Evaluating the importance of fodder trees to soil nutrition of farming systems in the mid-hills region of Nepal

A thesis submitted to The University of Adelaide in fulfilment of the requirements for the degree of Master of Philosophy

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Thesis Declarations

I hereby declare that this work contains no material which has been accepted for the award of any other degree in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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The *EnLiFT* project 'Enhancing livelihoods and food security from agroforestry and community forestry in Nepal' is funded through the Australian Centre for International Agricultural Research (ACIAR). Commencing in April, in 2013, it has three key objectives including 1) to improve the capacity of household based agroforestry systems to enhance livelihoods and food security, 2) to improve the functioning of community forestry systems to enhance equitable livelihoods and food security of community forest user group members, and 3) to improve the productivity of, and equitable access to, under-utilised and abandoned agricultural land. I encourage any comments and enquiries, and attribute any mistakes to the author.

Abstract

The livelihood of Nepali farmers in mid-hills Nepal is interrelated to forest-livestock-farming system. Farmers go to the forest to take fodder as feed for livestock then the livestock products are used for their consumption and income sources. The fresh manure is utilized as fertilizer for crop farming as farm yard manure (FYM). However, the nutrient relationship among fodder, manure, and farm yard manure has not been clearly understood. In addition, the monetary value of the nutrient of FYM has not been quantified.

The aim of this study is to evaluate the importance of fodder trees as a source of soil nutrition. To achieve this, this study has the following objectives: 1) to examine the nutrient status in commonly-used fodder trees, 2) to determine the nutrient status of fresh manure from livestock feeding on different fodder trees, 3) to survey the use and quality of farm yard manure, and 4) to determine the equivalent market value of the nutrients in farm yard manure.

This study explains the results of analysis identifying the concentration of Nitrogen (N), Phosphorus (P) and Potassium (K) in four forest fodder species. Additionally, it analyses the nutrient composition (NPK) of the manure of five goats, cows and buffalo feeding on three types of fodder species over a 27 day cycle. Finally, it calculates the monetary value of the nutrients in both fodder and manure.

The nutrient content of each fodder species is different for each village and according to livestock type. The nutrient content of fresh manure produced by different fodder types also differed in K concentration (for cows) and in P and K concentrations (for buffalo). This study shows that *Quercus* is a promising fodder for cows and buffalo, along with *Ficus* fodder also for buffalo. Furthermore, the P concentration in FYM differed for each village. Lastly, an analysis of the equivalent monetary value of FYM determined that it is five to ten times less than the market value of FYM traded.

Contents

Content of Tables

Content of Figures

Acronyms

ACIAR	Australian Centre for International Agriculture Research
ADF	Acid Detergent Fibre
AEC	Aquatic Ecology Centre
ANOVA	analysis of variance
AUD	Australian dollar
Brassaiopsis	*Brassaiopsis hainla*
C	Carbon
Ca	Calcium
cf	compare to the mean
C/N ratio	Carbon and Nitrogen ratio
CP	Crude protein
DDM	Digestibility Dry Matter
EM	Effective Micro-organism
EnLiFT	Enhancing Livelihoods and Food Security from Agroforestry and Community Forestry in Nepal
FCS	Food Consumption Score
FECOFUN	Forestry Community the Federation of Community Forestry Uses Nepal
Ficus	*Ficus nemoralis*
FYM	Farm Yard Manure
GDP	Gross Domestic product
GE	Gross Energy
K	Potassium
KU	Kathmandu University
LRP	Local Resource Person
N	Nitrogen
NAF	Nepal Agroforestry Foundation
NDF	Neutral Detergent Fibre
NO_3-N	Nitrate-nitrogen
NPK	Nitrogen, Phosphorus, and Potassium
NTFP	Non-Timber Forest Products
O	Oxygen
OC	Organic Carbon
P	Phosphorus
®	Trade mark
%	Percentage
Prunus	*Prunus cerasoides*
PSM	Plant Secondary Metabolism
Quercus	*Quercus lanata*
NRs	Nepali Rupees

SOC	Soluble Organic Carbon
t	ton
USDA	United States Department of Agriculture
y	year

Common Nepali words

bari	rain fed terraced field
doko	basket carried on back using a head strap
khet	irrigated field, usually lowland but can occur on terrace
ropani	land size unit, 1 ropani= 0.05 ha, or 508.8 m^2

Common names of fodder species

bainjh	*Quercus lanata*
dudhilo	*Ficus nemoralis*
gogun	*Saurauria nepaulensis*
hatipaile	*Brassaiopsis hainla*
kanyu	*Ficus semicordata*
kimmu	*Morus alba*
payun	*Prunus cerasoides*
siltimul	*Litsea cubeba*
timila	*Ficus auriculata*

Chapter 1: Introduction

1.1 Background

Farm yard manure (FYM) is essential to crop production throughout Nepal. It typically consists of a mixture of manure, plant residuals, grasses and fodder litter that contain nutrients that respond to mixing, fermentation and decomposition. Ruminants digesting different fodder types excrete manure containing correspondingly differing levels of Nitrogen, Phosphorus, and Potassium (NPK) (Osti et al. 2006). It is therefore possible to manage and improve the quality of FYM by feeding livestock different fodder types, as shown by Throne et al. (1999). Farmers favour organic manure containing a high nitrogen content (Thapa, Walker & Sinclair 1997). Dietary N intake has a strong correlation to N manure concentration (Yan et al. 2006) showing that manure nutrient content correlates to nutrients in fodder which the ruminant digests and excretes.

Livestock fodder featuring high nutrient content can enhance livestock weight, increase milk production and improve the quality of manure in areas with variable fodder vegetation species and fodder availability. The improvements contributed by a high nutrient content make an important contribution to the livelihoods, crop production and food security of farmers in the mid-hills of Nepal.

Since 2013, the Australian Centre for International Agriculture Research (ACIAR) has enhanced the livelihoods of people in Kavre and Lamjung districts of Nepal through the project “Enhancing Livelihoods and Food Security from Agroforestry and Community Forestry in Nepal” (*EnLiFT*). The objectives of this project have been stated in the Acknowledgements section. A parallel objective that emerged after the project began was to clarify the nutrient flow in the forest-livestock-crop field system, thereby addressing a key research gap.

1.2 Aim

Therefore, the aim of this study is to evaluate the importance of fodder trees as a source of soil nutrition to be achieved through the following objectives:

1. Survey the use and quality of farm yard manure;
2. Examine nutrient status of commonly used fodder trees;
3. Examine nutrient status of fresh manure of livestock feeding on selected fodder trees, and;
4. Determine the equivalent market value of farm yard manure derived from selected fodder trees.

1.3 Structure

The structure of the thesis is as follows. Chapter 2 describes food security issues in Nepal that underpin the need for this research and presents a theoretical framework to understand the role of fodder trees in delivering livelihood and food security. Literature is presented to describe fodder trees in the region, before outlining the methods used to analyse nutrient status in plant tissues and manure.

Chapter 3 provides a brief overview of the methods used in this study and describes how each objective is achieved through three field studies and a desk-top review. This chapter also provides a description of the study site.

The results of the field studies and desk review are presented in Chapters 4 to 7. Chapter 4 details the survey outputs related to the first objective, describing the use and quality of farm yard manure. Chapter 5 presents results of the examination of nutrient status of commonly used fodder trees. Chapter 6 establishes nutrient status of fresh manure from livestock feeding on fodder trees selected in Chapter 5. The final results section, Chapter 7, draws on information from the previous chapters to determine the equivalent market value of farm yard manure derived from fodder trees.

Chapter 8 integrates and interprets data from results chapters and presents a discussion that evaluates the importance of fodder trees in soil nutrition of farming systems of the mid-hills of Nepal. Then Chapter 9 represents the discussion between study results and former researches that attempts further insights of the consequences. Finally, Chapter 10 concludes and summarises the study results.

Chapter 2: Literature Review

2.1 Introduction

Fodder trees and FYM are crucial components of farming systems of the mid-hills of Nepal. This research project aims to understand their importance and present an integrated and holistic understanding of the social and ecological context. This chapter provides a review of the literature to build understanding of food security issues in Nepal, the status of agroforestry and community forestry, and the contribution to food security through a farm-forest link. The significance of fodder trees is the key factor of the farm-forest link through the provision of nutrients from forest to farm. The literature review concludes by outlining practical methods for measuring nutrients at various points of the farm-forest cycle.

2.1.1 Food security issues in Nepal

Food security is determined by the quantity of available food, quality of food for sustenance of household members and seasonality or availability of food. A farming system often cannot provide subsistence food all year for a household, and farmers must often rely on other sources of income (i.e. livelihood) that can be used to purchase food, contributing to food security.

Food security and poverty in the mid-hills of Nepal are closely related and crucial issues in the development of Nepal (CBS 2013); IFAD (2013). The mid-hills region is home to 11 million people which is approximately 43% of the country's population, as compared to the mountain area 6.7% and Terai[1] 50.3% (CBS 2011). Many households in the mid-hills are food insecure and struggle to find enough food or earn sufficient income to purchase enough food for sustenance.

Studies show that the food deficit in grain (grains consumption minus supply as a proportion of the local population) in the mid-hills area is 47 kg per capita

[1] Terai; Area of Nepal divided into three area, such as the mid-hills which include Mahabharat and southern Himalaya hills, the upper hills including the Himalayas and inner Himalayas and the Terai region consists southern plains and the Siwaliks (Pariyar 2008).

(Pyakuryal, Roy & Thapa 2010). The balance of cereal supply and consumption in the mid-hills is minus 336 metric ton (Pyakuryal, Roy & Thapa 2010). The regions with the highest poverty rates are the mountains and mid and far western hills areas with relatively higher scores than the Terai area on the Food Consumption Score (FCS[2]) (CBS 2013). In the mid-hills area, the poverty rate is high in 33 of 39 districts (Subedi 2003). Karkee (2008) reports 60% of households are in food deficit for varying lengths of time, with 40% being deficient between one and six months and 20% deficient for more than six months. The food energy deficiency rate in the mid-hills area is 44.2% (Haslett 2011) meaning almost half of the population are suffering from a lack of nutritious food. As a consequence, 40% of Nepal's population is considered to be undernourished according to international standards (FAO 2010a).

Food insecurity is strongly correlated to an underperforming agricultural sector and over-reliance on agriculture for livelihoods which currently engages 66% of Nepal's population (Heifer 2015). Most cultivation in Nepal is subsistence farming, evidenced by the fact that the agriculture sector contributes only 34.7% of total GDP (Department of Agriculture Nepal 2015). There is room for improvement within the agriculture sector, in not only crop productivity and provision of food for people, but also for to generate income through commercial production.

Food security is dependent on the natural climate, environment, productivity and seasonality of rural production. In the mid-hills area, rural production refers to a combination of food and income from agricultural production on private land, and income derived from forest-based commodities accessed from community forests on public land. The following section demonstrates the important link between farm production and forest products (i.e. the 'farm-forest link'). This is followed by descriptions of agroforestry and community forestry, and their contribution to food security.

[2] FCS; WFP (2008): Food Consumption Score = number of days for each food group in eight categories was consumed during the past seven days multiplied by the weight of each food group nutrient.

2.1.2 The farm-forest link and food security

Subsistence livelihoods of mid-hills farmers are contingent on mixed farming systems, such as forests, crops and livestock production (Maltsoglou & Taniguchi 2004). As land size held by Nepalese farmers is very small, farmers cultivate products for home consumption or to sell to the market. The average size of land per household in Nepal is 0.80 ha, in Terai is 0.96 ha, and 0.66 ha in the mid-hills area, with land size decreasing over time (CBS 2012).

Figure 2-1 describes the main elements that determine the productivity of the farm and forest, and the links between these two sub-systems. This close-relationship between different contributors can be called the forest-livestock-farming system (Desbiez et al. 2004). For example, in the forest, slashed branches are used for firewood and livestock fodder, as well as other household uses, such as bedding material. Important by-products are livestock manure used for making FYM to apply to cropped fields, and the milk from livestock that is consumed by farmers or sold in local markets. The diagram also indicates several areas identified for development in the *EnLiFT* project (Nuberg 2014).

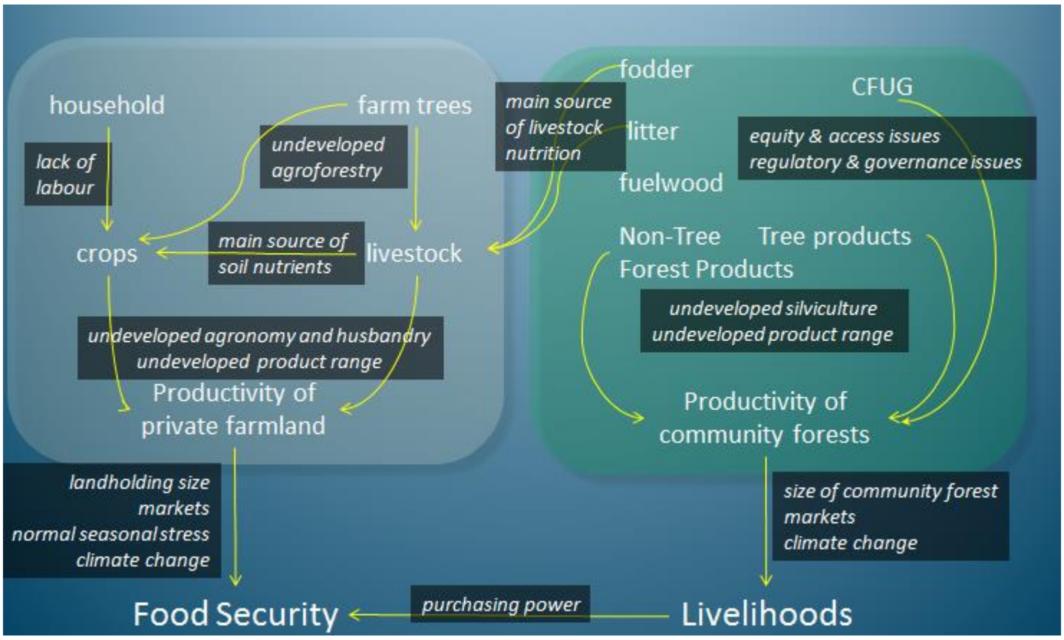

Figure 2-1*: The farm-forest link, food security and the importance of farm yard manure (modified from Nuberg (2014))*

2.2 Agroforestry and food security

Agroforestry refers to any land-use system which aims to maintain and improve the economic and ecological balance among crops, trees and livestock (Lundgren & Raintree 1983; Nair 1985; Young 1990). While most traditional farming systems naturally fall into this definition, agroforestry has only been recognised as a separate discipline of scientific study since the 1970s. There is a great diversity of agroforestry systems that reflects a range of ecological and socioeconomic contexts. Some techniques, for example, involve introducing crops such as medicinal plants, herbs or spices into the forest, whereas others transplant useful forest trees into field crops. In particular, nitrogen fixing trees or fruit trees are often planted at the edge of terraces where crops are grown. The benefit of organic matter and nitrogen fixation to soil fertility and crop production outweighs the competition for space, light and water (Soltis et al. 1995). Agro-forestry also mitigates soil erosion as rain run-off can be more productively managed, further optimising land productivity and improving food security and farmers' livelihoods (FAO 2014a; Paudel 2012).

2.2.1 Farming systems and their fertility in mid-hills of Nepal

To understand the context of agroforestry system development in Nepal, this section describes the regions' main attributes, including soil types, rainfall patterns, main field crops and the composition of typical rural households.

As mentioned previously, the agriculture ecological regions of Nepal are divided into to three regions based on altitude, crop and livestock characteristics (Pariyar 2008), including Terai, the mid-hills and mountain regions (Table 2-1). The Terai occurs along Nepal's southern border with India and is generally lower than 500 m in altitude. It has a sub-tropical climate suitable for intensive cultivation and the use of agricultural machinery. In this region, the main cultivated crops are rice, wheat, beans, gram, lentils, and sugarcane. Surplus is sold into markets to the south in India or other regions in Nepal. The ethnicities living within this region include the Tharus, Yadavas, Satar, Rajvanshis and Dhimals (Consulate General of Nepal 2015).

Table 2-1*: Area of agro-ecological zones (source; MOAC 2004)*

Agro-ecological zone	Area (km^2)	Percentage of zone per total area (%)
mountain	51,817	35
mid-hills	61,345	42
Terai	34,019	23
Total	**147,181**	**100**

The area of interest in this study, the mid-hills region, spans 500 m to 2,500 m altitude (MOAC 2004), and is represented by a very hilly landscape with a subtropical to temperate climate. Home to 43% of the population (CBS 2011), the area has great cultural diversity, including the Gurungs, Magars in the west, and the Rais, Limbus and Sunwars in east (Consulate General of Nepal 2015). The main cultivated staple crops are maize, rice, millet and potato. Cash crops, such as tea, coffee, ginger, spices and honey are produced where possible and the main livestock reared are cow, goat and buffalo.

The mountain region begins at over 2,500 m altitude and is dominated by seasonal and permanent snow and glaciers. Potato and barley crops are cultivated between 2,500 and 4,000 m (von Fürer-Haimendorf 1975) and kept livestock include yak, chauries (yak–cattle crosses), cow, sheep, goats and horses (Pariyar 2008). The area's ethnicities include Sherpa, Gurung, Manangpas, Lopas and Tibetan people who live with a distinctive culture (Consulate General of Nepal 2015).

At a national scale, the number of people per household in Nepal is decreasing due to modernisation and migration as people seek employment or education opportunities. In 2001, the number of people household was 5.44 and declined to 4.7 in 2011 (CBS 2011). Land is limited in Nepal and only 40% of the total land area is arable, including cultivated, uncultivated lands and grassland (MOAC 2004). The growing population in Nepal has decreased land size per household which has halved from an average of 0.88 ha per household in 1995/96 to 0.44 ha in 2010/11 (CBS 2013). Similarly, in the mid-hills region, where 12 million people reside, the land-holding size is scarce and area per household is less than

0.5 ha (Acharya et al. 2007). Decreasing land size for households directly impacts food self- sufficiency and security throughout Nepal.

