

CROP-LIVESTOCK INTEGRATION OF CEREAL-BASED MIXED FARMING SYSTEMS IN THE TERAI AND MID-HILLS IN NEPAL

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1 Introduction

In Nepal, the possibilities for expansion of agriculture are limited due to land scarcity. Therefore, intensification has been the strategy to increase production particularly in the lowland agro-ecosystems (Terai) (Dahal *et al.*, 2007) due to their fertile soils, uniform climate and availability of improved communication systems that contribute to market access. The growing urbanization has increased the demand for livestock products in the area (Yadav and Devkota, 2005). In contrast, due to its topography the Mid-hills agro-ecosystems of Nepal face issues of remoteness, erosion and low availability of external inputs. Similar to almost all the farming systems in Nepal, households in the Mid-hills are based on cereal production (maize, wheat and rice) and livestock is a source of income and buffer against food shortages. The additional role of livestock in providing manure and draught power strengthens the integrated nature of farming systems of the Mid-hills (Kiff *et al.*, 2000). Pilbeam *et al.* (2000) estimated that around 80% of N supplies to the soil are made via the manure pathway. However, the productivity of the crop-livestock systems is low. Farmers face trade-offs at farm and landscape level, especially crop-livestock intensification vs. labor availability, environmental impact and competing uses of natural resources. Although a small amount of fodder is obtained from on-farm trees and/or crop residues, tree leaves are generally gathered from communal forest areas (Kiff *et al.*, 2000; Devendra and Thomas, 2002; Lawrence and Pearson, 2002; Thorne and Tanner, 2002). Yet, the forest resources have been reduced progressively in the whole country (FAO, 2011; Nepal Central Bureau of Statistics, 2012).

The mixed nature of the agro-ecosystems, the increasing demand for livestock products, and the continuous land fragmentation in both Terai and Mid-hills emphasizes the importance of better integrating crop and livestock subsystems to attain agricultural intensification. However, the livestock sector contributes notably to serious environmental issues with substantial impact on demand on land for pasture or feed crops, shortage and water pollution, and loss of biodiversity (Steinfeld *et al.*, 2006). With this study we evaluate the degree of diversity and crop-livestock integration within diverse cereal-based farms in contrasting agro-ecosystems.

2 Materials and Methods

The study took place in two districts in the Mid-hills (Palpa, Dadheldura) and one district in the Terai (Nawalparasi). One hundred households were surveyed to obtain socio-economic and biophysical data. The Y-sampling frame (Tittone, 2008) was used to select households. One farm was randomly selected, and nine farms were selected at 100, 300 and 900 meters distance in three directions from the first household. The farms were categorized based on resource endowment through hierarchical cluster analysis in R software. One typology was created for each district. From each farm type, ten representative farms were selected and surveyed in detail to calculate nitrogen (N) fluxes through ENA (Ecological Network Analysis) (Rufino *et al.*, 2009). The Farm DESIGN model (Groot *et al.*, 2012) was used to quantify the nitrogen flow matrix for ENA.

3 Results – Discussion

3.1. Socio-economic and structural characteristics of the farming systems

The average productive land size in the Mid-hills was 0.5ha and 1.2ha in Terai. Livestock densities were higher in Mid-hills (20 TLU/ha) than in Terai (9 TLU/ha). Dairy cows and bullocks were more common in the districts of the Mid-hills, and dairy buffalos in Terai. In both districts of the Mid-hills the average number of household members was slightly lower than in Nawalparasi (Terai), of these household members 50% in Mid-hills and 40% in Terai were involved in the farming activities. In all the three districts the farms relied mostly on family labour. The income derived from farming activities was higher in Terai than in the Mid-hills, being almost 50% of the total income, while 30% in the Mid-hills.

3.2. Farm household typology

Farm households were grouped into four clusters based on labour, yearly income, farm size, food self-sufficiency and TLU considering main drivers of strategies represented by proxy indicators through PCA at each site independently. Clusters were interpreted as four farm types in each of the sites.

3.3 Ecological Network Analysis

Farming systems differed strongly in N flows in the network. The number of animals and associated feed imports largely determined the size and activity of the networks. The T and TST (Throughput and Total System Throughflow), expressing respectively size and activity of the network, were both higher in Mid-hills than in Terai, increasing from the poor to the more wealthy types. As expected, imports of biomass were large but did not contribute in a large extent to internal nitrogen recycling, resulting Finn's cycling indexes (FCL) lower than 10% in all the systems. FCL were comparable to those found in the farms studied by Rufino *et al.* (2009b). Wealthier farm households recycled slightly more than poorer farm households. Imports per hectare were 3.5 times larger in Mid-hills than in the Terai, with great variability in each district.

Farms in the Mid-hills smaller than 0.1 hectare with a high livestock density relied mostly on imported feed to support the requirements of the livestock, thus these farms could be considered as landless livestock production systems. Large imports resulted in large losses. The total N losses per farm were on average 135 kg N and the farm with the highest losses had 315 kg N, in line or to some extent higher than the ones of several studies of nitrogen balances in the mid-hills of Nepal (Pilbeam *et al.* 2000, Bastakoti 2011, Giri and Katzensteiner 2013). The main N loss pathway was found in soil losses. Manure management was identified as one of the main constraints to N recycling. Poor farms had the lowest internal N recycling and highest dependency from external inputs, as well as lower labour and area productivity. Hr, expressing the diversity of N networks, was correlated to area and livestock. Organization of the N flows (AMI) was slightly higher in mid-hills, meaning that flows in the system were distributed more heterogeneously. Poor types farm households had in all the three districts the highest AMI/Hr (few flows connect few compartments), suggesting that these were less diversified systems.

4 Conclusions

The types identified in each of the agro-ecosystems differed in labour, income, land size, TLU and self-sufficiency. The N cycling indicators showed that in general all the farms recycled only a small portion of the nitrogen that flows in the network, therefore having high losses. Losses were higher in the Mid-hills mostly due to high imports and the deficient manure management. In the Terai region, recycling and nitrogen use efficiency at farm level were slightly greater. In all the farms with higher cycling indexes, farmers were growing fodder crops. However, farms across the districts were dependent on external inputs to support the internal N cycling in a similar degree. Diversity of N networks was correlated to land and livestock: farms with more resources were more diverse in N networks, while poor farms had the lowest internal N recycling and the highest dependency on external inputs.

The results of this study allow understanding the high diversity and degree of diversification and integration of distinct types of farms across contrasting agro-ecosystems, which has implications in the design of specific strategies to achieve sustainable intensification in each agro-ecosystem.

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