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# Farm Management Strategies to Enhance the Farm Performance in Changing Climate: A Case Study in the Mid-hills of Nepal

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## Introduction

The environmental and economic sustainability of farming systems depend on sustaining soil fertility, which is affected by agricultural practices (Davis and Abbott, 2006). Soil management is one of the main agricultural practices. In Nepal, soil degradation can be severe, especially in the hilly regions (Chalise and Khanal, 1997) and may be accelerated by increase in annual temperature and erratic rainfall. Annual temperature increase in Nepal between 1975 and 2006 amounted to 0.042 ºC $yr^{-1}$ while rainfall is also becoming more erratic, which increases the risk of soil degradation (Malla, 2008). In this context Sustainable Soil Management (SSM) practices are becoming the cornerstone of local cropping systems since they can enhance inherent soil fertility (SSM-P, 2000). Moreover, these systems were shown to be more effective in sustaining food production and improving livelihood especially in the developing regions where climatic conditions are changing drastically (Jordan et al., 2009).The Nepalese mid-hill region is mostly dominated by upland agriculture. According to Bronson *et al*., (1997) soil organic matter (SOM) is the key support factor for maintenance of soil fertility and future production potential in the upland. This is due to the fact that in the absence of external inputs (other than common natural resources (CNRs) like chemical fertilizers), SOM provides the main source for most plant nutrients (Kayal et al., 2001). Though some farmers in the mid-hill region in Nepal are adopting improved and indigenous practices for soil conservation on their farms, most of them are unaware of the ecological benefits of improved SSM-practices. Moreover, this region is characterized by low productivity because of poor soil management and crop husbandry due to lack of knowledge on for instance the use of farm yard manure (FYM) and urine, the use of slash and burn, and shifting cultivation (Tiwari *et al*., 2004). On the other hand, nutrient losses from FYM/compost and urine, local resources for restoring soil fertility, can also be very high. These losses are largest when urine leaching is not being prevented, FYM/compost is stored in an open space, and/or FYM is applied to the field too long prior to incorporating into the soil. In addition to excess nutrient losses, poor FYM management practices also can greatly contribute to global warming (IFOAM, 2009). Therefore, improved awareness of the benefits of sound FYM/compost management practices is critical to enhance inherent soil fertility and to reduce negative impacts of agriculture on global warming and climate change. The objective of this study was to analyse and elaborate the potential impacts of different farming practices on farm performance, and soil organic carbon (SOC) and nitrogen (N) budgets.

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## Material and methods

A farm survey was conducted by interviewing 62 farmers in two communities in the Baglung district: Amarbhumi and Tityang, which was followed by soil sampling and analysis of fields of interviewed households. Sixteen FYM samples were analyzed in the lab. Farms in each community were grouped in two types: improved and traditional as related to use of sustainable soil management (SSM) practices with special reference to manure and urine management. One representative pilot farm from each group from both communities was selected based on total land area, area under major crops and their productivity, use of internal and external resources, and available farm feed sources per year. Both principal component analysis (PCA) and hierarchical cluster analysis (group average sorting method) was carried out to verify whether preliminary selected farms were representative of the corresponding groups. The selected farms were then used for further study using the FarmDESIGN model.

## Results and discussion

## Resource use

The small land holdings had high livestock densities (on average 5.1 LU/ha in both communities) and since forage productivity was low these farms were strongly dependent on external resources for livestock feed. Since there was no evidence that farms were purchasing external feedstuffs this implied that both communities relied greatly on CNR land. Based on feed balance calculations we estimated that 48% and 37% of DM intake for livestock was derived from CNRs in Amarbhumi and Tityang, respectively. From the farm analysis it became obvious that farmers were harvesting the bulk of feed resources during a specific period of time in a year. All these feeds are high in fiber and such diet may increase $CH_4$ emission compared to concentrate feeding (Aluwong et al., 2011; Shepherd et al., 2003, cited in Kasperczyk and Knickel, 2006). However, importing concentrates from outside the region or using non-sustainable practices and chemical fertilizers to produce concentrates would off-set the benefits of the use of concentrates. We observed no differences in the application of FYM/compost between improved and traditional farms in the Tityang community (21 Mg/ha), but in the Amarbhumi community improved farms had considerably higher rate of FYM application than traditional farms (44 vs. 32 Mg/ha). This implied that improved farms were applying more local resources and farm inputs than traditional farms.