Nepalese soil characteristics vary greatly and are described using a widely-used indigenous typology based on colour, texture and pH types. These are kalo (black), rato (red), kailo (grey), balaute (sand), domat (loam), chim (clay), masino (fine) and amilo (low pH, sour) (Pariyar 2008). The USDA soil taxonomy describes fourteen soil types, and the soil types in Nepal under this categorisation are primarily entisols, inceptisols, mollisols and alfisols (Fig 2-2) (Pariyar 2008).

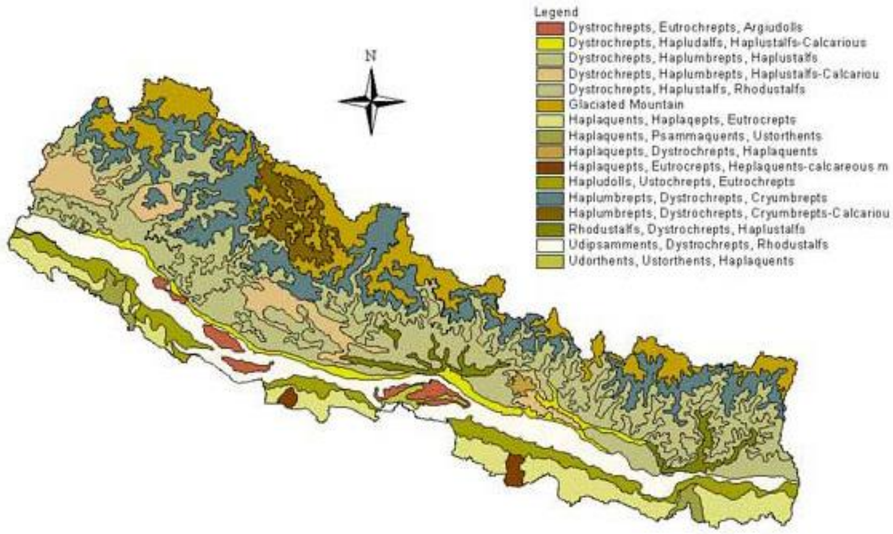

***Figure 2-2**: Soil type using USDA taxonomy (source and approved by: Soil science division, NARC)*

2.3 Agroforestry systems in the mid-hills of Nepal

In the mid-hills of Nepal, agroforestry has been practised as a traditional farming system for a long time (Thapa & Paudel 2000) and is well integrated into the forestry, agriculture and livestock sectors. Natural resources are regarded as vital because they influence the daily activities of farmers and are interrelated. If one sector is degraded, for instance, other sectors are negatively affected. For example, forest degradation can cause soil erosion from run-off where trees once held a large amount of water, soil and nutrients, resulting in lower crop yields. In contrast, if soil erosion can be controlled, nutrients are stored on the sloped landscape and delivered to crops through the farm-forest link (Acharya & Dangi 2009; Tiwari et al. 2010).

The earliest description of agroforestry in Nepal (Amatya & Newman 1993) identified the benefits as 1) use of multi-purpose tree[3] grown to produce fuel, firewood, timber, fodder for livestock, and bedding materials, 2) planting of non-timber forest products (NTFP) plants, such as medicinal plants, herbs, fruit trees, coffee, tea, and mushrooms, 3) wildlife habitat, 4) mitigation of soil erosion, landslides and floods, and 5) wise and intensive use of land when land is scarce or population is high. Some studies suggest that inter-cultivated crops contribute to enhancing carbon, phosphorus and potassium in forest soil post-harvest (FAO 2015).

The mid-hills region of Nepal has distinctive characteristics of agroforestry which are categorised to reflect the typical agroforestry management system (Nair 1985) and function (Watanabe 1998), as shown in Table 2-2, below. Agroforestry has evolved in a complex biophysical and socio-cultural landscape in the mid-hills region, conforming to the biophysical constraints and subsistence needs of households. Its natural output, however is inadequate to meet the economic demands of rural people, evidenced by the large out-migration of rural labour seeking better incomes. Despite this, it is widely regarded that the conscious development of modern agroforestry systems offers the best approach to enhancing rural livelihoods and food security (Mbow et al. 2014).

[3] multi-purpose tree; The tree which can be used many purposes such as timber, fodder for feed for livestock, fuel wood, and consumption for fruits.

***Table 2-2**: Agroforestry types in Nepal (source: Nair (1985); Watanabe (1998); Amatya (1993); Newman (1997); Upadhyay (2009))*

	Nature of components	Type of system	Tree or crops	Category standard (Watanabe 1998)
1	Agri-silviculture	Crops and tree, shrubs/tree	*Flemingia macrophylla*, Ipilipil (*Leucaena glauca Linn*), *Sesbania grandiflola*, *Alnus nepalensis, Desmodium rensonii*, vegetables, legume (*Medicago sativa, Trifolium repens, Desmodium intorum, Stylosanthes guianensis*), maize, millet, shrubs, broom grass.	Functional, Socio economic
2	Silvo-pastoral	Pasture/ animal and trees	Fast-growing shrub and trees, pine (*Pinus patula and Pinus roxburghii, P. patula*), pasture, livestock grazing.	Structural, Socio economic
3	Agro-silvopastral	Crops, pasture/ animals and trees	Mix with 1 and 2.	Structural, Socio economic
4	Others	Multipurpose tree lot, apiculture with trees, aquaculture with trees, wind break, home gardening.	*Alnus nepalensis, Ficus semicordata, Leucaena leucocephala, Gliricidia sepium, Populus deltoids, Poplus euamericana*, *Shorea robsta*, *Terminalia, Angeissus, Pinus roxburghii*, *Quercus leucotrichophora*, *Artocarpus lakoocha*, *Bauhinia purpurea, Bauhinia variegate*, various species of bamboo, coffee, tea, aromatic plants (*Mentha* spp. and *Cymbopogon* spp.), herbs (*Cymbopogon martini, Palmarosa grass, Cymbopogon nardus, Mentha arvensis* (mint), and Citronella grass), cardamom (*Amomum subulatum*), and pepper.	Socio economic

2.3.1 Importance of fodder trees in Nepal agroforestry systems

Before tree-planting was undertaken on a large scale in the mid-hills region in the 1970s, most farmers' grazed livestock increasingly deforested hills. As the soil degraded, the government recognised the need to protect the landscape and placed restrictions on where farmers could graze cattle. This was the first stimulus for farmers to plant fodder trees close to their houses. As the planted forests grew and un-planted slopes naturally regenerated tree fodder became increasingly available.

This amount of fodder available on the ground soon decreased, however, as the trees grew and the canopy of the new forest closed over. What little fodder remained became restricted due to over-extraction by the community (Regmi 2003).

The demand for nutritious livestock fodder has climbed in districts close to cities, such as Kathmandu and Pokhara, which are ready markets for meat and milk. In 1989, the number of trees in farms in the central Nepal region increased three-fold (Regmi 2003) when the government established the Master Plan for the Forestry Sector (MPFS) (MPFS 1991). Farmers now plant fodder trees in fields close to their houses and transport fodder to cattle over shorter distances. One aim of the MPFS was to incorporate community forest and agroforestry programs via a sustainable adaptation strategy implemented by community forest rules (MPFS 1991). Subsequent promotion of the community forest program increased tree numbers to 13,000 (Adhikari 2007) which increased fodder availability, time savings in terms of labour and food security (Baul & Ullah 2013). In the mid-hills region of Nepal farmers started planting fruit, fuel, timber trees and fodder trees in community forests and private agroforestry fields (Regmi 2003) to create a sustainable livelihood system.

2.4 Agroforestry contribution to food security

The productivity of farming systems in Nepal remains very poor. This is the main reason for the out-migration of labour to find employment in cities and internationally. Several strategies to develop Nepalese farming systems are identified in Figure 2.1, including 1) improved productivity of agroforestry element of the farming system, 2) greater transfer of nutrients from forest to farm via FYM, 3) agronomy of field crops, 4) husbandry of animals and, 5) better access to markets. This thesis is specifically concerned with the second development area, transfer of nutrients from forest to farm via FYM, as it strongly influences components 1, 3, and 4 described above.

In recent years, population growth and urbanisation have increased demand for larger quantities of more nutritious food in Nepal. The problem was exacerbated between 1996 and 2006, by migration of rural people into urban areas seeking physical safety during the period of the Maoist Insurgency (Seddon 2005). Nepali moving to urban areas were exposed to international culture through various media and were made increasingly aware of health issues around food. Gurung (2010) highlights the impact of urbanisation in increasing demand for meat and dairy products. As a result, peri-urban villages are investing in dairy, meat and fresh vegetable production, and are linked to growing transportation businesses.

The growth in livestock industries correlates to an increased demand for fodder and bedding materials. Agroforestry trees on private farms can rarely provide year-round supply of fodder making trees in community forests significant contributors to this nutrient supply chain. Due to growing competition for these resources, there are signs of resource depletion and degradation which presents a serious challenge to the expansion of these industries (Acharya & Dangi 2009).

2.5 Community forestry and its contribution to food security

2.5.1 History of community forestry in Nepal

In Nepal, community forestry involves collective management of forest resources at a local or village level and has been a legally-recognised institutional structure in forest management since the 1970s. The early conceptual development occurred in Nepal and is viewed internationally as an example of good practice. In the mid-hills region, over 1.6 million households participate in 17,600 community forest user groups involving 72% of the rural population (Hobley 2012).

Community forestry emerged when Nepal was ruled under the Rana feudal regime in the 1950s (Ojha & Chhatre 2009; Regmi 1978). In 1957, the Private Forest Nationalisation Act was introduced so that all forests belonged to the state (Blaikie 2002), but little consideration was given to sustainable management practices. Eventually, largely though the influence of international aid programs operating in Nepal, the government recognised that local community cooperation was necessary to manage forests. In the late 1970s, the government acknowledged Himalayan forest degradation as a critical environmental issue and, in 1978, handed forest management to local government. The Community Forest Program was established under the National Forestry Plan in 1978 (Colfer 2005) during the non-democratic Panchayat administration (Ojha & Chhatre 2009). In 1989, the government established the Master Plan for the Forestry Sector (MPFS 1991).

After voting in a democratic regime in 1990, the new Forest Act was inaugurated in 1993. The regulation was enacted in 1995, enabling forest user groups to establish an action plan, make autonomous decisions and implement activities in collaboration with government officials (Bartlet 1992; Kumar 2002; Malla 1997).

2.5.2 Successful community forest projects

Achievements of community forest projects demonstrated that user groups became wealthier, increased the amount of forest foods and products, and improved forest security and livelihood accessibility. From an educational perspective, the projects reinforced local organisational capacity, involved all ethnicities and acknowledged entitlement, offered training opportunities and was inclusive of women. Forest product outputs included timber, fodder, fuel wood, litter, grass for livestock feeding, stone, medicinal plants, mushroom, cardamom and pine tree resin (Dev et al. 2003; Gauli & Hauser 2009). Non-timber forest products gained more profit from medicinal plant production, such as lokta (*Daphne bholua*), argeli (*Edgeworthia gardneri*), machino (*Gaultheria fragrantissima*), allo (*Giardina diversifolia*), chiraito (*Swertia chiraita*), simta (cone of *Pinus spp*.), jhyau (raw lichen), and sugandawal (*Veleriana wallichaii*).

Dev et al. (2003) point out that community forest projects expanded employment opportunities and enabled households to optimise income sources. Similarly, Chapagain (2009) demonstrated that from 2003 to 2008 mean household earnings of forest users increased by 113% and women’s participation in community forest user groups increased to 25% (Kanel 2004).

2.5.3 Factors for successful Community Forest Management

Influential factors in community forest management related to institutional condition, physical features of forests and influence of markets. Institutional factors include: selection of local leaders, traditional forest based livelihood system in place, network and level of participation of local communities, rules and regulations, inclusion of committee representation as a group activity, degree of decentralisation and group experiences of community forest activities. Taking a pro-poor approach to livelihood development, non-timber forestry products (NTFPs) market chains are able to improve economic benefits to the poor through involvement of outside firms who can sell products and understand market demands.

Gauli and Hauser (2009) demonstrate that the factors that improve success of NTFP market chains are the degree it participates with outside firms, financial rank of users, availability of substitute work, and links to a solid market connection. Additional factors are described by Pagdee, Kim and Daugherty (2007) including property rights, institutional aspects, incentives and interests, financial and human resource support, physical features of forests, degree of participation and decentralisation, available technology, and market conditions.

Understanding property rights and community relationships with the forest system is important to building successful forest plans (Gibbs & Bromley 1989; Pagdee, Kim & Daugherty 2007). Rules and regulations, experience and leadership are essential to enable community forestry activities to address the problem of rule breakers and achieve outcomes (Pagdee, Kim & Daugherty 2007). Regarding incentives and interest, members feel 1) the value of resource gained from their participation, 2) the benefit to forest users groups, 3) necessity of forest resource dependency and sharing output of common resources and, 4) the expectation that group responsibilities will enable members to participate in community forest activities (Pagdee, Kim & Daugherty 2007).

In order to be successful, community forest programs must contribute financial and human resources to enhance the willingness and skills of NGOs, forest staff and users' groups, and support implementation and project activities with technical assistance from the forest office. Physical features of the community forest, including its size, location, access to outside community, diversity and ecological complexity influence program outcomes (Pagdee, Kim & Daugherty 2007).

The size and composition of a community, including population growth, social-cultural diversity, previous experience in cooperative working models and resolving conflicts are also important considerations. Members must trust local groups to work autonomously, have a clear process of governance and allocate budget and administrative functions to local groups (Pagdee, Kim & Daugherty 2007). Technology and market conditions rely on high market demand and construction of infrastructure which help to progress and achieve community livelihood goals (Pagdee, Kim & Daugherty 2007).

2.5.4 Negative impacts of community forestry

Despite positive impacts of community forest activities, there are still challenges to address, particularly in terms of decision making, resource sharing and addressing knowledge, and skills gaps between group members. For example, wealthy group members can acquire more forest resource benefits from the community forest than poor members, while poorer household farmers face more difficulty in accessing forest resources even though their livelihood is more dependent on forest products (Adhikari 2004).

2.5.5 Protecting the forest through community activities to increase nutrient load in the forest

An increased demand for livestock products influences supply of livestock feed. Farmers respond by seeking larger amounts of nutrient rich fodder in the forest, which in turn degrades forest resources. To address this demand, community forest activities have increased the forest cover rate, excluded non-members from intruding into the forest and enforced forest rules and management. However, in practice the implementation of rules often limits the extent to which forest resources can be used and the opportunities for farmers to enter and use forest resources freely.

Neupane (2003) states that forest resource degradation influences the poorest of the poor who depend on common forest for livestock fodder and basic needs. In the mid-hills of Nepal, the feed shortage for livestock is 40.5% dry matter, 55% total digestible nutrients and 68% crude protein (Rajbhandari 1991). The resulting over exploitation of forest resources impacts the mobilisation and mineralising of organic Nitrogen in the soil (Miller 1995). As a result, farmers often seek other resource options to access nutrients, as explained in the next section.

2.5.6 Contribution of community forestry to food security

Community forests contribute to food security via two routes (Figure 2-1). The primary route is through fodder trees and bedding materials that community forests provide farmers. The volume and quality of fodder trees needs to be increased to supplement fodder available on farm and silvicultural management regimes are designed specifically for this purpose.

Adhikari, Williams and Lovett (2007) report that one community forestry program improved the collection amount of grass/fodder and leaf litter, however, decreased the amount of fuel wood available. Restricted rules on forest access have encouraged people to plant trees in fields close to their home and gradually improved natural regeneration, crown density and growth of trees (Maharjan 1998). Furthermore, these practices have positively influenced soil nutrient management, such as leaf, litter, compost making, tree, and water management rules (Dev et al. 2003).

The other pathway to increase food security is to raise commercial productivity of community forests. Not only is timber available, but NTFPs, such as cardamom, pepper, turmeric, ginger, and medicinal plants, such as *Daphne bholua* (‘lokta’), *Edgeworthia gardneri* (‘argeli’), *Gaultheria fragrantissima* (‘machino’), *Giardina diversifolia* (‘allo’), *Swertia chiraita* (‘chiraito’), and mushrooms increase the value of forests. Estimated sales contribute between seven to thirty million US dollars every year to household income (Olsen 2005). NTFP promotion in the community forest program aims to gain income for marginalised ethnic groups to alleviate poverty (Gauli & Hauser 2009).

A final consideration for improving livelihoods from community forests is to nurture the institutional and regulatory environment to increase supply of timber and other forest products. Supporting a ready market with a sustainable management regime and ensuring an equitable distribution of profits are two tactics discussed at length (Dhakal, Bigsby & Cullen 2007; Gauli 2011; Khadka & Vacik 2012; Ojha 2014; Pokharel 2012; Thoms 2008), however, they are not directly relevant to this thesis and will not be discussed further.

2.6 Soil fertility and Quality of FYM: Making condition of FYM in the field

2.6.1 Soil organic carbon

Low soil fertility, commonly reported in developing countries including Nepal, originates from an imbalance of low input and high output cropping (Lal 2006; Samuel, St.Clair & Lynch 2010; Shrestha 2009; Turton et al. 1995). While fertiliser application is low, extraction of plant residues drives a soil carbon deficit that can escalate mineralisation and loss of soil organic carbon and impact soil fertility deterioration (Bouwman 1990; Lal et al. 1995; Post & Mann 1990; Sitaula 2004). Soil organic carbon is an essential element of major micro-nutrient mobilisation in soil and FYM, and impacts soil chemical, biological and physical characteristics (Krull et al. 2004). High soil organic carbon content is associated with fertile soil, high water holding capacity and a soil physical structure conducive to good plant growth.

When soil organic carbon content is high in the presence of well-balanced concentration of nutrients, NPK, it becomes an energy provider to promote biological plant soil systems and processes (Krull et al. 2004). In addition, it has special characteristic such as storing nutrients, facilitates the soil aggregation, and the resilience to soil erosion (Hobbs et al. 2013). Interestingly, in India one study for 12 to 15 years' term cultivating rice and wheat pattern shows the difference of the soil organic carbon concentration in the certain fertiliser treatments measured with the available NPK, and two types of crop yields. It shows that if a recommendable concentration of NPK, 120 kg N, 26 kg P, and 33 kg K were applied consistently to the soil, soil organic carbon decreases where organic carbon (OC) content is more than 6.5 g· kg^{-1} whereas OC increases where OC initial content is less than 5.0 g· kg^{-1} in the soil (Yadav et al. 2000).

