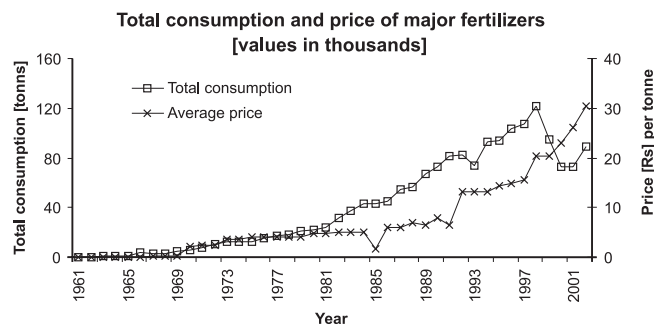
sugarcane also increased to about 35% during the same period. Considering potatoes alone, the production rate was 14%. The overall amount of food production is increasing, but the production rate of cash crops is much higher than cereal crops (Figure 7). Clearly, the low average yields of cereal crops (maximum of 5 t/ha, Saleem, 1994) cannot support the ever-increasing population of Nepal. Hence farmers are attracted to and intensifying farming by growing higher yielding vegetables, which yield up to 40 t/ha (Saleem, 1994).



**Figure 7: Yield of cereal crops as compared to cash crops.**  
Data source: FAOSTAT data, 2004.

## Fertilisers

Cropping intensification has been practiced with farmers applying more fertilisers as necessitated by the changing cropping pattern. The rapid increase in the use of chemical fertilisers (Figure 8) after the 1970s reflects the intensification process. On an average, the annual chemical fertiliser use increased by about 22% over the last forty years (calculated from FAOSTAT data, 2004). However, after 1998, fluctuations in the fertiliser use may be attributed to price and subsidy policies, as well as political unrest in the nation. Nevertheless, considerable amounts of fertiliser use have become indispensable for enhancing crop yields.



**Figure 8: Trend of total consumption and average price of urea and muriate fertilizers.**  
Data source: FAOSTAT data, 2004.

## Land Use and Cropping Pattern

Intensification is being practiced in Nepal by changing land use and cropping pattern. Irrigation availability is one of the contributors to land use change. As a result of irrigation facilities, farmers have increased crop rotations from an average of 1.3 crops to 2.6 crops per year (Shrestha and Brown, 1995). However, year-round irrigation is available on only 22% of the agricultural land (calculated from FAOSTAT data, 2004). As pointed out earlier, most of the potential arable land is already cultivated and there has been no significant land use change for major cereal crops over the past 10 years, while there is an increasing trend of potato and vegetable cultivation. Hence change of cropping pattern i.e., vegetable, tomato and potato, in the hill region of Nepal is a part of the intensification process.

## Global Driving Factors of Intensification in Context with Nepal

Globally, agricultural intensification has been driven by population growth, food demand, labour etc., particularly in the advanced countries of the world. Agricultural assets

like improved and high-yielding crop varieties, irrigation facilities and chemical fertiliser have contributed to intensification of production in Nepal (World Bank, 1998). External organizations also play a positive role in intensifying agriculture through awareness, education and empowerment. This, along with population, cultivable land area and agricultural GDP of farmers are driving them to shift towards cropping intensification. Such factors have individual and/or combined effects on intensification and play an important role in the policy making process for sustainable agricultural development in the Nepalese context.

### **Population**

Population growth is the main driving factor for intensive agriculture throughout the world (Ananda and Herath, 2003; Boserup, 1965; Carswell, 1997; Metz, 1991; Ojha and Morin, 2001; Shrestha et al., 2004; Templeton and Scherr, 1999). Sometimes the compulsion to acquire enough food may force vulnerable people to engage in unsustainable practices (Sen, 1989) and that may lead to land degradation. However, the relationship between population growth, agricultural change and environmental degradation is highly complex and no single explanation is entirely satisfactory (Holden and Sankhayan, 1998).

### **Space/Land Area**

With increasing demand for food, larger areas are needed to produce more food. In the past, farmers have encroached upon forests and public lands to increase crop production (Thapa and Paudel, 2000). However, most of the suitable lands in Nepal are already under cultivation (Bajracharya, 1983; Thapa and Weber, 1990). Hence, farmers are left with no option but to intensify production from their existing parcels of land. Boserup (1965) clearly highlighted that slowing of agricultural development and land scarcity drives intensification. In this respect, Nepal is no exception.