The improved pilot farm in Amarbhumi had a slightly higher N efficiency (40%) than the traditional one (38%), which had relatively high N-loss of 178 kg/ha that was attributed to a long off-farm grazing period. Similarly, in the Tityang community, the improved pilot farm had relatively high N-efficiency (54%) compared to the traditional one (36%), which was related to lower N-losses (55 vs. 125 kg N/ha). Therefore, overall N loss was much lower in the improved farm, which was probably related to proper management and utilization of FYM/compost and urine at farm. This indicates that on an average, mixed farms in mid-hills are not utilizing the input resources efficiently. However, among the traditionally managed farm N-efficiency was even lower.

### SOC and N budgets

In improved farms, farmers applied well-decomposed FYM (along with litter) and their FYM heaps were protected from sunlight and water. These practices are expected to minimize the losses of nutrients, especially nitrogen and potassium. In improved farms, farmers' covered manures either by thatch/tin/slate or by plastic sheets. The soil N content was significantly higher for improved farms (0.46 and 0.25%) than for traditional farms (0.41 and 0.20%) in Amarbhumi and Tityang communities, respectively. Covering FYM with plastic sheets is supposed to increase nutrient retention and reduce nutrient losses due to volatilization and leaching of nutrients. Weber (2003) reported that traditionally prepared FYM has lower (0.5-1.0%) nitrogen compared to well-prepared (protection from sunlight and water) FYM that may contain 1-1.5% N. Moreover, on a dry mater base, urine contains much more nitrogen than dung (Waber, 2003) and its effective use in SSM systems resulted in improved nutrient utilization, while urine-derived nutrients are not properly utilized in traditional farms. Most of the improved farmers were using urine properly in both study sites. These practices could help to reduce GHG emissions (Jordan et al., 2009) especially $CH_4$ (Steinfeld *et al*., 2006) and $N_2O$, which contribute severely to global warming (Kasperczyk and Knickel, 2006). Moreover, these practices help to reduce $NH_3$ emission while such losses are greatly increased when solid manure is not being covered (Horning, 2006). Similarly, CNRs were contributing about 45% of the total organic carbon either in the form animal feed or bedding material, and the variation in CNRs contribution between the farms was influenced by the farm size and livestock density. The difference in SOC over traditional farms was found higher (2.8 vs. 2.3%) in Tityang than in Amarbhumi community (5.3 vs. 4.8%). Smith (2008) documented that soil carbon sequestration can be achieved by increasing the organic inputs amendments, residue management and increased plant carbon input or by reducing the losses. But high animal density also can cause land degradation and its severity will be high in hilly region.

High application of FYM/compost might have caused high accumulation of OM in improved farm at Amarbhumi. Kaur *et al*., (2005) reported that the application of FYM during 7 year of a pearl-millet-wheat cropping sequence was shown to improve the SOC, total N, P and K status. Dux and Fink (2007) reported similar findings. Based on difference in SOM values between improved vs. traditional farming systems it appears that improved SSM practices have the potential to improve soil N and OM content within a time frame of 5-10 years and that when farmers adopt SSM practices, soil fertility on their farm could improve significantly.

## Conclusions and outlook

High livestock densities combined with low N efficiency and high (ca. 45%) contribution of CNRs to the overall farm organic carbon budgets could result in high potential ecological and environmental impacts including soil degradation in sloping regions. N-efficiency and N-loss in both study sites indicated that on an average, mixed farms in mid-hills are not utilizing the resources efficiently. Traditionally managed farms were the least N-efficient. Based on soil analysis at the field level and input resources used at the individual farm level it became apparent that improved farms had higher soil organic carbon and N levels which appeared to be related to proper management of farm resource inputs. Farms adopting improved soil management practices either have high N efficiency or low N losses or both. These findings signal the effectiveness of SSM practices in enhancing environmental performance of mixed farming system in the mid hill region. Therefore when farmers adopt SSM practices, soil fertility in terms of N and SOM/C on their farm can be increased considerably.

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