FYM has a high concentration of plant residues and soil organic carbon concentration, unlike chemical fertilisers, and strengthens soil ability to provide nutrients to plants. Studies show a higher amount of soil organic carbon in soils containing FYM than in soils containing mineral fertiliser. A meta-analysis estimates at least a 53% higher soil organic carbon as compared to chemical fertiliser use or non-fertilised soil (Maillard & Angers 2014).

Another study determined that water soluble organic carbon in the rice-wheat cropping pattern was significantly influenced by the application of 100% NPK and 100% NPK + FYM (Brar, Singh & Dheri 2013). In addition, this study highlights that the long term application of NPK fertiliser and NPK with FYM can improve the content of water stable aggregate OC, which is five percentage of the total soil organic carbon. The reason of improved aggregate OC comes from aggregation of soil particles by the FYM treatment. FYM treatment with enhancing soil C storage increased the organic mineral formation then it stimulated the aggregation soil C storage (Elliott & Coleman 1988).

The application of rice straw and compost raises and rehabilitates the soil C and N content, according to a rice-wheat cropping study undertaken in India (Sodhi, Beri & Benbi 2009). The study found a significant difference in mean weight and stem diameter of rice and wheat when rice straw compost was applied at 2 ton ·ha^{-1} or 8 ton· ha^{-1} with or without inorganic fertiliser. In addition, soil N and C content increased when rice straw was applied at 8 ton ·ha^{-1}. From these results, continuous single rice straw compost or together with mineral fertiliser treatment can accommodate the soil N and C levels. Furthermore, another study shows that application of FYM for seventeen years with wheat straw and green manure resulted in higher carbon content in the soil than in an unfertilised control (Tirol-Padre & Ladha 2004). The soil organic manure and plant residuals displayed a positive relationship with lignin content, and soil organic carbon had a high correlation with total carbon in the soil.

Sustaining soil organic carbon in soil to enable plants to grow in tropical countries is pivotal to maintain soil fertility. In the tropics, decomposition rate of organic matter is faster than in cold climates because of the strong sunshine, temperature differences and seasons which accelerate weathering and decaying of organic matter (Brar, Singh & Dheri 2013; Mandal et al. 2007). Maintaining soil organic carbon in tropical areas is more difficult compared to cold climates, and it requires more effort and techniques than in temperate climates.

2.6.2 Fertiliser use in the mid-hills region

In the mid-hills of Nepal, FYM is the most indispensable input for agricultural production (Niroula & Thapa 2007; Shrestha 2009). Farmers rely on FYM for soil fertility due to remote location and cost of transport of fertiliser from market to farm (Shechan & Karki 2006). Often farmers lack financial resources for purchasing fertiliser (Maskey 2003) and there is poor penetration of agricultural extension services across the mid-hills region. In summary, subsistence farming in Nepal is hampered by lack of education, credit and financial services, infrastructure, and extension services (Kebede 2001). FYM is one of the most important inputs for crop cultivation in mid-hills of Nepal (Niroula & Thapa 2007).

2.6.3 Nutrient quality of FYM

Even though all farmers in the mid-hills apply FYM to their fields, soil fertility remains inadequate. The reasons for low soil fertility are low rates of fertiliser application, low soil organic carbon and subsequent lack of ability for micro-organisms to efficiently process nutrients for plants. Furthermore, when the crop harvested, 60 to 80 kg of plant nutrient such as NPK are extracted in every ton of crop grain produced (Thapa 2010). Therefore, the output as the plant product is higher than the input by the fertiliser. Namely, the NPK nutrient in the soil between inputs and outputs is imbalanced.

Simple techniques exist to maintain and improve FYM quality, including covering the soil with a plastic vinyl sheet, installing a roof to avoid strong direct sunshine and keep FYM moist, adding cattle urine to FYM, inoculating FYM with fermentation promotion materials, such as micro-organisms, and maintaining a constant humidity and temperature for composting (Shrestha 2009). Furthermore, simply maintaining forest cover of key sub-canopy species that can be used for compost contributes greatly improving the quality of FYM regardless of what other practices are followed (Dougil et al. 2001).

Nutrient rich FYM improves plant growth because well fermented organic materials are efficiently absorbed by plants. FYM that has decomposed efficiently contributes to soil fertility (Baca et al. 1995) and crop productivity (Tomasoni, Borrelli & Ceotto 2011). However, FYM composting practices in Nepal rarely follow best practice so nutrients in FYM are often lost (Dougil et al. 2001).

2.6.4 Impact of FYM application to crop yield and soil properties

FYM can increase the physical and chemical soil properties and improve crop yield. A recent study in India demonstrated that the application combined of FYM and synthetic fertiliser can increase soil properties and soil breaking volume, decrease soil temperature, contribute to carbon sequestration, reduce carbon emission and increase crop yields (Mahanta et al. 2013). Other studies concur with this finding, demonstrating improved water efficiency in rice-wheat cultivation in Pakistan (Abbasi & Tahir 2012) and increases in rice yield and system sustainability (Shahid et al. 2013). The impact of different FYM application amounts on yield and chemical content was studied in peppermint (*Mentha piperita L.*) in India, determining that an FYM application of 45 $t \cdot ha^{-1}$ produced the highest yield (Gopichand et al. 2013). In Kavre district, the average amount of FYM application of 20 to 30 percentage moisture content in warm-temperate climate are 10.8 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-wheat, 7.2 $t \cdot ha^{-1} \cdot y^{-1}$ for maize-buckwheat, 25.0 $t \cdot ha^{-1} \cdot y^{-1}$for maize-potato, and 17.4 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-potato cropping pattern. In the sub-tropical climate in Kavre district, they are 4.7 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-wheat, 2.4 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-mustard-maize, 5.5 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-mustard-maize, 13.4 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-vegetable, and 1.0 $t \cdot ha^{-1} \cdot y^{-1}$ for rice-sugarcane cropping pattern. The overall observation of FYM impact is that it improves yield and soil physical properties (Shrestha 2006).

2.7 Contribution of fodder quality to FYM quality

2.7.1 Fodder types influence on milk amount and health of livestock

The quality and proportions of fodder, grasses and plant residues fed to livestock influence body weight and milk production. When more nutritious fodder is provided in larger amounts, milk production increases (Dhungana et al. 2012). In addition, one scholar reports that the milk production is responsive to local climate and accessibility of green fodders (Goletti 2001). It is understandable that the local climate, such as the number of rainy days and sunny days, difference temperature day and night, also through the year in a particular location can influence to the cow's health, which may affect to their milk production. Besides, it also can imagine that the amount of fodder feeding to the cow depends on the availability in the area. Interestingly, Dhungana et al. (2012) report that *Artocarpus lakoocha* fodder has high nutrient value and improves milk and fat yield, weight gain, growth rate and good health of cattle. Fodder types such as *Ficus semicordata (khanayo), Shorea robusta (sal), and Catannopsis tribuloides (katus)* have been shown to improve the body weight of goats (Pandey et al. 2013). Interestingly, farmers also believe that some fodders improve milk yield and fat concentration, referring to *Artocurpus lakoocha, Litsea monopetala* and *Bambusa nutans* fodder plants (Thapa, Walker & Sinclair 1997).

2.7.2 The impact of fodder quality and nutrient intake on manure nutrient

Fresh manure from livestock feeding with tree fodders is the main source of nutrients in FYM. While it may be a minor component in terms of volume compared with other constituents, such as bedding material and dry crop residues, it is the most nutrient-rich. The nutrient content and density of fodder fed to livestock therefore impacts on FYM nutrient quality and its value as a fertiliser for crop production. Osti et al. (2009) show that three types of fodder, *Ficus* *roxburghii* (nimaro), *Ficus cunia* (rai khanyu) and *Castanopsis indica* (dhalre katus) had positive effects on digestibility of crude protein, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin, and calcium (Osti et al. 2006; Upreti & Shrestha 2006). Thus, the high nutrient and fibre contents of fodder reflect to increase manure nutrients. Interestingly, one study found that famers have indigenous knowledge of fodder ability, such as 'posilo pan' related to nutritional better value (Throne et al. 1999). A correlation was identified between farmer knowledge and laboratory tested nutrition values showing that the 'posilo pan' plant had 1) crude protein content plus dry matter digestibility of 72 hours in vitro gas production plus non-extractable condensed tannin, and 2) crude protein content, neutral cellulose digestibility plus non-extractable condensed tannin (Throne et al. 1999). Therefore, farmers recognise fodder which has nutrients and palatability, 'posilo pan' as some high and better value fodders, whereas others do not (Thapa, Walker & Sinclair 1997). For example, *Litsea monopetala* has high nutrient load with low palatability, while *Bridelia retusa* has high palatability and low nutritive value (Thapa, Walker & Sinclair 1997). Dietary N intake has a strong correlation to the N manure concentration (Yan et al. 2006) and farmers preferred fodder types strongly correlate with nutritious content and positively impact on manure quality (Thapa, Walker & Sinclair 1997).

2.8 Nutrient flow studies

Nitrogen, Phosphorus and Potassium are key macronutrients that can be used to examine the flow of nutrients in the farm-forest link in Nepal. These are key for soil fertility and are mainly supplied through synthetic fertilisers. The flow from forest to farm follows this path: 1) NPK in tree fodder is fed to livestock, 2) after digestion, NPK is absorbed into animals' body and in milk, 3) remaining nutrients are excreted as urine and fresh manure, 4) urine is lost to the system, but manure is moved to a pile next to the barn, 5) used bedding material and dry crop residues are added to the pile which is usually left for 11 months (Figure 2-3). During the composting process, nutrients are lost by leaching to the soil by rainfall or volatilisation, and, 6) the remaining NPK in the FYM is transferred to the newly cultivated field to be incorporated into the soil bed prior to seeding.

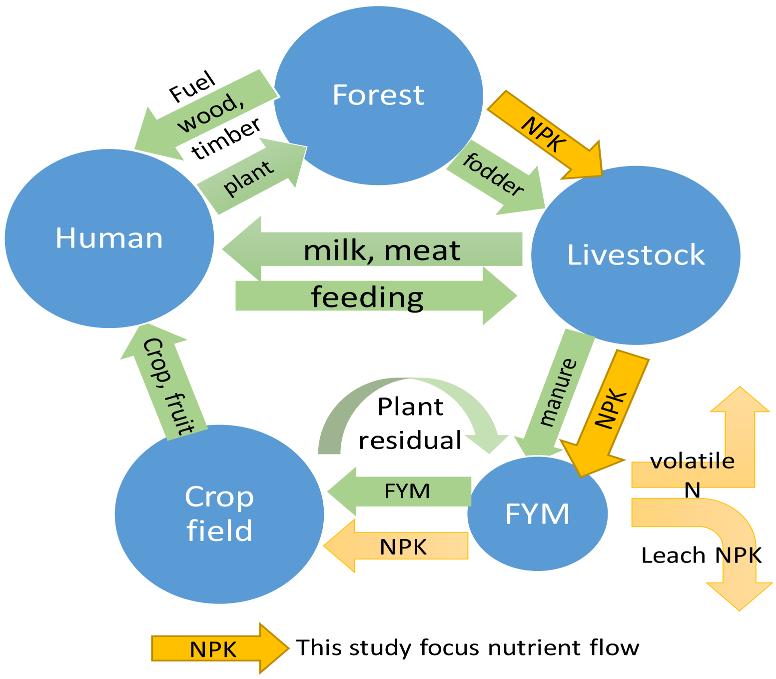

Figure 2-3: *Diagram for studied nutrient flow within forest, livestock, FYM, and crop field cycle*

Flows of NPK through similar systems have been investigated by many researchers (Table 2-3; Figure 2-3). For example, Masaka (2013) identified the NO_3-N and nitrate leaching in cattle manure, and N uptake in dry matter absorbed by tomato and rape crops in Zimbabwe (Masaka et al. 2013). In the study, when the high N content manure were applied to the tomato and rape cropping pattern, the concentration of the leachate, NH4-N and NO3-N in the wetland soil were remarkably accumulated. In other words, the nutrient flow from the manure to the soil significantly linked that the manure quality especially high N content fairly improves the mineralisation in the wetland soil (Masaka et al. 2013). Another example, C and N flow in trees, fodder and fuel wood were measured in forests, shrubs, herbs, organic matter, FYM and crops in Solkhumbu district in Nepal (Giri & Katzensteiner 2013). The study estimated the amount N and C ($t \cdot ha^{-1}$) flux per one household from forest lopping, fuel collection, livestock manure, FYM production and compost, fuel wood use in household, and manure application. For example, it reports that C and N fluxes intake from the forest as a fuelwood to the households are 1.1 – 1.2 $t \cdot ha^{-1}$ C and 18.4 – 20 $kg \cdot ha^{-1}$ N. Intake by the litter for FYM from the forest are 0.27 – 0.34 $t \cdot ha^{-1}$ C and 7.4 – 10.6 $kg \cdot ha^{-1}$ N. Intake as a fodder for livestock are 0.19 – 0.2 $t \cdot ha^{-1}$ C and 6.2 – 6.4 $kg \cdot ha^{-1}$ N respectively. The fresh manure production from livestock per household is 4 -5.4 $t \cdot hh^{-1}$, and C and N flux to the agricultural land are 293 – 400 kg C and 10 – 14 $kg \cdot hh^{-1}$ N. The produced C and N by crop cultivation are 1.8 – 1.9 $t \cdot ha^{-1} \cdot y^{-1}$ C and 49.4 – 52.2 $kg \cdot ha^{-1} \cdot y^{-1}$ N. It concludes that improved composting practices were needed to maintain soil fertility.

The amount of NPK drawn from forest fodder and grass was examined in Mustang and Kaski districts in Nepal (Balla et al. 2014). The study demonstrated that farmer dependency on forests in these two districts had decreased, and that nutrient flow data is needed to incorporate into future forest management and farming systems for sustainable resource use (Balla et al. 2014).

Another study explored the impact of different applications of synthetic fertiliser and manure on crop yield (Pilbean et al. 2000). The study investigates the balance of nutrient flow, input and output through the farming- livestock system, such as fodder, grass, livestock, crop, and soil in terms of loss and production in Kaski and Dhankuta districts. In the study, the hypothetical household holding with 1 ha of land with two thirds upland (bari) and one third irrigated land (khet) identified that the fertiliser input is about 26 kg N and removal as crop production is about 60 kg N. Then, the intake from forest resource to the household as a fodder and grasses are 80 kg N. Besides, FYM applied to the crops is about 100 kg N and grain content as a product is 36 kg N respectively. Another study reported that the soil fertility balance and N, P and Ca levels vary according to fertiliser input through different cropping systems in khet and bari villages in the Kavre district (Brown 1997). The research explores the nutrient flow of biological fixation, loss of nutrient of synthetic fertiliser and FYM, and the effectiveness of synthetic fertiliser and FYM to the soil. In addition, it further demonstrates that soil fertility and yield nutrient uptake relate to the presence and requirement of soil nutrients in Kavre district. Furthermore, one research in Nepal defined nutrient status in NPK and pH, soil OC and compost (Dougil et al. 2001) identifying a lack of labour and livestock impacted the quantity and quality of compost. These former studies closely related to the study to identify the nutrient flow from forest, livestock, and farming system as a form of fodder, feed, manure, and farm yard manure of the nutrient flow (Figure 2-3).

2.8.1 Monetary value of FYM

As previously noted, Nitrogen, Phosphorus and Potassium are fundamental nutrients for plant growth, which is important for setting flowers, seeding and fruiting. The nutrient flow (Figure 2-3) described in the former section demonstrates that nutrients (NPK) are transferred from litter and grasses (Balla et al. 2014) and from leaves, fodder, FYM and crop residuals (Giri & Katzensteiner 2013). The real value of NPK in FYM is invisible, however, and farmers in the mid-hills region cannot recognise the value of FYM. This study aims to demonstrate the economic value of NPK in FYM to build farmer understanding.

Delbridge (2011) estimated the purchase cost of manure converted from NPK content in the equivalent amount of N, P_2O_5 and K_2O as synthetic fertiliser (Delbridge et al. 2011). The study evaluated and compared the profit and risk of organic and chemical fertiliser input over long-term and short-term crop rotation in four years of maize cropping (*Zea mays L.*) with soybean (*Glycine max L. merr.)* oat (*Avena sativa* L.) and alfalfa (*Medicago sativa L.),* and two years' corn-soybean over 18 years of data. The research states if the organic price premium were considered, the net return of organic input rotation would be the higher than the chemical input in the United States. However, similar studies have not been undertaken in the mid-hills region of Nepal, so it important to evaluate the monetary value of FYM for this region.

2.8.2 The usefulness of determining the monetary value of FYM

If the monetary value of FYM equivalent to synthetic fertiliser were determined, farmers in mid-hills of Nepal would recognise the quality and value of FYM in the field. In addition, identifying monetary value enables to farmers to compare the nutrient quality of FYM with other methods of capturing nutrients and could be a useful indicator to grade the quality of organic fertiliser for plant cultivation and anticipate plant yield.