### **Market Access**

Production for own household consumption and for sale are the two types of crop production systems operating in the country. Market-based production has led to cropping intensification in hills of Nepal (Brown and Shrestha, 2000). Intensification is evident in farms with market access, such as in the northeast of Kathmandu, where fresh vegetable production has expanded (Dixon et al., 2001). Intensive vegetable cultivation in the Jhikhu khola watershed is also due to markets in Banepa and

Kathmandu (Brown and Shrestha, 2000). The economic reform in China after 1979 can be attributed to the rapid expansion of agricultural output after freeing of markets and the unleashing of productive opportunities connected with profit incentives (Sen, 1989). Therefore market and profit motives are also driving Nepalese farmers towards intensification to raise household income. Market access to agrochemicals is another important driving factor for intensification.

### **Road Access**

Road access helps in commercial production, agribusiness and distribution of agricultural products (World Bank, 1998). The main highway, Mahendra highway, running east to west in the Terai region, has facilitated distribution of agricultural products throughout the southern part of the country and the capital. However, the absence of link roads between this highway and hill districts has created distribution problem in hill districts and could be a cause for food deficit in the hills. For example, in the absence of road access, apples from Marpha are used for compost manure or liquor, while city markets are flooded with apples imported from abroad.

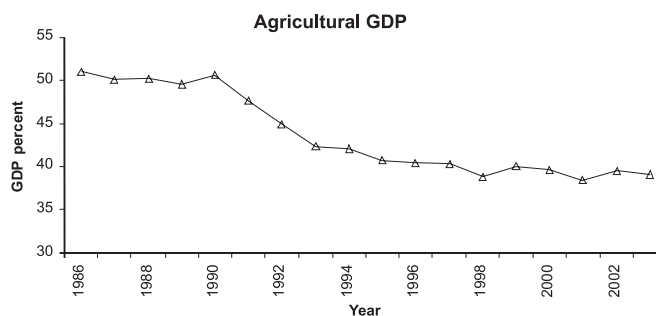
### **Irrigation and Inputs**

The introduction of multi- and annual cropping often depends upon the creation of irrigation facilities, which help in raising crop yields per hectare (Boserup, 1965). Food deficit situation occurs in absence of irrigation facilities, droughts, and/or heavy rainfall conditions (Pandey, 1997). Annual gross income per hectare has increased by more than 100% after the introduction of irrigation facilities in three districts of Nepal (Angood et al., 2002). Therefore, Nepal has a potential for higher production by increasing irrigation facilities.

Earlier, the practice of grazing and collection of forage and litter from the forest helped in sustaining nutrients in croplands. These practices have been curtailed in recent years due to labour shortage, restriction of access to forests, less production of compost and higher nutrient demand by hybrid crops. Thus, average crop yields declined 5 to 30% during the past few decades in a number of mountain watersheds in Nepal, along with the Indian Himalayas, and the Tibet (Partap and Waston, 1994). Farmers have started using chemical fertilisers to replenish soil nutrients. Along with the practice of intensification, use of chemical fertiliser in Nepal is increasing but still inadequate (see Figure 8). Cost is the reason for inadequate fertiliser use (Figure 4), thus affecting overall agricultural production.

## Agricultural GDP

Nepal remains heavily dependent on its agricultural economy and there is still a tendency to equate food security with food self-sufficiency (CBS, 2004). Although the agricultural GDP has declined from 75 per cent during 1950s and 1960s (CBS, 2004) to below 40 per cent at present (Figure 9), it continues to influence the overall GDP. The declining trend of the national GDP reflects, to a large extent, a decline in agricultural productivity. This decline in productivity is partly due to inefficient utilization of land resources (UN, 1999).



**Figure 9: Declining trend of agricultural GDP.**

Data source: FAOSTAT data, 2004.

## External Organizations

External assistance in small-scale hill irrigation schemes have made a significant impact on agricultural productivity and cropping intensity in parts of Nepal (Banskota and Lohani, 1999). Without the assistance and cooperation of different organizations, farmers, on their own, would have difficulty in using improved seeds, chemical fertilisers, and large-scale irrigation facilities. Thus evidently, there is a major role of external organizations in the process of agricultural intensification. However, the majority of farmers lack access to new agricultural practices due to geographical, economical, financial, risk-avoidance and socio-cultural factors (Bajracharya, 2001).