Table 2-3: Review of former nutrient studies

Type crop	Category	Results and comments	Country	Author	Year
Maize, rice, wheat, mustard, legumes, potato, tomato	Input fertiliser, FYM, and soil nutrient	1. Intake, biological N fixation is 15 kg·ha^{-1}·y^{-1}, synthetic fertiliser N efficiency is 40%, FYM mineralisation in 1st year is 40%, and N erosion is 25 kg·ha^{-1}. 2. In N budget, N input as fertiliser is 35 kg·ha^{-1}, organic residuals are 21 kg·ha^{-1}, compost is 53 kg·ha^{-1}, and deficit is 142 kg·ha^{-1}. 3. In N loss from the soil, erosion loss is 25 kg·ha^{-1}, volatilisation, leaching, and denitrification is 30 kg·ha^{-1}, crop uptake is 164 kg·ha^{-1}, and organic retention is 32 kg·ha^{-1}, which is succinctly measured. However, the method to measure of loss has not well explained. 4. Some of the data used by literature review. The study area is similar to the research by the author in Kavre district. However, the sea level, soil type, types of dominant tree species, land use type differ to the research sites of the author.	Nepal	Brown	1997
Maize and rice	Fodder, grass, livestock, crop	1. N input for the fodder and grasses is 80 kg·ha^{-1}·y^{-1}, fertiliser is 26 kg·ha^{-1}·y^{-1}, loss is 60 kg·ha^{-1}·y^{-1} as a crop removal, manure compost supply is 100 kg·ha^{-1}·y^{-1}, and crop production as a grain is 36 kg·ha^{-1}·y^{-1}. 2. This study result relates to the survey of the author's study to refer the N input from FYM to compare the study and the hypothetical model of data. 3. Some of the data collected from Kaski and Dhankuta region, which is, tend to biased because of only two regions of the data and the data range is from 1986 to 1999. The N loss amount by volatilisation, leachate, and decomposition of FYM have not measured.	Nepal	Pilbeam	2000
Maize and rice	Forest, FYM, soil	1. Nutrient status on NPK in FYM are 1.00, 0.35-1.69, 0.34 - 2.36 (%), which can be refer to the author's result of NPK status of FYM. 2. Soil chemical properties C (%), total N (%), P (%), and exchangeable K are 1.67, 0.13, 0.41, and 0.44 in khet and 1.36, 0.12, 0.44, and 0.76 in bari. 3. In forest nutrient in C (%), total N (%), and exchangeable K are 4.21, 0.28, and 0.55. 4. Mean FYM input to bari (upland) is 6.52 t·ha^{-1}·y^{-1}, and in khet (lowland) is 1.12 t·ha^{-1}·y^{-1}. 5. The criteria and judgement decision, no impact of community forest activities to the farming system are difficult to understand. It needs better clarification.	Nepal	Dougil	2001
Vegetable, potato, maize, wheat	Forest litter, fodder, grass, livestock, manure	1. Producing the FYM amount of 40 kg N ha^{-1} per year needs 25 kg N of forest litter, 23 kg N of forest fodder, 9 kg N of human waste, and 3.5 kg N of field grazing and straw for livestock. 2. The losses, volatilization, denitrification, and leaching for C and N have not been measured. 3. Fuelwood C and N fluxes from forest to house were 1.1 – 1.2 t·ha^{-1} C and 18.4-20 kg·ha^{-1} N. Litter intake to the house 0.27-0.34 t·ha^{-1} C and 7.4-10.6 kg·ha^{-1} N. 4. The research conducted in Solkhumbu district, which the climate differ to the research area, Kavre district.	Nepal	Giri	2013

Type crop	Category	Results and comments	Country	Author	Year
Tomato and rape	Cattle manure, soil nutrient	1. High and low quality manure, C%: 22.82: 9.13, N%: 1.36:0.51, C:N ratio: 16.8:1, 17.9:1 was reported in the application to the soil impact on the Nitrate concentration in leachate after 42 and 98 days planting vegetables. 2. N rate in the 30 t·ha^{-1} of manure application influenced to the NO_3-N and NH_4-N in the soil. 3. Increased manure application from 15 to 30 t·ha^{-1} has improved the tomato and rapeseed yield by 25-26% and 0.2-4 t·ha^{-1} accordingly. 4. The research conducted in Zimbabwe, which the cattle variety and manure quality may differ to the case in Nepal.	Zimbabwe	Masaka	2013
Beans, potato, maize, barley, millet, buckwheat, vegetables, rice	**Forest litter, fodder, grass**	1. In Lete, the average collected fodder 582 kg *Pinus wallichiana*, and made FYM and transferred NPK to 3.84, 0.54 and 2.99 kg for 0.8 ha·hh·y^{-1}. 2. In Kunjo, the average collected fodder is 2,162 kg and transferred NPK to 19.66, 1.84 and 10.39 kg for 0.55 ha·hh·y^{-1}. 3. In Hemja, the average 250 kg fodder collected *Schima-Castonopsis* and removed NPK are 11.08, 1.26 and 5.86 kg. In addition, the average 612 kg grass transferred NPK were 16.27, 2.22 and 11.42 kg·y^{-1} to farmlands (0.1538 ha·hh·y^{-1} upland- bari and 0.2383 ha·hh·y^{-1} lowland- khet). 4. The altitude, main fodder tress, and climate in studied three villages differ to the research area of the author in Kavre district which result can refer in a certain extent. 5. For NPK analysis, two grass sample and six fodder samples seems to be insufficient to determine the mean level of nutrient of NPK.	Nepal	Balla	2014

2.9 Research gap and contribution

For understanding of Nepali farmers' livelihood and farming system, it is necessary to review various sectors' component such as Food security, Farm-Forest link, Agroforestry systems, Community forestry systems, Soil fertility and FYM quality, and FYM monetary value. Those sectors closely linked each other to understand the socio-economical condition of mid-hill farmers. Although most of related former studies in those sectors reviewed in the chapter, some of the unknown issues were remained. For example, in the target research locations, Dhunkharka and Chaubas villages of *EnLiFT* project in Kavre district, successive investigation of nutrient content for NPK in fodder, fresh manure, and FYM in the nutrient cycle of forest-livestock-crop field system has not been identified. Regarding the nutrient content in fodder, one scholar investigated the nutrient NPK concentration for 30 species (Osti et al. 2009). However, the fodders collected from different part in Nepal and every season may have different nutrient content because the climatic conditions and soil types and altitude are different. In addition, NPK nutrient of livestock fresh manure fed by certain fodder species in Kavre district also has not been determined. Furthermore, the monetary value of FYM in project target villages also has not clarified yet. Therefore, it is important to identify those issues.

Determining those research gaps helps for project stakeholder to demonstrate present nutrient level of fodder, fresh manure, and FYM, which are one part of the forest-farm nutrient flow system. In addition, it develops activity design in the project cycle management. Furthermore, it will help to publish the articles of nutrient status among the fodder, manure, and FYM in forest-farm system in the mid-hills region of Nepal. Finally, farmers will understand the value of fodder and fresh FYM that may help them to choose the useful fodder species and to improve the practical methods of FYM.

Chapter 3: Methodology

This research is composed of four different studies shown in Table 3-1. The following chapter focuses on the connection between each research activity, keeping in mind that specific details of each method is given in a dedicated chapter (Table 3-1).

Study 1 (Chapter 4) surveys the use and quality of farm yard manure (FYM) according to its NPK and soluble organic carbon (SOC) nutrient concentrations in two villages. Additionally, total P and K concentrations in fine and coarse textured two mm sieved particles of FYM were determined. The determined NPK amount value per kg is used for a valuation of monetary equivalent for Study 4 (Chapter 7). Study 2 (Chapter 5) examines the nutrient status of commonly used fodder trees by measuring the NPK concentration of four fodder species favoured by farmers in Dhunkharka village. Study 3 (Chapter 6) clarifies the nutrient status of livestock manure fed on three types of fodder trees. Study 4 (Chapter 7) determines the equivalent market value of FYM derived from fodder trees using NPK concentration value per kg obtained in Study 1 (Chapter 4) to compare and evaluate the equivalent monetary value of FYM and synthetic fertiliser, and compare this to the farmers trading monetary value of FYM per doko[4] (18.9 kg; dry matter). Finally, Study 5 (Chapter 8) observes correlations between fresh manure and fodder nutrients using data from Studies 2 and 3.

3.1 Study boundaries

There are three categories of material that carry nutrients: foliage of fodder trees, livestock manure and farm yard manure that is applied to cropping soils. The levels of N, P and K are measured in all of these. The However, the intention of this study is not to follow the nutrient flow and estimate the proportion of nutrients in fodder that ends up in FYM (Figure 3-1). While the NPK of four

[4] doko; The Nepali farmers' basket name as well as unit name. 18.9 kg= 25kg (fresh manure) * 0.75 (moisture content of field survey by the author). 25 kg· doko^{-1}, fresh manure per doko; Vaidya (1988).

fodder species is measured in Study 1, the feed delivered to livestock is mixed with other ingredients, such as plant residual, green leaves, maize and wheat powder, the NPK contents of which could not be measured. Secondly, as that feed converted to manure much of the NPK is either incorporated in the animal growth or lost as urine.

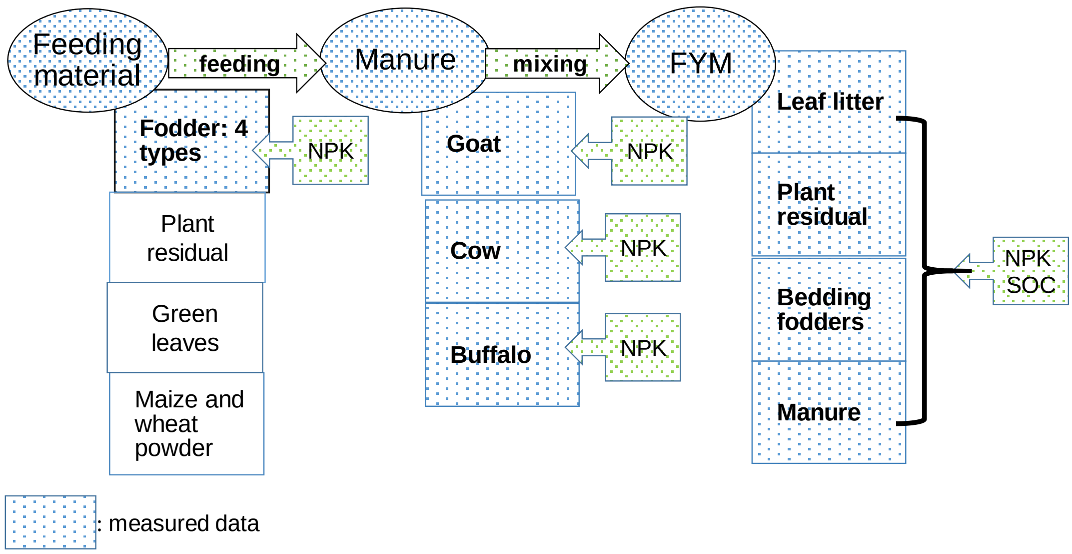

***Figure 3-1**: Measured data (SOC: Soluble organic carbon)*

***Table 3-1**: Chapter connection to each study and objective*

Objective	Chapter Title	Methods	Application
Survey the use and quality of farm yard manure	4 : Survey of farming information and FYM	Study 1 Questionnaire survey of 60 farmer households across two villages to describe cropping and livestock systems, practices of collection and application of farmyard manure (FYM). Samples of FYM were collected, sieved and analysed for NPK, and soil organic carbon using Kjeldahl method (Anderson 1993), Modified Olsen's method (Dewis & Freitas 1970), Ammonium acetate method (Schollenberger 1945), and Wet oxidation method (Shimadzu 2009) as the measurement of soluble organic carbon respectively. Total P and K concentration in fine and coarse textured 2 mm sieved particles of FYM were determined.	Information of the different contexts in the two villages. Data on FYM practices and analysis used in Chapter 7
Examine the nutrient status of commonly used fodder trees	5 : Fodder sampling and analysis	Study 2 Four types fodder, 10 samples of species of 50 to 150 g were collected from 5 to 6 farmers' trees in Dhunkharka in September 2014, dried and sieved then analysed for NPK using Kjeldahl method (Anderson 1993), Modified Olsen's method (Dewis & Freitas 1970), and Ammonium acetate method (Schollenberger 1945) respectively.	Data on fodder analysis to determine the fodder nutrient.
Examine the nutrient status of the fresh manure of livestock feeding on three types of fodder trees	6 : Fresh manure sampling and analysis	Study 3 Fodder feeding experiment for goat, cow, and buffalo conducted. For goat, *Ficus, Prunus*, and *Brassaiopsis* fodder were fed. For cow and buffalo, *Ficus, Quercus,* and *Brassaiopsis* fodder were fed. The feeding proportion of grass plus maize leaves, dried plant matters, fodders, and maize and rice powder were 10: 4.4: 5: 2.5 (kg) per day. The eighth and ninth days' fresh manure samples of every 200 gram were collected, dried, and sieved then analysed for NPK using Kjeldahl method (Anderson 1993), Modified Olsen's method (Dewis & Freitas 1970) , and Ammonium acetate method (Schollenberger 1945) respectively.	Data on fresh manure nutrient fed by three types of fodder in every goat, cow, and buffalo to investigate the fodder effect on fresh manure.
Determine the equivalent market value of farm yard manure derived from fodder trees	7 : Valuation of FYM	Study 4 The mean of NPK concentration of FYM in every studied village ($g \cdot kg^{-1}$) multiplied to the synthetic fertiliser price$\cdot$ kg^{-1} to determine the equivalent value of FYM. Then, to measure the doko (basket) base FYM equivalent price, the NPK equivalent value FYM price multiplied to the dried amount of doko 18.9 kg.	Valuation to evaluate the FYM monetary value comparing to synthetic fertiliser and trading price of FYM in NPK nutrient base.
Examine correlation between nutrient status in manure and fodder	8: Observation of nutrient trend in FRESH MANURE and fodder	Study 5 Acquiring the nutrient NPK data of fresh manure fed by three types of fodder (Study 3) and four types of fodder (Study 2), 1); the relationship between N, P, and K of fresh manure and fodder nutrient and 2); the relationship between livestock manure nutrient status fed by three types of fodder and fodder nutrient by constructing figures, and 3); Pearson's correlation and coefficient ratio between fodder and manure nutrient were observed.	Understanding of the trend between manure nutrient fed by fodder and the nutrient of fodder.

3.2 Site description

3.2.1 Study area

The climate in Kavre district is temperate and divided into a dry season from the last week of October to May and a rainy season from June to October. The maximum temperature is 34^{o}C in July and August and minimum is 2^{o}C in December to February. The mean annual precipitation is 1,581 mm (Shrestha 2009). The study carried out in Chaubas and Dhunkharka VDC in Kavre district, in the central development area of the mid-hills region in Nepal. The field study sites indicated in Figure 3-2. Two field study villages are two of the research sites of *EnLiFT* project as described in the acknowledgements section.

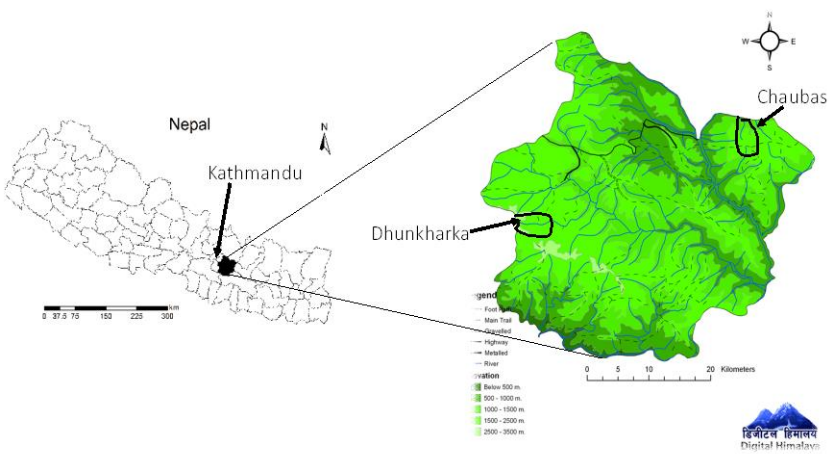

***Figure 3-2**: Map of two study sites in Kavre district (source and approved by: Puri (2015); Joshi (2015))*

Both Chaubas and Dhunkharka have a variety of landforms including lowland paddy fields, upland crop fields and forested upper slopes. In both villages, the central part is located on hilltops. The elevation in Chaubas ranges from 1,385 m to 2,020 m (average 1,800 m), while in Dhunkharka elevation is between 1,600 m to 2,150 m (average 2,000 m). The main industry in Dhunkharka is intensive cultivation of cabbage, radish and production of fresh milk for the Kathmandu market (46 km by road). In contrast, Chaubas is 76.5 km from Kathmandu on a steep and difficult road. Chaubas has diversified subsistence agriculture with the majority of the economy circulating within the village.

3.3 Experimental set ups

3.3.1 Explanation of *EnLiFT* project, community forest information, and preparation of farmers' meeting

Among the eight community forest groups in Chaubas, four community forest user groups belong to the *EnLiFT* project. Fagarkhola is a project intensive research community forest user groups, whereas Toprekamere, Dharapani and Chapani are collaborating community forest users (Table 3-2). In Dhunkharka, interviews were held with community forest user groups Kalapani, Khahare, Janjagriti and Narayansthan. In both villages, farmer interviews conducted from mid to late July 2014 as recommended by a local resource person (LRP) with purposive sampling. The objectives of the interview were as follows:

1) to acquire the cropping pattern of farmers' lowland and upland farming system,

2) to capture their preferable fodder species for livestock,

3) to gain information of FYM, such as amount of application to their field, times making per year, the month to apply to the field, and materials of FYM.

3.3.2 Selecting farmers for interview

The selection of farmer interviewees was determined using purposive sampling. The reasons of purposive sampling are, 1); the objective of this research is to utilise the result for the *EnLiFT* project to improve the conventional method in the target village such as method of making FYM, type of fodders for feeding livestock, and soil fertility. Therefore, the interviewee were the people who are the project beneficiaries, 2); the project beneficiaries, interviewees are familiar to the project and cooperative to reply without hesitation. Conversely, if sampling method were random sampling, the interviewee may include illiterate or people who cannot reply the interview question properly and comfortably. The criteria given by the researcher to LRPs was that 30 farmers should be selected randomly, but be from three different community forest groups, have livestock and an ability to reply to the interview questions (Appendix 1).

At the beginning of the field study, the first inception meeting was held in Dhunkharka village with two LRPs, two staff from the Nepal Agroforestry Foundation (NAF) and one representative from the Federation of Community Forestry Uses Nepal (FECOFUN). In Chaubas, the first meeting was held in the house of the LRP where interviewees were introduced to the LRP and the field staff of NAF.

Table 3-2: *Number of interviewed and community forest information in two studied villages*

Village name	Community Forest name interviewed	Area (ha)	House hold no	Interviewed HH no
Chaubas	Fagarkhola	53.5	84	16
	Toprekamere	48.9	112	4
	Dharapani	42.3	62	5
	Chapani	83.5	117	5
Sum of four community forest			375	30
Total population in village and house hold number	2,068		487	
Village name	**Community Forest name interviewed**	**Area (ha)**	**House hold no**	**Interviewed HH no**
Dhunkharka	Kalapani	168.75	278	15
	Khahare	91.67	146	5
	Janjagriti	217.16	147	5
	Narayansthan	209.1	112	5
Sum of four community forest			536	30
Total population in village and house hold number	4,916		1,035	

3.3.3 Meeting preparation for fodder sampling, feeding experience, and FYM sample

To arrange the collection and sampling of four types of fodder feed and fresh manure and for FYM sampling, a farmers' meeting was held in Dhunkharka in the second week of July 2014. In Chaubas, an inception meeting was held to collect information on cropping pattern, livestock feeding habits and livestock numbers, FYM manure information and collect of FYM samples.

3.4 Explanation in Chapter 4 to Chapter 8

The following Chapters 4 to 7 explain the methods and results now will be published in a journal paper, and Chapter 8 describes results that are not published.

3.5 Section detailing the various chemical analyses undertaken

For analysing nutrient status in fodder, manure and FYM, samples obtained in the field were brought to the Aquatic Ecology Centre (AEC) in Kathmandu University (KU). Prior to laboratory analysis, samples were dried and sieved using the mortar by the researcher. Additionally, the digestibility of the leaf was used the secondary data (Upreti 2006) and discussed about four types of leaf species, which applied for the feeding experiment in Discussion section, 9.4, Fodder nutrients.

The leaf samples were firstly air-dried for one to three days at the open-air dry room (green house) in the laboratory in KU. Then they were dried by the forced air oven at 75 ℃ 24 hours. Then, they were sieved 1 mm mesh. After that, they were taken about one gram for chemical analysis.

Fresh manure samples were dried for three days at the open-air dry room until they were dried for sieving. Then they were sieved two mm mesh. Then samples were obtained for five grams for chemical analysis.

FYM samples were dried at the open-air dry room for three days until they were dried to sieve. Then they were dried by the forced air oven at 96-98 ℃ for 24 hours. Then they were sieved by two mm mesh. Every sieved sample was obtained five grams, then both coarse and fine particles of samples were put separately in the plastic bag for chemical analysis. For SOC analysis, fresh twenty-five-gram sample was obtain then mixed with 100 ml distilled water then it was shaken by hand for five minutes then filtered using 42 Whatman® filter paper for about three hours. After that, approximately 50 ml of solution was obtained and packed to the plastic bottle for analysis.

The testing regime for determining NPK used the Kjeldahl method (Anderson 1993) to test for N, the Modified Olsen's method (Dewis & Freitas 1970) for P and the ammonium acetate method to test for K (Schollenberger & Simon 1945). To determine SOC content of FYM a wet oxidation method (Shimazu 2009) was conducted. The crude protein (CP) in fodder was calculated for N concentration using the Kjeldahl method and multiplied by 6.25 (AOAC 1990; Osti 2006). The dry matter digestibility of four types of fodder was also tested, however, the data was not obtained due to a technical error in the KU laboratory. Secondary data was used from the literature (Upreti & Shrestha 2006).

3.6 Statistical analysis

To interpret the data of farmer interviews for the number of possessing livestock, land holding size, ranking of favourite fodder species, ranking cultivated crops, and duration of piling the FYM in the heap, descriptive statistics such as mean, standard deviation, and standard error were used by Microsoft Excel 2013®. The NPK concentration was determined in the four types of fodder and fresh manure from the feeding experiment and total NPK and SOC were examined for FYM. For types of inferential statistics significance level testing ($p=0.05$), one-way ANOVA, non-parametric test, and Pearson' correlation and coefficient were utilised by SPSS 21®. Details were described in each chapter's statistical analysis section.

Chapter 4: Survey of farming information and FYM

4.1 Introduction

The objective of this chapter is to examine the use and quality of farm yard manure (FYM). This chapter outlines the results of farmer interviews in Chaubas and Dhunkharka villages, including the preferred fodder species, cropping patterns, livestock information and materials of FYM of the survey of 60 farmers from two villages in the mid-hills region, and compares the differences between each. It also introduces data on FYM practices and its analysis used in Chapter 7.

4.2 Methods

4.2.1 Survey design

At the beginning of the field research, a survey was designed to collect information related to forest fodder, cropping practices and FYM. In Chaubas and Dhunkharka villages, thirty farmer interviews conducted and a manure sample was collected from each participating household between the last week in July and the second week of August 2014. The topics of the interview were shown in Table 4-1.

According to the reply from the interviewee, the mean of upland and lowland size, number of livestock unit every cattle, buffalo, and goat, number of making FYM per year, number of month kept FYM beside of the cattle barn, month of start piling FYM, month apply to the field, major material of the FYM, estimated FYM amount were calculated. Besides, the estimated NPK fix amount both two studied villages ($kg \cdot ha^{-1} \cdot year^{-1}$) were calculated. It was calculated from the NPK nutrient concentration of FYM in every studied village, which was analysed from the laboratory analysis multiplied by the estimated FYM production per hectare per year (kg·hh-1·year-1), collected from the interview.

Table 4-1*: Topic of the questionnaire for farmers' interview (number of farmers interviewed is every 30 in Dhunkharka and Chaubas)*

Section	Topic of interview
Sociological	1. Age 2. Sex
Farming and livestock	1. Number of possessing livestock (cow, goat, buffalo; adult and baby; male and female) 2. Crop types cultivated (upland and lowland)
Forestry	1. Favourite fodder species for livestock
Fertiliser (Farm yard manure)	1. No of time making FYM per year 2. No of month keep piling of FYM 3. The time (month) for start piling FYM 4. The time (month) apply FYM to the crop field 5. The material of the FYM (manure, crop residual, litter, green foliage)

Samples of 200 to 300 g were obtained from the FYM pile closest to the cattle barn, collected from the top, bottom, sides and the middle of FYM heaps. In every thirty samples in one village, all sixty samples for two villages were sealed and labelled in the plastic bag. After collection, samples were kept in dark cool room then they were brought to AEC laboratory in KU for chemical analysis NPK and SOC.

4.2.2 Statistical analysis

To support FYM data interpretation, descriptive statistics, such as mean, standard deviation, and standard error have been calculated. For analysing the variance of five percentages' statistical significance for FYM samples for NPK, parametric, ANOVA was used. For comparing the ratio of coarse and fine particles of FYM, the P concentration between coarse and fine particles, and K concentration between coarse and fine particles, t-test was used by SPSS21®.

4.3 Results

4.3.1 Village information

Chaubas is located at a lower altitude than Dhunkharka and exhibits larger upland and lowland sizes and more staple crops demonstrating a subsistence livelihood. Dhunkharka is located at a higher altitude, has smaller upland and lowland areas and grows more commercial and marketable types of crops such as cabbage and potato (Table 4-2).

The altitude ranges of Chaubas ranges from 1,385 m to 2,020 m, its mean upland (bari) and lowland size is 1.25 ha and 0.34 ha respectively, and grows main crop types are maize (*Zea mays L.*), millet (*Eleusine esculenta*), rape seed (*Brassica napus L).* Conversely, the altitude of Dhunkharka ranges between 1,600 m to 2,150 m, its mean upland (bari) size is 0.53 ha, mean lowland (khet) size is 0.15 ha and main crop types are maize (*Zea mays L.*), rape seed (*Brassica napus L.*), cabbage (*Brassica oleracea L.),* wheat (*Triticum aestivum L.*) and potato (*Solanum tuberosum L.*). Village information relating to altitude, land size of the upland (bari) and lowland (khet), and the main cropping types, are shown in Table 4-2, below.

Table 4-2*:Village information, mean size of upland and lowland per household, main crop cultivated, and altitude range in the village (n=30), SD: standard deviation, SE: standard error*

Village		Mean size of upland (bari) (ha)	Mean size of lowland (khet) (ha)	Crop type cultivated	Altitude Range (m)
Chaubas	mean	1.25	0.34	Maize, millet, rape seed, sesame, wheat	1,385 to 2,020
	SD	16.1	5.9		
	SE	2.9	1.1		
Dhunkharka	mean	0.53	0.15	Maize, rape seed, cabbage, wheat, potato	1,600 to 2,150
	SD	5.9	4.1		
	SE	1.1	0.7		

4.3.2 Livestock information

Table 4-3 describes livestock information including the average number of goats, cows and buffalo per household as acquired from farmer interviews in each village (n=30). The number of cows in both Chaubas and Dhunkharka is almost similar. Besides, the number of buffalo in Chaubas is smaller than in Dhunkharka, while the number of goat is higher in Chaubas. In both upland and lowland, the land holding size in Chaubas is larger than in Dhunkharka, whereas the numbers of cow and buffalo in Chaubas is less than in Dhunkharka. Considering the land size and livestock number, if the land is large, then the livestock number is mostly higher than small land size. Because the large land can have larger amount of feed and keep graze livestock. Thus, there is no correlation between size of the land holing and the number of livestock possessed by farmers in two villages. The reason of higher number of possessing buffalo in Dhunkharka may be the high demand and opportunity to sell the milk to Kathmandu and big markets.

Table 4-3*: Mean number of livestock per household interviewed in two villages (n=30), the number is animal unit. SD: standard deviation. SE: standard error. n=30 each village*

village		Cow	Buffalo	Goat
Chaubas	Mean	0.7	1.7	1.0
	SD	1.24	1.11	0.47
	SE	0.23	0.20	0.09
Dhunkharka	Mean	1.2	3.0	0.4
	SD	1.14	2.20	0.34
	SE	0.21	0.40	0.06

4.3.3 The cropping pattern of farmers' lowland and upland farming system

Crop species cultivated by farmers were obtained from farmer interviews (Figure 4-1). The most popular crop types to least grown in Chaubas are maize (*Zea mays L.),* millet (*Eleusine esculenta*), rapeseed (*Brassica napus L*.), sesame (*Sesamum indicum L*.), wheat (*Triticum aestivum L*.), buckwheat (*Fagopyrum esculentum)* and rice (*Oryza sativa L.)*. The most popular crop type to least grown in Dhunkharka are maize, rape seed, cabbage (*Brassica oleracea L*), wheat, potato (*Solanum tuberosum L*.) and barley (*Hordeum vulgare)* and rice.

The cropping pattern in Chaubas reflects subsistence farming of staple crops suited to low altitude, such as pulse, millet and pumpkin. Dhunkharka farmer grows commercial crops, such as cabbage, potato and cauliflower, and is closer to the largest market, Kathmandu, by road. Differences in crop type between the two villages are due to differences in climate, altitude, proximity to market and road accessibility. Dhunkharka farmers have access to five to six times of bus transport per day and are positioned to supply large markets, such as Panauti (14 km), Banepa and Kathmandu. Accordingly, crops are suitable for high altitude and marketability. In contrast, Chaubas is further from large markets and has a less accessible road and transportation, however, it is positioned to supply the Dolalghat market around 18 km away.

4.3.4 Favourite fodder species

In Chaubas and Dhunkharka, farmer favourite fodder species were determined as lower altitude species including *Ficus semicordata* (kanyu) in Chaubas and higher altitude species, such as *Quercus lanata* (banjh) in Dhunkharka.

The favoured species in Chaubas, along with the number of farmers responding that they use fodders are *Ficus nemoralis* (dudhilo) (17 respondents), *Morus alba* (kimmu) (11 respondents), *Ficus auriculata* (timila) (7 respondents), *Ficus Semicordata* (kanyu)(4 respondents), *Litsea cubeba* (siltimul) (4 respondents), and *Prunus cerasoides* (payun) (4respondents). In Dhunkharka, the favoured fodder species were *Ficus nemoralis* (24 respondents), *Saurauria nepaulensis* (gogun) (22 respondents), *Quercus lanata* (banjh) (21 respondents), *Brassaiopsis hainla* (hatipaile) (19 respondents), and *Prunus cerasoides* (payun) (17 respondents) and *Quercus semecarpifolia* (17 respondents). Differences in preferred fodder species in each village is likely due to topographic, climatic and soil types’ condition.

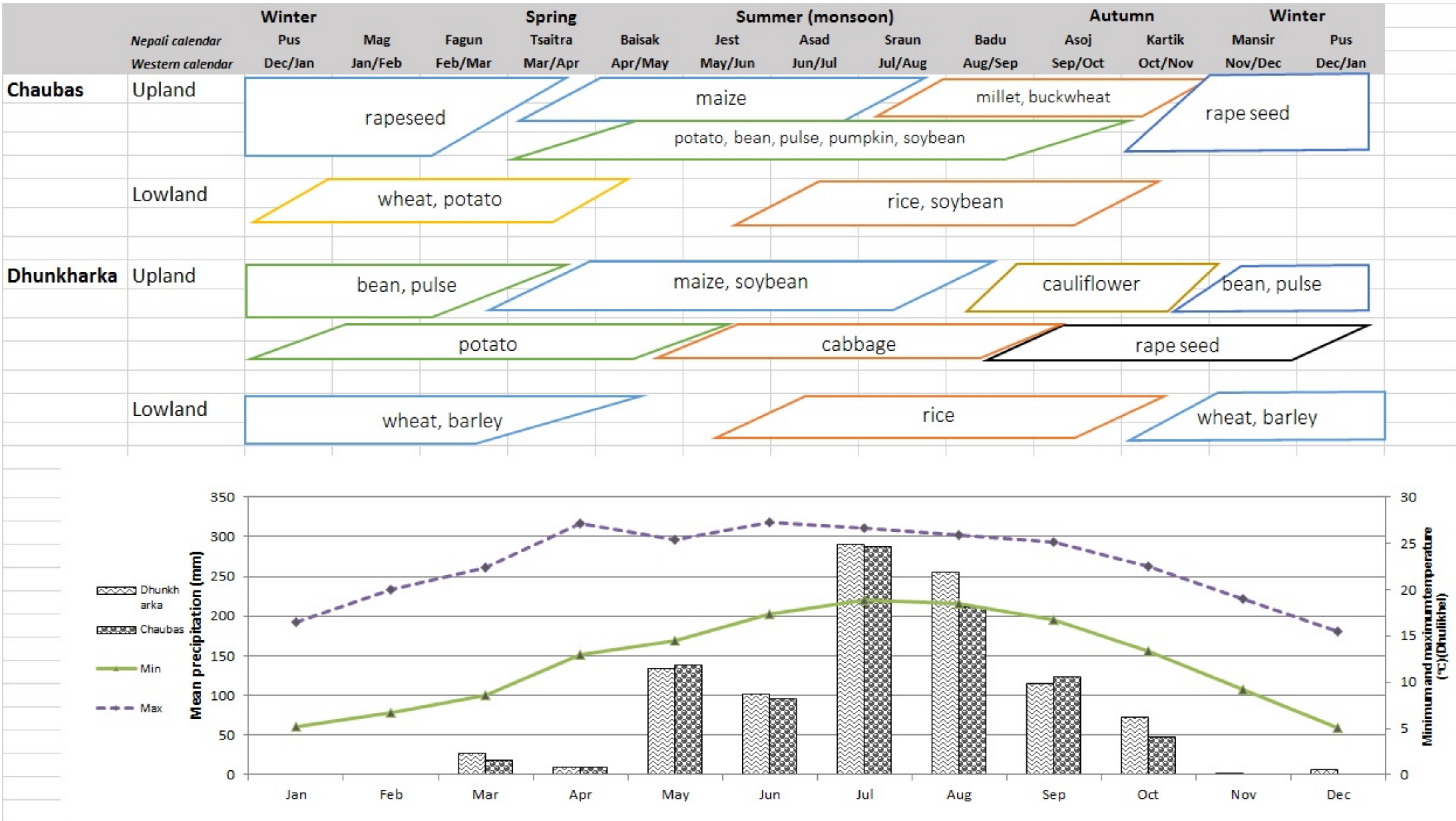

Figure 4-1: *Cropping pattern in studied two village (source: Climate data; Department of Hydrology & Meteorology, Ministry of Science, Technology & Environment Nepal (2009). Temperature data is Dhulikhel in Kavre district)*

***Table 4-4**: FYM information, times making per household per year, number of months kept piling, month to start piling to outside cattle barn, estimated production per household per year, month piling FYM, month apply to the field, and major material of FYM contents (n=30), SD: standard deviation. SE: standard error*

Village		Times making·year^{-1}·hh^{-1}	Number of month kept FYM piling outside the cattle barn	Production (t·hh·year^{-1}, dry matter)	Month to start piling	Month apply to field	Major material of FYM contents
Chaubas	Mean	1.3	10.0	9.3	Feb-Mar	Jan-Feb	Green foliage
	SD	0.57	1.55	225.09			
	SE	0.10	0.28	44.14			
Dhunkharka	Mean	1.5	9.5	18.5	Nov	Sep-Oct	Leaf litter & plant residual
	SD	0.59	2.94	872.14			
	SE	0.12	0.89	159.23			

4.3.5 FYM results

According to farmers' interviews for FYM production practice, the mean amount FYM production per household per year was 9.3 t·year^{-1} (dry matter) in Chaubas and 18.5 t·hh^{-1}·per^{-1}·year in Dhunkharka (Table 4-4). In Chaubas, farmers made FYM 1.3 times·year^{-1} and kept it 10 months, whereas farmers in Dhunkharka made it 1.5 times·year^{-1} and kept FYM for 9.5 months. In Dhunkharka, farmers commenced compiling materials from November for use in September or October for crop cultivation to use for winter vegetable cultivation, such as cabbage and cauliflower. The average month of application of FYM in the farmer's field in Chaubas was January to February. The major material of FYM in Chaubas was green foliage, while in Dhunkharka it was leaf litter and plant residuals.

The mean nutrient value (NPK) and SOC of FYM in Chaubas and Dhunkharka are displayed in Table 4-5. Nutrient profiles in FYM differ between the two surveyed villages. For example, in Dhunkharka, P is dominant followed by N and K. The P concentration in Dhunkharka is 7,103 mg·kg^{-1}, which is significant different (p=0.000), 118% higher than that of Chaubas, 3,260 mg·kg^{-1}. In Chaubas, N is dominant followed by K and P. However, the N concentration of both villages was similar, with values in Dhunkharka is 5,132 mg·kg^{-1} and in Chaubas is 4,956 mg·kg^{-1}. In terms of K concentration, there is no significant difference between two villages, Dhunkharka has 3,670 mg·kg^{-1}, which is 9%

higher profile than Chaubas, 3,368 mg·kg^{-1}. In the soluble organic carbon (SOC) in FYM, Chaubas has 304 mg·kg^{-1}and Dhunkharka, 271 mg·kg^{-1}, which was no significant difference.