## National Agricultural Policies

The national agricultural policy of Nepal emphasises boosting agricultural production through the use of agricultural inputs, road network, marketing infrastructure and rural electrification (NPC, 1995). Earlier, the government had provided capital, interest and fertiliser subsidies to encourage investments in agriculture, especially in irrigation, cash crops and livestock. The subsidy policy has promoted the use of chemical fertilisers but production was limited by the

absence of irrigation facilities. Because of the same, small farmers were unable to overcome food insecurity (Timsina and Upreti, 2002). Hence, intensification has been stressed again in the ninth and tenth five-year plans.

## Analysis of the Effects of Agricultural Intensification

Intensification of agriculture has effects on both the socio-economic conditions of farmers and on the environment. More often than not, intensive production has increased crop yield, progress in farm income, and better management practices of cultivated land (Carswell, 1997; Katwal and Sah, 1992). This is a positive trend to overcome food security by increasing yield per hectare in intensively cropped areas. Yet, in the absence of adequate infrastructure like roads and irrigation facilities, markets of agro-chemicals and agricultural products, initial inputs like hybrid seeds, capital, trainings and awareness, the impacts are limited to semi- and peri-urban areas of Nepal. Therefore, the overall contribution of agricultural intensification at the country scale is hard to quantify. Nonetheless, several cases of food security and economic improvement of farmers involved in agricultural intensification have been reported.

A case from Kavre district showed that vegetable farming had a higher gross margin of US\$137 compared to US\$12 per year for farmers growing only staple crops (Brown and Kennedy, 2005). Other cases from Dhading, Tanahu and Parsa districts indicated irrigation-promoted agricultural intensification. Cropping of higher value crops like potato, tomato and other vegetable improved the household food security and household incomes (Angood et al., 2002). Paudel (2002), in Phewatal watershed, reported an increase of cash-crop cultivation from 37% in 1975 to 59% in 1998 which resulted in a tripling of household incomes for vegetable growing farmers. Similarly in Palpa district, women involved in vegetable production were noted to have better financial and food security conditions (Upadhyay, 2004).

Along with the positive effects on production and income, some authors have reported negative impacts of agriculture in Nepal. Most of the studies related land degradation, environmental pollution and pesticide pollution with agricultural intensification, which needs further verification. The overall impact of agricultural intensification is difficult to pinpoint through the available literature. However, a number of literatures have highlighted both positive and negative impacts of agricultural intensification (see Table 1).



**Table 1: Comparison of positive and negative impacts of agricultural intensification**

<i>Positive impacts</i>		<i>Negative impacts</i>	
<i>Field of impact</i>	<i>Literatures</i>	<i>Field of impact</i>	<i>Literatures</i>
Increased crop yield and income	Blaikie et al. (2002), Katwal and Sah (1992), Matson et al. (1997), Timsina and Upreti (2002)	Soil erosion and land degradation	Ananda and Herath (2003), Carswell (1997), Metz (1991), Shrestha et al. (2004), UNEP (2001)
Higher productivity and environmental quality	Boserup (1981)	Environmental pollution	Collins and Jenkins (1996), Lee, et al. (2001), Matson et al. (1997), Schreier et al. (1997)
Improved air quality and water quality	Bunch (1988)	Fertility loss	Thapa and Weber (1990)
Year round ground cover by crops check run-off and soil loss hence maintains soil fertility	Gardner and Gerrard (2003), Matson et al. (1997)		
Overall increased quantity and quality of livelihood	Carswell (1997)		

From Table 1, there are apparent contradictions among positive and negative impacts of intensification. For example, Bunch (1988) claims positive impact on environment (improves air and water qualities); however other studies (Matson et al., 1997; Schreier et al., 1997; Lee et al., 2001; Collins and Jenkins, 1996) emphasized negative impacts on environment. Overall, Table 1 shows positive effects towards crop yield and farm income. But soil loss, nutrient loss and environmental—pollution mainly by chemicals—are regarded as negatives. Conversion of land use and other negative impacts to positive ones is achievable through soil conservation and fertility management practices with intensification.