The amount of NPK in FYM for Chaubas and Dhunkharka was lower than in former studies conducted in Tanahun, Syanja, Myagdi, Parbat, Palpa in Nepal (Bhattarai & Pant 2008; Dougil et al. 2001; Sherchan & Gurung 1999). Specifically, N and K concentrations in Chaubas and Dhunkharka were lower than former studies (Bhattacharyya et al. 2008; Das et al. 2010), but not P concentration in Dhunkharka which was higher (ICAR 1986; Subedi & Gurung 1991).

For the particle proportion of FYM, both villages of FYM, fine particle proportion is higher than the coarse particle proportion (Table 4-5). Especially, the fine particle in Chaubas is about two times' larger than coarse particle, whereas that of Dhunkharka is 1.2 times larger proportion than coarse particle. To compare the proportion of fine particle and coarse particle of FYM in two villages, fine particle of FYM is quite high proportion in both Chaubas and Dhunkharka implies that the FYM in both villages were decomposed and mineralised.

Table 4-5: *Nutrient concentration (NPK) and Soluble Organic Carbon (SOC) in FYM in two villages (n=30 each village, N: Nitrogen concentration, P: Phosphorus concentration, K: Potassium concentration, and SOC: Soluble Organic Carbon, each letter (a,b) is different in significant level (p = 0.000), SE: Standard error)*

Village name		N (mg·kg^{-1})	P (mg·kg^{-1})	K (mg·kg^{-1})	SOC (mg·kg^{-1})	Particle proportion of FYM	
						Coarse (>2mm)(%)	Fine (<2mm)(%)
Chaubas	Mean	4,956	3,260b	3,368	304	34.3 a	65.7 b
	SE	276	309	382	37	6	12
Dhunkharka	Mean	5,132	7,103a	3,670	271	45.3 a	54.7 b
	SE	285	489	346	28	8	10

The estimated NPK fix amount both two studied villages (kg·ha-1·year^{-1}) were calculated (Table 4-6). In Chaubas it was, 29.0, 19.1, 19.7 kg · ha^{-1} · year^{-1} whereas that in Dhunkharka was 139.6, 193.2, and 99.8 kg^{-1} · ha^{-1} · year^{-1} (Table 4-6). The distinctive differences were found between two villages that P fixation in Dhunkharka is ten times higher, N and K fixation are five times higher than in Chaubas. The main reasons of these differences are origin from the estimated FYM production in Dhunkharka is about two times larger than in Chaubas and the mean P concentration in FYM sample in Dhunkharka is higher amount.

Table 4-6*: Estimated nutrient fixing amount to the filed (kg ·ha^{-1} ·year^{-1})*

Village	Estimated FYM production (t·hh^{-1}·year^{-1})	N fix (kg·ha^{-1}·year^{-1})	P fix (kg·ha^{-1}·year^{-1})	K fix (kg·ha^{-1}·year^{-1})
Chaubas	9.3	29.0	19.1	19.7
Dhunkharka	18.5	139.6	193.2	99.8

In terms of P and K concentrations of sieved coarse textured and fine textured particle of FYM, the results show that there is no statistical significant difference between P and K concentration in the coarse-textured and fine-textured samples taken from each village (Figure 4-2). The overall difference between fine and coarse-textured particles in P and K status of FYM did not differ more than 2 to 15% (Figure 4-2).

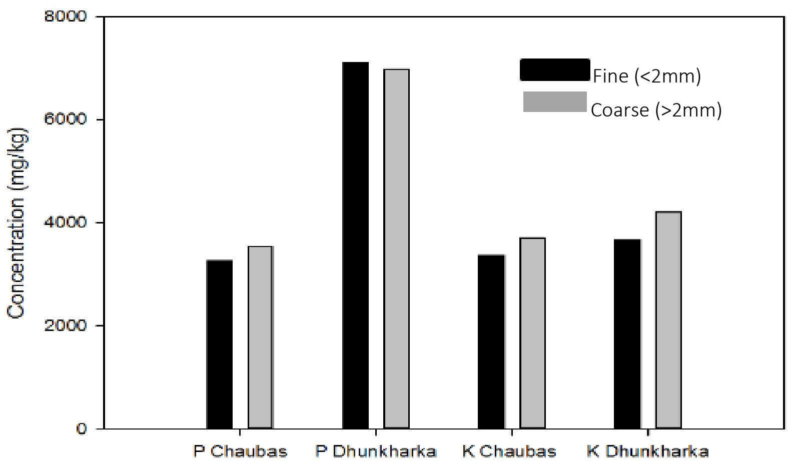

Figure 4-2*: P and K concentration coarse-textured and fine-textured particles in FYM*

Regarding the materials of FYM (interviewed information) in Chaubas, FYM was composed mainly of green foliage followed by manure, dried leaf litter and plant residual. In Dhunkharka, the dominant portion of FYM was dried leaf litter and plant residuals, followed by manure and green foliage (Figure 4-3). Comparing materials between the two villages, the proportion of manure in Dhunkharka was

36% higher, as was the proportion of leaf litter and dried plant material by 125%. Alternatively, the proportion of green fodder and bedding material in Chaubas was higher (127%).

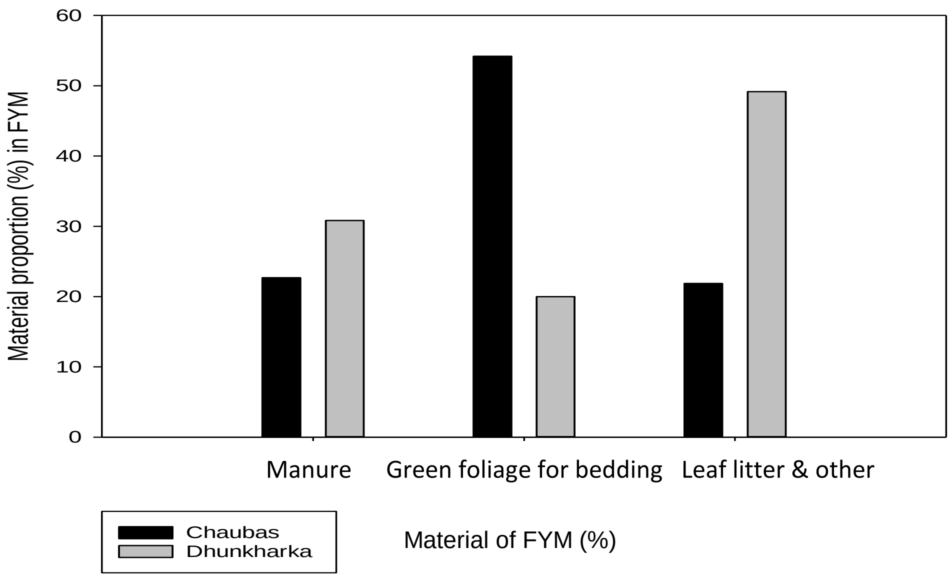

***Figure 4-3**: Material proportion of FYM (interviewed information)*

The reason for high P concentration in FYM samples from Dhunkharka possibly relates to a high proportion from buffalo and cow manure (Fig 4-3, Chapter 6, Fig 6-2 and 6-3) in FYM, which contains more P than other materials. Fujiwara (2003) also reported high proportion of P concentration in manure than in plant residuals in FYM (Fujiwara 2003). In addition, the FYM in Dhunkharka may contain more woody materials, such as branches and woodchips, which have high P. Former studies show that woody materials and manure mixed with FYM have higher P concentration than materials only containing manure (Fujiwara 2008). Therefore, if manure proportion in FYM were higher, the P content in FYM would also be high.

Considering SOC concentration in FYM in both Chaubas and Dhunkharka villages, it ranged from 271 to 304 mg·kg^{-1}, which was consistent with the former studied reports (Gauthier et al. 2010; Hishi et al. 2004; Said-Pullicino, Erriquens & Gigliotti 2007). The similar concentration of SOC in FYM in both villages implies that the activity of microorganism, which helps mineralisation, and maturing processes is similar stage at the time researched. SOC concentration is derived from materials and components in the compost and is correlated to compost mineralisation that decreases during decomposition (Bernal 1998; Chefetz et al. 1998; Iannotti et al. 1994; Zmora-Nahum et al. 2005).

4.4 Chapter conclusions

Chaubas has more subsistence farming cropping than Dhunkharka, as Dhunkharka grows commercial crops due to factors related to altitude, climate, access and proximity to market. Preferred fodder species in Chaubas inhabit at a low altitude location, which is opposite to Dhunkharka where farmers prefer to grow higher altitude fodder species. Estimated FYM production per household is 9.3 ton in Chaubas and 18.5 ton per household in Dhunkharka. Dhunkharka has higher FYM production than Chaubas due to households having larger number of buffalo, which makes larger amount of manure and FYM. In addition, Nutrient status in P concentration of FYM in Dhunkharka is subsequently significantly higher than in Chaubas.

Compared to previous research, nutrient values NPK were lower, except P concentration, which was higher in Dhunkharka. There is no statistical difference the SOC concentration of FYM in each village and there was no difference between coarse and fine-textured particles of FYM in P and K concentration. For material proportion rate, the proportion of manure in FYM is higher for Dhunkharka, than for Chaubas. Furthermore, for materials of FYM, green foliage for bedding and livestock was in the highest proportion for Chaubas, whereas leaf litter and other plant residuals were the most dominant materials in FYM for Dhunkharka village.

Chapter 5: Fodder sampling and analysis

5.1 Introduction

The objective of this chapter is to examine the nutrient status of commonly used fodder trees and detail the survey and nutrient analysis of fodder samples from four samples in Dhunkharka village. Fodder species sampled were determined in the farmers' meeting prior to conducting the feeding experiment described in Chapter 6.

5.2 Methods

5.2.1 Survey design

Types of four kinds of fodder species were applied. They were *Ficus nemoralis* (called *Ficus,* Nepali name: dudhilo), *Quercus lanata* (*Quercus,* banjh), *Prunus cerasoides* (*Prunus,* payun) and *Brassaiopsis hainla* (*Brassaiopsis,* hatipaile). Fodder samples were chosen based on healthy green colour, wide leaf size and no damage from pests and diseases. For justification, fodders that are fed to the five livestock of farmers who conduct the feeding research were obtained as a nutrient sample. Thus, the fodder samples were same fodder tree to which farmers feed to the livestock for their feeding experiment. In addition, the fodder samples were obtained as a nutrient analysis in the time when the feeding experiment conducted in August to September 2014 at Dhunkharka village. There is no seasonal difference between fodder fed to livestock and fodder obtained as a sample for nutrient analysis. Therefore, the nutrient status of fodder and fresh manure from feeding fodder experiment are justifiable as samples to analyse the nutrient status. Ten bags of fodder samples, each 50 to 100 g were obtained from five to seven participating farmers. Samples were kept in the farmers' dark room for one day before brought to the Kathmandu University (KU) Aqua Ecology Centre (AEC) laboratory.

5.2.2 Statistical analysis

To support fodder data interpretation, descriptive statistics, such as mean, standard deviation, and standard error have been calculated. For analysing the variance of five percentages' statistical significance, parametric, one-way ANOVA for P concentration, and non-parametric, Kruskal Wallis test for N and K concentrations were used by SPSS21® depend on the dispersion relation of the sample.

5.3 Results

5.3.1 Nutrient value of key fodder species

Five farmers determined the fodder species to use in the feeding experiment according to availability and livestock preference. Fodder species selected for goat included *Ficus nemoralis, Prunus cerasoides* and *Brassaiopsis hainla*, and for cow and buffalo were *Ficus nemoralis*, *Quercus lanata* and *Brassaiopsis hainla*.

5.3.2 Nutrient profile of key fodder species

The nutrient profile was similar across all fodder species, being that N is dominant followed by K and then P. The mean nutrient values (NPK) of four types of fodder species, *Ficus, Quercus*, *Prunus* and *Brassaiopsis* are displayed in Figure 5-1. The N:P:K ratio for *Ficus* fodders is 73:3:24, for *Quercus* fodder is 77:5:18, for *Prunus* fodder is 75:5:20, and for *Brassaiopsis* fodder is 78:6:16. On the other hand, focusing on N concentration among four types of fodder, *Prunus* and *Brassaiopsis* are richer in N than the other species, containing 18% more N than *Ficus* and 59% more than *Quercus*. The profile for K is that *Ficus* and *Prunus* have higher concentrations of around 18% more in *Brassaiopsis* and 54% more K in *Quercus*. P levels are relatively low across all species, however, *Brassaiopsis* and *Prunus* have about 58% more P than the other two species.

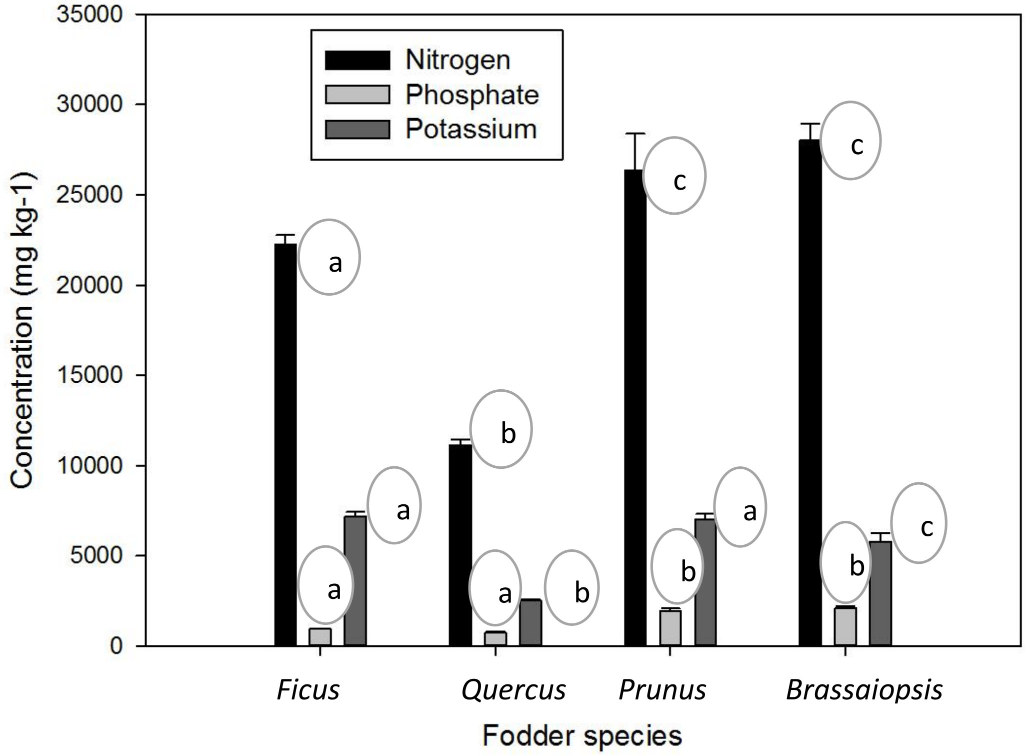

***Figure 5-1**: NPK concentration in fodder; the different character (a,b,c) in each NPK level has statistically difference (p<0.05).*

5.3.3 Comparison of NPK status by fodder species

The highest N concentration was found in *Brassaiopsis*, then *Prunus*, *Ficus* and *Quercus.* This order was similar for P concentration. However, for K concentration the highest amount is *Ficus*, followed by *Prunus*, *Brassaiopsis* and *Quercus*. The percentage of N concentration in fodder is 2.2% in *Ficus* and 1.1% in *Quercus* found to be relatively lower, and 2.6% in *Prunus*, which is a similar range to previous study results (Bajracharya et al. 1985; Panday 1990).

The P concentration of *Ficus nemoralis* (0.1%) was found to be lower than in former studies (Khanal 2001; Upreti & Shrestha 2006). The P concentration of *Quercus lanata* had no data available, so *Quercus lamellosa* was used resulting in a lower P than previous studies (0.07%) (Upreti & Shrestha 2006). Similarly, *Prunus cerasoides* and *Brassaiopsis hainla* had low P concentration of 0.19% and 0.21% were lower than results of previous studies (Khanal 2001; Osti et al. 2006; Upreti & Shrestha 2006).

The result for K concentration of *Ficus nemoralis* (0.7% K), *Q. lanata* (0.3%), *Prunus cerasoides* (0.7%) and *Brassaiopsis hainla* (0.58%) were lower than concentrations found in previous studies (Khanal 2001; Upreti & Shrestha 2006). The difference of the study concentrations to former research may have been caused by differences in sample location, seasonality, tree age and leaves. Thapa (1997) shows that the nutrient differences in fodder may originate from sub-species, season, and leaf maturity. The location of each species differs according to climate, altitude and soil type, which may influence nutrient conditions of soil and fodder. Fodder nutrient differences may also be caused by metabolism changes influenced by rainfall, temperature and sunlight (Wood et al. 1994).

5.3.4 Comparison of crude protein (CP) levels by fodder species

The CP content of four types of fodder is shown in Figure 5-2. Crude protein (CP) concentration in *Ficus nemoralis* (139 $g \cdot kg^{-1}$) is similar to the results of Osti (2006), however is higher than the result of Upreti and Shrestha (2006) and Khanal (2001). *Quercus lamellosa* data replaced *Quercus lanata*, resulting in 70 $g \cdot kg^{-1}$, that is the lower range of *Quercus lamellose* tested by Wood et al. (1994) and Upreti and Shrestha (2006). *Prunus cerasoides* CP content was 165 $g \cdot kg^{-1}$, which is lower than CP found in Wood et al. (1994), similar to Osti et al. (2006) and Khanal (2001), and higher than Upreti (2006). *Brassaiopsis hainla* (175 $g \cdot kg^{-1}$) had a CP concentration lower than Dhungana (2013) and higher than previous studies (Khanal 2001; Osti et al. 2006; Upreti & Shrestha 2006; Wood et al. 1994). The difference in CP from previous studies is assumed to be related to the different sampling locations, sampling month of the year (Upreti & Shrestha 2006) and soil nutrient condition which influence to plant nutrient status.

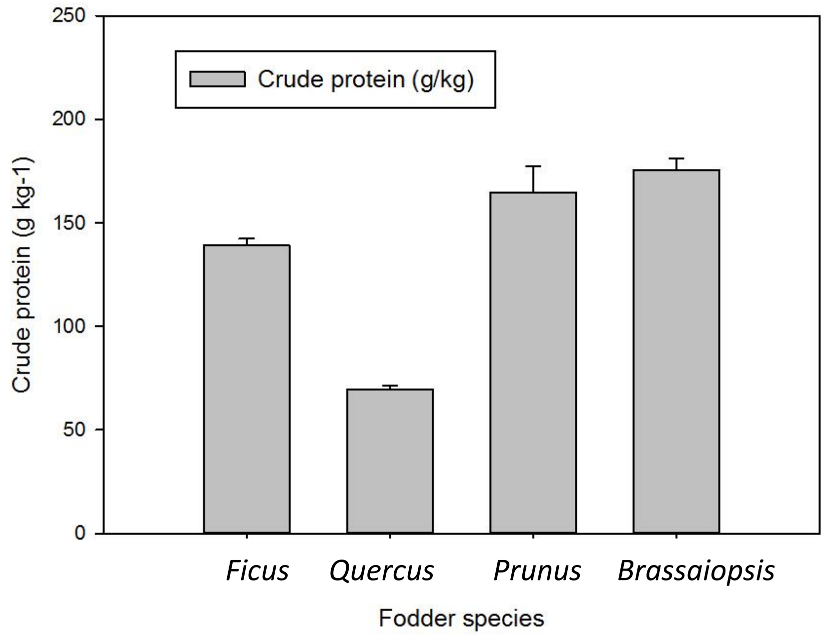

Figure 5-2*: Crude protein concentration in four types of fodder*

5.4 Chapter conclusions

In this evaluation of nutrient concentration, the N, P and K concentrations of each fodder type were lower than previous research with the exception of the N concentration found in *Prunus*. Additionally, the CP concentration differed for each species. *Ficus* CP content was higher than in previous studies, where as *Quercus* and *Prunus* fodders were lower. *Brassaiopsis* CP content was both higher and lower than former research. These differences are assumed to be related to variable sampling locations, different sampling times (Upreti & Shrestha 2006) and differing soil nutrient conditions influencing plant nutrient status.

Chapter 6: Fresh manure sampling and analysis

6.1 Introduction

The objective of this chapter is to examine the nutrient status of the fresh manure of livestock feeding on three types of fodder trees. This chapter details the feeding experiment and analysis of fresh manure samples in NPK concentration from feeding experiment to livestock fed by three different types of fodders.

6.2 Methods

6.2.1 Survey design

The feeding experiment in Dhunkharka was performed as follows:

Step 1: Firstly, the study objectives were explained in the meeting. Six farmers participated in the meeting in Dhunkharka village and were selected on the basis that they owned livestock, lived close to the main centre of the village, were able to reply to interview questions and were interested in the feeding experiment. The aims of the meeting were: 1) to explain field research objectives, 2) to decide which five farmers could contribute to the feeding experiment for each type of livestock, and 3) to determine and evaluate the fodder preferences of goats, cows and buffalo. In the meeting, farmers decided feeding materials including grass, dry plants, fodder, maize, and rice powder. Four fodder types were selected by farmers. The *Saurauria* was disregarded by the farmers because of its inability to regenerate if lopped in the rainy season. *Prunus* was chosen for the goat instead of *Quercus* because of its habit and farmers previous experience with feeding.

Step 2: Feeding method was explained including feeding materials, ratio and amount (kg) of material, duration, farmers' contribution, and obtained the agreement paper. The total amount of feeding material per day was 22 kg (fresh amount) for buffalo, 20 kg for cow. The composition was 46: 20: 23: 11 of grass, maize + dried leaves, tree fodder, and maize and rice powder. For goat, it was 3 kg (fresh amount), and the composition was 45: 0: 45: 9 grass, maize + dried leaves, tree fodder, and maize and rice powder.

Step 3: Recording materials including a notebook, ballpoint pen, a bucket for manure collection and a plastic bag were distributed to participants.

Step 4: Feeding experiment commenced. Each fodder type fed to the livestock was for 9 days feeding, then it changed to the another type of fodder.

Step 5: The amount of fresh manure and animal health condition was recorded in the morning and in the afternoon every day in five farms for each livestock type.

Step 6: 200 g samples of manure were collected every morning and evening at the eighth and ninth day of each fodder feeding cycle.

Step 7: Manure samples were brought to KU every ninth feeding day for analysis.

For fresh manure sample, five cows (aged three to seven years old), five buffaloes (aged six to fourteen years old) and five goats (aged three to four years old) were selected by famers to participate in the experiment. Livestock included a Jersey cow and a local variety cross cow, the ‘Murrah’[5] and indigenous cross variety of buffalo, and the ‘khari goat’. Three fodder types were selected for goats including *Ficus nemoralis, Prunus cerasoides* and *Brassaiopsis hainla*. *Ficus nemoralis, Quercus lanata*, and *Brassaiopsis hainla* were selected for the cows and buffaloes. The ration of feeding, the time to feed to the livestock every day and composition of fodder was recorded by the LRP daily. The tree fodder was changed every ninth day’s feeding of three types of fodder species.

Manure samples were obtained on the eighth and the ninth day of each fodder cycle from each of the five cows, buffaloes and goats in Dhunkharka village. The total fresh manure samples equated to five farmers x three fodder types x three types of livestock x two days’ sample, totalling 90 samples.

6.2.2 Statistical analysis

To support fresh manure data interpretation, descriptive statistics such as mean, standard deviation, and standard error have been calculated. For analysing the

[5] Originally introduced from India and crossbred to local type, which improved milk production.

variance of five percentages' statistical significance, parametric, one-way ANOVA and non-parametric, Kruskal Wallis test for N and K concentrations were used by SPSS21® depend on the dispersion relation of the sample.

6.3 Results and discussion

6.3.1 Determining the fodder species for the feeding experiment

The fodder species for this experiment were selected by farmers in accordance with availability and palatability for livestock. For goats, the preferred fodder species were *Ficus nemoralis,* followed by *Prunus cerasoides* and *Brassaiopsis hainla*. For cows and buffalo, preferred fodder species included *Ficus nemoralis*, followed by *Quercus lanata* and *Brassaiopsis hainla*. Differences in favourite fodder species and cropping patterns, and availability are probably due to variance in topographic, climatic and soil type factors.

6.3.2 Trends in the manure nutrient content of three types of livestock

Nutrient trends in the manure of each livestock type showed interesting results. The amounts of NPK differed according to livestock, fodder and nutrient type. For example, the highest N concentration was found in goat, then cow and buffalo. The highest P concentration was identified in buffalo feeding on *Ficus* fodder, followed by cow and goat, which had similar order. The highest K concentration was found to in the manure of cows feeding on *Quercus* fodder, followed by buffalo then goats. These trends support former studies determining that the N concentration in goat manure is higher than in cattle manure (Brouwer 1998; Brouwer & Powell 1998; Esse 2001; Landais 1993; Landais & Lhoste 1993).

6.3.3 NPK concentration in fresh goat manure

The mean nutrient value (NPK) of fresh manure from goats feeding on fodder species, *Ficus, Prunus* and *Brassaiopsis* is displayed in Figure 6-1. The nutrient profile is similar across all fodder species in that N is dominant, followed by P and then K. In the way of another understanding to focus on the nutrient data in each N,P, and K levels, *Prunus* is 8% and 10% richer in N than in *Ficus* and *Brassaiopsis*, respectively. *Ficus* has a 13% and 30% higher concentration of P than *Prunus* and *Brassaiopsis*, respectively. For K, *Prunus* has a 19% and 28% higher concentration than *Ficus* and *Brassaiopsis*. There are slightly differences in every nutrient level in nutrient data, however, to analyse statistically in every N, P, and K levels has no significant difference in the manure nutrients fed with three types of fodder. The concentrations of NPK in goat manure analysed in this study were lower than that found by (Moreno-Caselles et al. 2002). Specifically, N and K concentrations were lower and P concentration was higher than in previous studies (Loh et al. 2005; Mupondi, Mnkeni & Brutsch 2006).

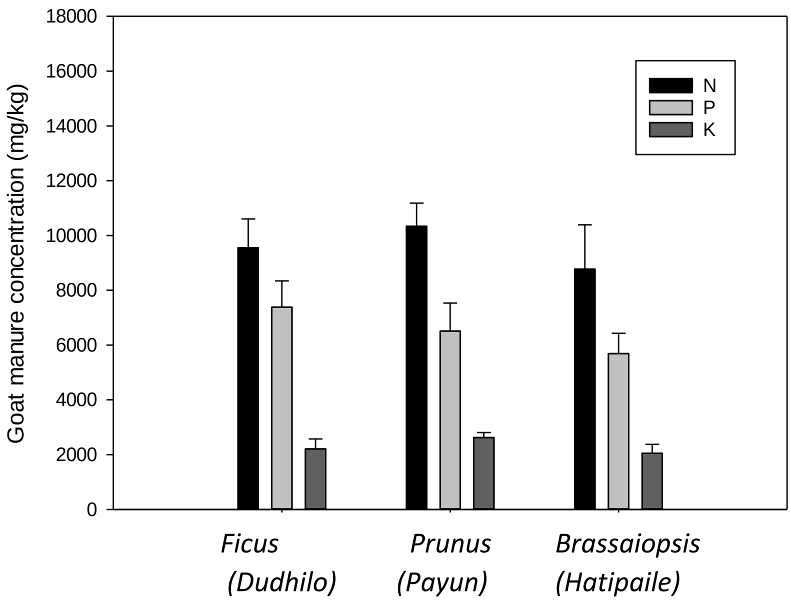

***Figure 6-1**: Mean NPK concentration in goat manure fed by three types of fodder*

6.3.4 NPK concentration in fresh cow manure

The mean nutrient values (NPK) of manure from cows fed three fodder species, *Ficus, Quercus* and *Brassaiopsis* are shown in Figure 6-2. A higher K concentration was noted in manure feeding on *Quercus* fodder than feeding on *Ficus* fodder (p=0.046). The nutrient profile is similar across all fodder species, in that P is dominant, supporting previous studies (Keityou, Fujita & Murata 2005; Nagano prefecture 2005) (Table 6-1). However, other former studies report that ordering the highest nutrient among NPK, N is the highest concentration in Parbat, Palpa, and Myagdi district in Bhakimli village (Bhattarai & Pant 2008) and Makwanpur district (Chapagain & Gurung 2010) whereas K is the highest concentration in Tanahun, Sanjya, and Myagdi district in Ratnechaur village (Bhattarai & Pant 2008) (Table 6-1).

Table 6-1*: Ordering the highest nutrient among NPK in FYM from former researches*

Source	category	The 1 st highest	The 2 nd highest	The last
Current study result	*Ficus*	P	N	K
	Quercus	P	K	N
	Brassaiopsis	P	N	K
Keityou (2005)	cow FYM	P	K	N
Nagano prefecture Japan (2005)	cattle FYM	P	K	N
Bhattarai (2008)	Parbat district	N	K	P
	Palpa district	N	K	P
	Myagdi district	N	K	P
	Tanahun district	N	K	P
	Syanja district	K	N	P
	Myagdi district	K	N	P
Chapagain (2010)	Makwanpur district	N	K	P

N and K concentrations differed for each sample. Livestock feeding on *Quercus* fodder produced manure featuring the second highest amount of K followed by N (Figure 6-2). However, livestock feeding on *Ficus* and *Brassaiopsis* produced manure with the second highest concentration of N followed by K (Figure 6-2). There is no statistically difference, whereas observation of feeding on *Ficus* produced manure likely to be richer in P, at around 20% and 11% higher than in *Quercus* and *Brassaiopsis* (Figure 6-2).

The concentration of N and K in cow manure in this study was found to be lower than in former studies (Bhattacharyya et al. 2008; Bhattarai & Pant 2008; Fujiwara 2003; Njunie & Ramadhan 2008; Yadav et al. 2000). In this study, N concentration fed by the *Ficus* fodder was similar, the concentration fed by *Brassaiopsis* fodder was lower, and the concentration fed by *Quercus* fodder was higher, also, concentrations of P and K were higher to former study (Kamiyama, Houshino & Sasaki 2006). When compared to ICAR (1986), a similar concentration of N was found in manure produced from *Ficus* fodder, a higher concentration detected in *Quercus* and a lower concentration determined in *Brassaiopsis*. In terms of P concentration, *Ficus* and *Brassaiopsis* fodder produced manure with similar concentrations to other studies, and *Quercus* produced a higher concentration than that found in ICAR (1986).

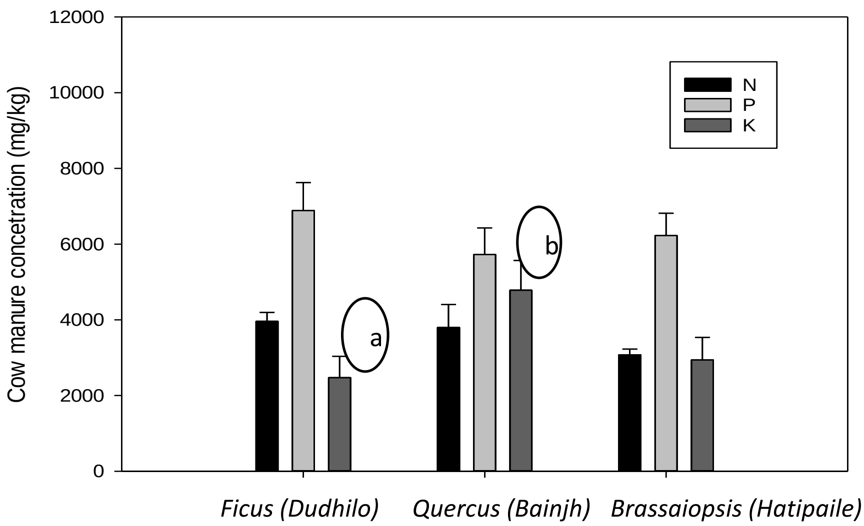

Figure 6-2*: Mean NPK concentration in cow manure fed by three types of fodder: the each letter ‘a’ and ‘b’ is different in p<0.05*

6.3.5 NPK concentration in fresh buffalo manure

Manure produced by buffalo grazing on *Ficus* fodder had a much higher P concentration than manure produced by *Quercus* and *Brassaiopsis* fodders (p=0.019). Similarly, manure produced by buffalo feeding on *Ficus* and *Quercus* had higher K concentration than manure produced by *Brassaiopsis* fodder (p=0.022). The mean nutrient value (NPK) of fresh buffalo manure is displayed in Figure 6-3.

The N and K nutrient profiles in buffalo manure were similar to cows with the exception of P concentration that was found to be higher, as shown in former studies (Keityou, Fujita & Murata 2005; Ministry of agriculture Japan 2002). In this study, N and K concentration profiles differed under each feeding regime. Besides, to focus on the nutrient data, *Ficus* in P concentration has around 66% richer than for *Quercus* and *Brassaiopsis*. Alternatively, the K concentration in *Quercus* and *Ficus* were found to be 47% higher than in *Brassaiopsis*, respectively.

Overall, concentrations of NPK in buffalo manure were lower in this study than in Fujiwara's (2003) study. Similarly, N concentration was lower, P concentration higher and K concentration lower than that found by Njunie (2008); Kamiyama, Houshino and Sasaki (2006) and ICAR (1986).

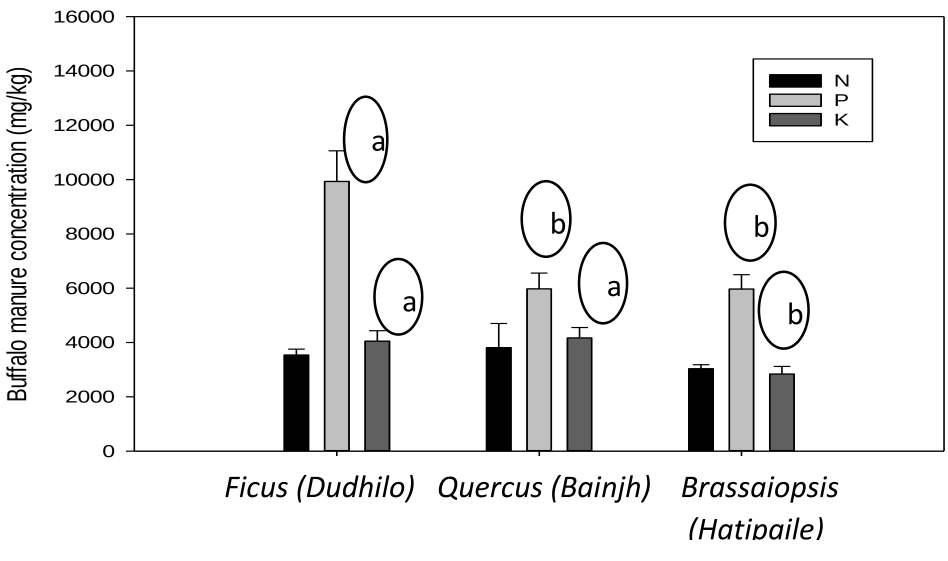

***Figure 6-3**: Mean NPK concentration in buffalo manure fed by three types of fodder: Each letter 'a' and 'b' is different in p<0.05*

6.4 Chapter conclusions

The nutrient content of manure differed by livestock and fodder type. Goat manure had the highest N concentration, buffalo manure had high P concentrations (grazing on *Ficus* fodder) and cow manure had high K concentrations (grazing on *Quercus).*

In goat manure, there was no difference in NPK concentrations for manure produced under each fodder condition. The nutrient profile was also similar across each fodder species, in that N is dominant, followed by P and K. In N status, *Prunus* was richer, in P status *Ficus* was richer and in K status *Prunus* had a slightly higher concentration.

In cow manure, there are noteworthy differences in K concentrations for manure produced by *Quercus* and *Ficus* fodder. Again, the nutrient profile is similar across each fodder species, in that P is dominant and N and K concentrations differed for each manure type. This result is lower than similar experiments undertaken in previous studies, with the exception of P concentration in Dhunkharka. Manure produced by *Ficus* fodder in N had a similar concentration, the concentration fed by *Brassaiopsis* fodder was lower, and the concentration fed by *Quercus* fodder was higher.