### **Sustainable Agriculture for Poverty Alleviation and Food Security**

Poverty alleviation and food security in Nepal is only possible through increased agricultural productivity and overall agricultural development. Here, the term development is equated to economic growth, i.e., when the country experiences increased growth, its productive capacity expands and it develops. In Nepal, policy research prioritizing poverty reduction needs to be undertaken in agriculture and rural development (Pyakuryal et al., 2005). Conway (1985) has linked productivity, stability, sustainability and equitability as four vital properties of agro-ecosystems. These four properties must be balanced to achieve sustainable agricultural development. This review indicates that intensive agriculture has the capacity for higher productivity to alleviate poverty and food insecurity,

although it may have some drawbacks for the environment. Therefore, a balanced approach, namely, sustainable agricultural intensification (as described earlier), is proposed to overcome the problem of poverty and food security in Nepal.

### **Why Sustainable Agricultural Intensification in Nepal?**

Food insecurity is both a cause and a consequence of poverty. Furthermore, poverty and household food insecurity are more prevalent and severe in rural compared to urban areas of all regions (Dixon et al., 2001). Nepal has a food deficit problem that is most acute in the mountain and hill districts with annual food shortage for six months or more (Bohle and Adhikari, 1998; FAO, 2003). The situation could become worse unless agricultural productivity and rural economies are transformed. Adoption of intensive farming throughout the country along with appropriate technological innovation offers promise for such a transformation. But such intensification must be done in an ecologically friendly manner due to the fragile mountain environment of Nepal.

Poverty tends to drive people to practice short-term benefit-oriented production that leads to land and environmental degradation imposing externalities on future generations (Holden and Shiferaw, 2002). However, poverty reduction is occurring in countries that are experiencing rapid growth in agriculture (Mellor, 1999), and livelihood security is achievable through agricultural intensification (Carswell, 1997). Agricultural

growth also reduces urban poverty due to consequent reduction in food costs and lower rates of migration from rural areas (Datt and Ravallion, 1998). Thus, sustainable intensification and agricultural growth offer a means to break the vicious cycle of poverty and resource depletion.

### **How to Achieve Sustainable Agricultural Intensification?**

The misconception that high doses of chemical fertiliser and pesticides increases productivity still persists in some areas. Decline in use of farmyard manure and soil nutrient insufficiency eventually threatens livelihood of farmers due to reduced production (Dougill et al., 2001; Schreier et al., 2001; Thapa and Weber, 1990). But it is well established that injudicious use of chemicals deteriorates soil quality, increases pest insurgency, and raises production cost. Thus, while improvement of soil fertility is a prerequisite for enhanced agricultural production, dependence upon chemical means alone is unsustainable (Schreier et al., 1997; Carswell, 1997). Integrated approaches to nutrient and pest management using combinations of chemical and organic fertilisers as well as biological/natural pest control measures are appropriate and sustainable for maintaining soil fertility and increasing productivity (Brown and Shrestha, 2000; Thorne and Tanner, 2002).

As yet governmental and non-governmental agencies endeavour to implement appropriate management approaches to improve production in Nepal (Gautam et al., 2003). The available literature and experiences of other developing nations indicate that sustainable agricultural intensification could be achieved through improved agricultural technologies. These include adoption of high yielding varieties, sloping agricultural land technology, terracing, legume intercropping, contour hedgerows, alley cropping, cover crops, agro-forestry, residue management, minimum tillage, rotational grazing, integrated pest management, organic and inorganic fertiliser etc., along with construction of irrigation and road networks. Clearly, the selection of appropriate crops, balanced application of nutrients, judicious use of pesticides, and adoption of appropriate conservation practices could enhance production while minimising environmental and human health impacts.

### **Limitations of Sustainable Agricultural Intensification**

The design and implementation of sustainable agricultural systems continue to be elusive due to socio-cultural and

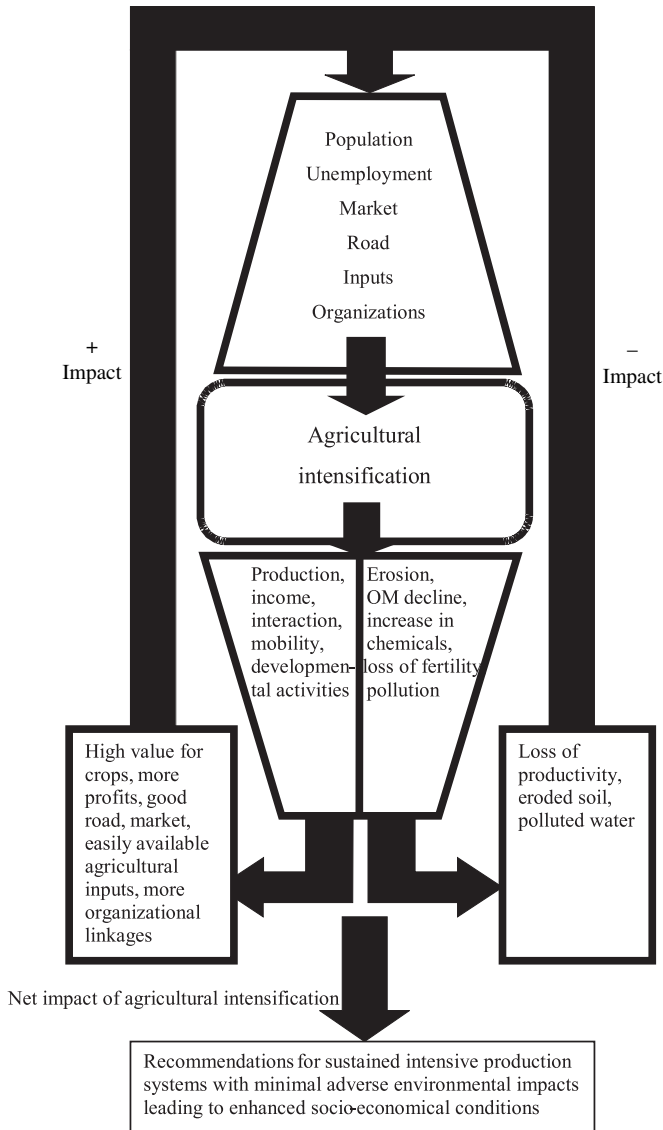
political instability in Nepal. Shortage and high price of agricultural inputs (Pandey, 1997) pose significant barriers for Nepalese farmers to replenish plant nutrients, without which it would be impossible to intensify production. Sustainable agricultural intensification must address socioeconomic, technological, managerial and environmental issues. Initially government intervention is unavoidable for construction of roads, irrigation canals, adoption of biophysical erosion control, etc., which involves capital investment. Unless these aspects are addressed at local and national levels, farmers would be unable to practice sustainable agricultural intensification. However, if these limitations are overcome through local and national policies, farmers will achieve higher production while avoiding environmental degradation, which will ultimately uplift their livelihood and increase food security in the country.

### **Conclusions**

At present, intensified cropping in Nepal is limited to peri- and semi-urban areas that have good road and market access. This review found that fragile ecological condition, irrigation availability, access to roads, markets and agricultural inputs, and national policies are the main factors limiting agricultural intensification in Nepal. Other factors for intensification that are in line with global driving factors include population growth, food deficit, low agricultural GDP, and external organization intervention. Previous studies revealed both positive and negative impacts of intensification on farmer's livelihood and the environment and stressed the need of sustainable intensive production.

Agricultural production may be increased either by expansion of agricultural land or through intensive cultivation. The former is no longer possible in Nepal, so intensified cropping is the only option. In view of the potential adverse environmental impacts, however, sustainable approaches need to be emphasised. Redclift (1987) states—'for sustainable development to become a reality it is necessary for the livelihoods of the poor to be given priority'. Hence, sustainable agricultural intensification with minimal negative environmental consequences may be achieved only if the economic and livelihood needs of the poor rural communities are met.

At present, a majority of farmers are unable to afford the capital investment or risk of changing or intensifying their farming practices. Therefore, at the outset government policies and practices should encourage



**Figure 10: Cyclic process of agricultural intensification based on existing literatures.**

sustainable intensive farming system throughout the country through subsidies for improved varieties, fertilisers, agricultural implements and small agro-industries. Further the government must invest in infrastructure development like roads, irrigation, credit and market facilities. The overall theoretical and empirical analysis of agricultural intensification in Nepal concludes with the model presented in Figure 10. The intensification model bifurcates in its impact, yet overall effect is on the socio-economic condition of people. Thus, the middle path of sustainable intensification is proposed to address livelihood and food security issues of Nepal.

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