In buffalo manure, *Ficus* fodder increased P concentration in manure as compared to *Quercus* and *Brassaiopsis* fodders (p=0.019). *Ficus* and *Quercus* fodders also increased K concentration in manure (p=0.022). Similarly, to cow manure, the nutrient profile for buffalo was similar, where P was highly dominant and N and K concentrations differed across fodder types. The results of N and K concentrations were lower than in previous studies, whereas P concentration was either higher or lower depending on the study.

Chapter 7: Valuation of FYM

7.1 Introduction

The objective of this chapter is to determine the equivalent market value of farm yard manure derived from fodder trees in terms of the quantity of NPK that it contains. Both FYM and synthetic fertilisers are available for purchase in the mid-hills farms. Traditionally, farmers relied on their own FYM and bought extra FYM from neighbours. The availability of synthetic fertilisers is only a very recent occurrence with development of road networks in the mid-hills. Previously, any synthetic fertiliser had to be carried up manually and so was very expensive. Nevertheless, less than half of mid-hills farmers use any commercial fertiliser because they are not convinced of its cost-effectiveness or are just not in the habit of using it.

The use of FYM has traditional credibility. There is also a growing interest, indeed enthusiasm, in promoting organic farming principles amongst high level policy makers (Pokhrel & Pant 2009). There is a ready market for organic vegetables in Kathmandu (Aryal et al. 2009; Bhatta, Doppler & KC 2009), and organic vegetable production in Chitwan district (in the Terai) has been shown to be economically more profitable than inorganic (Adhikari 2009; Kafle 2011). However, there appears to be no work directly comparing yields of crops fertilised by FYM with synthetic fertiliser on soils of the mid-hills region. Unfortunately, such a trial could not be undertaken in this study due to resource and logistical constraints. The method presented in this chapter is the next best approach. While it cannot demonstrate likely differences in yield under FYM and synthetic fertiliser, it can show the relative value of the two sources of crop nutrient in terms as a unit of cost of production.

FYM is always purchased in the unit of a doko. The doko is the conventional Nepali farmers' basket, which can carry vegetables, soil, food, and FYM. It is made of split bamboo, conical in shape and carried via a head rope. It can carry 25 kg fresh weight of FYM (Vaidya 1988). While there is a market for FYM sold per doko the trading price probably reflects the effort in collection and transport more than the actual NPK value. If the monetary nutrient value of FYM per doko were known to the farmers compared to synthetic fertilisers, the farmers would have more information on which to base their crop nutrition decisions. In addition, such information will be very useful for policy makers so that they can make a soberer assessment of the potential of organic farming in the mid-hills.

7.2 Methods and results

The steps involved in this method, and the results presented in Table 7-1 are:

1. The nutrient content of N, P and K in $g \cdot kg^{-1}$ in FYM collected from the two villages, Chaubas and Dhunkharka, were analysed in laboratory and results presented in Chapter 4. These summary values are presented in column '*a*' in Table 7-1.
2. The value per kg of each of N, P and K in the commercial fertilisers available in Nepal was determined. These fertilisers and elemental content percentage are 46% N in urea, 21.8% P in di-ammonium phosphate and 41.5% K in potassium sulphate respectively[6]. The single bag prices of these fertilisers were collected in the agricultural market in nearby town of Panauti. The value per kg of elemental N, P, K from each of the fertiliser sources is calculated by dividing price of 1 kg fertiliser by the percentage of element (column '*b*' in Table 7-1).
3. The values from columns '*a*' and '*b*' were multiplied to NPK amount ($g \cdot kg^{-1}$) of FYM in each village to obtain the nutrient equivalent monetary value of FYM (column '*c*' in Table 7-1).
4. Then, the monetary value ($NRs \cdot kg^{-1}$) is converted to the equivalent monetary value of FYM per doko (NRs·18.9 kg). The 25 kg of fresh FYM that can be carried in a doko was determined to be 18.9 kg dry weight from laboratory oven-dried samples (column *d'* in Table 7-1).

[6] : Market price of urea (46:0:0), di-ammonium phosphate (18:46:0), and potassium sulphate (0:0:60) are 27 $Rs \cdot kg^{-1}$, 55 $Rs \cdot kg^{-1}$, and 50 $Rs \cdot kg^{-1}$ respectively in Banepa market in Kavre district in September 2014.

5. The trading value per doko of FYM is presented in column *'e'* told by farmers for comparison with equivalent monetary value, 'd' of FYM calculated from manure samples per doko.

Table 7-1*: Steps for calculating equivalent monetary value of NPK in FYM based on commercial fertiliser prices and comparing it with FYM purchased on farm, (amount of doko 18.9 kg (dry matter)= 25 kg (fresh weight; Vaidya 1988) * 0.75 (moisture content mean of field research)*

Village name	Nutrient	Mean nutrient of FYM ($g \cdot kg^{-1}$)(current study result; study 1, Chapter 4)	Value of synthetic fertiliser of 100% ($NRs \cdot kg^{-1}$)	Equivalent monetary value of FYM ($NRs \cdot kg^{-1}$)	Equivalent monetary value of FYM per doko ($NRs \cdot 18.9\ kg^{-1}$)	Trading FYM value per doko ($NRs \cdot 18.9\ kg^{-1}$)
		a	**b**	**c (c=a/1000 x b)**	**d (d= c x 18.9)**	**e**
Chaubas	N	5	11	0.05	1	–
	P	3.3	25	0.08	1.5	–
	K	3.4	29	0.1	1.9	–
	Total (NRs)			**0.23**	**4.4**	**45**
Dhunkharka	N	5.1	11	0.06	1.1	–
	P	7.1	25	0.18	3.4	–
	K	3.7	29	0.11	2.2	–
	Total (NRs)			**0.35**	**6.6**	**35**

7.3 Discussion

The results from this analysis should cause concern among those who promote organic farming in the mid-hills region. The calculated equivalent monetary value of FYM (cell in 'c') in NPK basis in Chaubas is 0.23 $NRs \cdot kg^{-1}$ and that in Dhunkharka is 0.35 $NRs \cdot kg^{-1}$. Comparing the equivalent monetary value rate between two villages, the value in Dhunkharka was about 48% higher than in Chaubas. The reason for this higher value stems from the higher concentration of P in FYM in Dhunkharka.

The trading price of FYM per doko in the two villages was determined through farmer interviews. The equivalent value of nutrients in FYM (column ‘d’ in Table 7-1) from Chaubas and Dhunkharka was 10% and 19% respectively when compared with trading value price of FYM (column ‘e’ in Table 7-1) if farmers sell the FYM per doko. As the villages are distant from each other, farmers in the two villages did not know the price in the other village. The local economies and levels of natural and financial capital of the two villages are very different. Dhunkharka is much closer to Kathmandu and on a better road than Chaubas (46 km and 76 km respectively). Dhunkharka has stronger commercial links with the Kathmandu markets and while it has similar livestock numbers per household as Chaubas (2.38 and 2.25 Livestock Units respectively; (Cedamon et al. 2015)), the farmers of Dhunkharka have on average smaller landholdings (12.7 and 22.9 ropani[7] respectively), but double the average annual income (NRs 205,000 cf[8] 108,000 respectively). Farmers in Dhunkharka have higher levels of education (average 4.1 years cf 1.6), are 13% more likely to gain main income though agriculture and twice as likely to be engaged in community organisations (all comparative values from (Cedamon et al. 2015) in press). Based on the information of the percentage of the using synthetic fertiliser in Chaubas is 27% whereas that in Dhunkharka is 32% (Cedamon et al. 2015), it can be convincing that Dhunkharka farmers are more likely to purchase the commercial fertiliser and more discriminating in the price they pay for FYM. Additionally, in Dhunkharka has the convenient transportation access, more opportunity for selling vegetables, and likely to gain more market information which induce the use of chemical fertiliser.

As the farmers in Dhunkharka have an advantage of FYM quality in nutrient, the equivalent NPK nutrient monetary value of FYM per doko is 6.6 NRs$\cdot$ doko^{-1} compared with 4.4 NRs$\cdot$ doko^{-1} in Chaubas. Consequently, the trading market value of FYM in Dhunkharka per doko was five times higher than the actual NPK nutrient monetary value of FYM if the NPK was purchased a synthetic fertiliser; and for Chaubas the trading market value of FYM per doko was almost ten times

[7] ropani; Nepali land size unit. 1 ropani= 0.05 ha, or 508.8 m^2.
[8] cf; compare to the mean.

higher than nutrient equivalent value of FYM. It means that trading FYM value is over estimated by the farmers if the value focus on the NPK nutrient concentration. In other words, FYM purchased same price to chemical fertiliser is less effect on the NPK nutrient supply than effect of chemical fertiliser. On the surface, it appears that buying FYM is not an economically rational nutrient supply strategy if focus on the NPK nutrient for its effect compared to the chemical fertiliser. However, this evaluation does not take into account the other advantages of FYM over chemical fertiliser such as: soluble organic carbon, aeration content, microbial content, other mineral content, C/N ratio, pH buffering and water holding capacity, impact on water infiltration rates. If some of the yield advantages by the application with those indicators in FYM were identified compared to the chemical fertiliser, the difference of the yield and price would reflect to the equivalent monetary value of FYM. Furthermore, it is noted that the effect of FYM and mineral fertiliser differ after the application to the soil, which nutrient can be absorbed to the plant. The slow effect of the FYM whereas the quick effect on the mineral fertiliser should be considered to the monetary equivalent value if it can be calculated.

The equivalent monetary value of these other soil fertility factors in FYM still need to be determined. The actual quality of FYM can also be greatly improved. Although a lot of work already were performed in improving FYM quality in Nepal (Shrestha 2009), the diffusion of them is apparently poor. The farmers in this study sites have not used improved FYM production methods. Only one case was observed in Dhunkharka that one farmer made the roofing of FYM piling to keep moisture and temperature for better decomposition.

Sharing this monetary values both FYM per kg and per doko in two villages enables farmers to consider the present status of their FYM. Considering the present status of FYM monetary may hopefully start to improve or amend of FYM materials and making method with project stakeholders. On the other hand, the way of valuation the nutrient value can be also applied to the nutrient value of fodder and manure, which can contribute the source of FYM. The outcome of those values helps to understand the importance of nutrient in each material of FYM in forest farming system. As this nutrient monetary valuation of FYM is first and epoch-making approach in Nepal, this method can share to other projects which attempt to raise the farmers' livelihood in Nepal. Therefore, the valuation monetary value of FYM is very effective method to share the importance of FYM in nutrient basis among the project stakeholders.

In summary, the equivalent monetary values of FYM in both two villages are far lower than FYM trading value on a NPK basis. Although the monetary value did not include the organic carbon value, which influences the microorganism mobility, and it enhances the nutrient holding capacity, the farmer trades the enormous higher price in terms of the NPK nutrient basis, thereby overestimating the monetary value of FYM than actual nutrient ability of FYM.

7.4 Chapter conclusions

The equivalent monetary value of FYM in Dhunkharka, 0.35 $NRs \cdot kg^{-1}$ is 48% higher than that in Chaubas, 0.23 $NRs \cdot kg^{-1}$, which derived from higher concentration of P concentration in FYM. The NPK content equivalent monetary value of FYM per doko (18.9 kg [9] dry matter) in Chaubas is 4.4 $NRs \cdot doko^{-1}$ and in Dhunkharka is 6.6 $NRs \cdot doko^{-1}$. Therefore, the difference between the equivalent monetary value and the trading market price of FYM significantly differ. In detail, the market-trading price of FYM in Chaubas is ten times higher than the equivalent monetary value of FYM. In addition, the market-trading price of FYM in Dhunkharka is five times higher than that the equivalent monetary value of FYM. In summary, the equivalent monetary values of FYM in both two villages are remarkably lower than trading value in NPK nutrient basis. Thus, the FYM quality with the lower NPK concentration should improve through innovated techniques.

[9] : 18.9= 25kg (fresh manure; Vaidya 1988) * 0.75 (moisture content of field survey by the author).

Chapter 8: Observation of nutrient trend in Fresh Manure and fodder

8.1 Introduction

The objective of this chapter is to examine correlation between nutrient status of manure and fodder. It also details analysis of the correlation between fodder nutrient content and manure in each feeding experiment.

8.2 Methods

To observe the nutrient trend between fresh manure and fodder data from Studies 2 and 3 were analysed to construct a relationship between the two. They are 1) the N, P and K nutrient content in three types of fodder with R^2 value, 2) the Pearson's correlation and coefficient, and 3) the NPK content in the manure of livestock fed four types of fodder with R^2 value.

To perform the correlation analysis between the manure and the fodder nutrient, every ten samples of NPK manure nutrient fed with three types of fodder in three types of livestock and ten samples of NPK fodder nutrient were used and entered to the Excel 2013®. In statistical analysis for 1) NPK nutrient trends fed with three type of fodders and 3) the NPK content in the manure of livestock, correlation function in the Excel 2013® was used then investigated in R^2 ratio. For 2) to observe the Pearson's correlation and coefficient, the Pearson's correlation function in Excel 2013® was used then evaluate the trend of correlation and coefficient ratio.

8.3 Results

8.3.1 Relationship between N concentration in fodder and resulting manure

The main findings of observation of nutrient trend with fresh manure and fodder is shown in Table 8-1. The relationship between N concentration in fodder and resulting manure for three fodders fed to three livestock is shown in Figure 8-1. The overall trend in goat manure was relatively high in response to *Ficus* and *Prunus* fodder than *Brassaiopsis* fodder. For example, goat manure fed with *Ficus* fodder N showed 7,000 to 12,000 mg·kg^{-1} with *Ficus* fodder N ranged from 18,000 to 20,000 mg·kg^{-1} and manure fed with *Prunus* fodder N ranges from 7,000 to 15,000 mg·kg^{-1} as *Prunus* fodder N range from 12,000 to 34,000 mg·kg^{-1}. On the other hand, the manure fed with *Brassaiopsis* N ranges lower, which is from 1,000 to 15,000 mg·kg^{-1} as fodder N ranges from 24,000 to 34,000 mg·kg^{-1}. The trend for cow and buffalo manure showed low N concentration for the three types of fodders with similar ranges. The trend of N concentrations in cow and buffalo manure showed similar and low correlation with narrow range of fodder N concentration than goats. Thus, correlation in N for goat manure was different to the trend in N concentration for cow and buffalo manure.

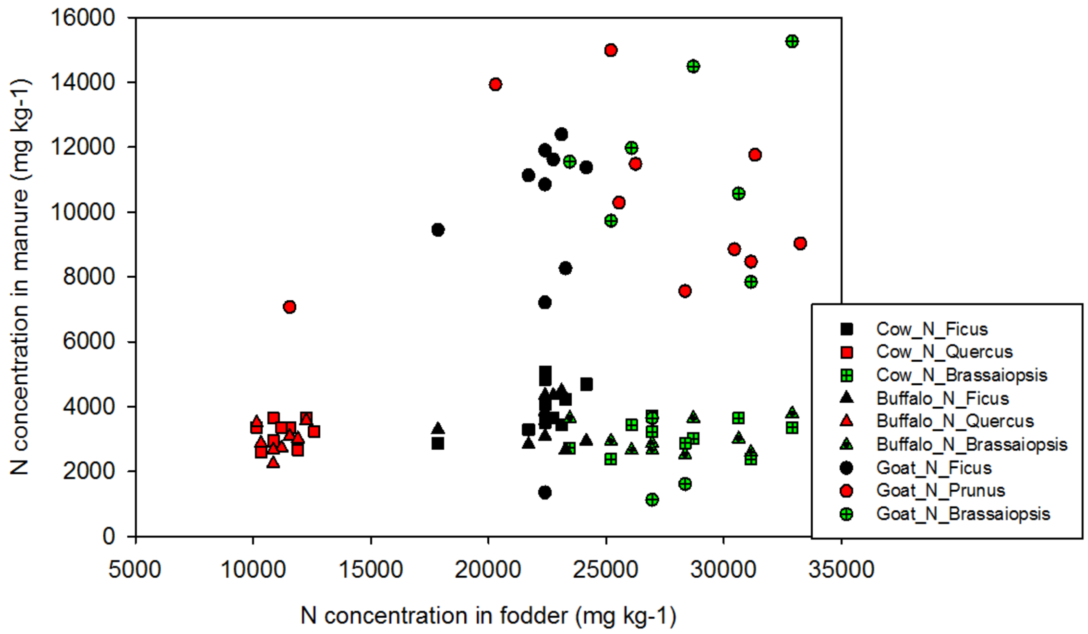

Figure 8-1*: Relationships between N concentration in fodder and resulting manure for three types of fodder and three types of livestock*

***Table 8-1**: Observation nutrient correlations*

Fig and Table	Category 1	Category 2	Trends
Fig 8-1	N	Goat	Relatively higher response with *Ficus*, ranged around 12,000 $mg \cdot kg^{-1}$ as narrow fodder range, which is from 15,000 to 25,000 $mg \cdot kg^{-1}$.
			Manure fed *Prunus* showed relatively higher concentration, more than 7,000 $mg \cdot kg^{-1}$ with wide fodder ranged from 12,000 to 34,000 $mg \cdot kg^{-1}$.
			The manure fed with *Brassaiopsis* ranged from 1,000 to 15,000 $mg \cdot kg^{-1}$ with fodder ranged from 24,000 to 34,000 $mg \cdot kg^{-1}$.
		Cow and buffalo	N concentrations in cow and buffalo manure showed similar correlation with fodder concentration Brassaiopsis is the highest, followed by *Ficus* and *Quercus*.
			N concentration in manure was not impacted with fodder three types.
Fig 8-2	P	Goat	The manure for three types of fodder shows a diverse range.
		three livestock	The manure produced from three livestock fed with the *Ficus* fodder had wide and similar range of P concentration with narrow and low P concentration in *Ficus* fodder.
Fig 8-3	K	Goat	The manure fed with three types of fodder indicates relatively wide and similar range of results as fodder K concentrations have wide variation.
		Cow and buffalo	The manure produced from cow and buffalo fed with *Quercus* fodder resulted wider range of concentration with narrow and low range fodder concentration.
		Three type livestock	The manure from livestock fed Ficus and *Brassaiopsis* fodder showed similar and spread concentration with wide range of fodder nutrient.
Table 8-2	Correlation manure and fodder		A strong correlation was found for K concentration between *Brassaiopsis* fodder and buffalo manure (0.789).
			Some relatively strong correlations were found for P concentration between Prunus fodder and goat manure (0.607), and N concentration between *Quercus* fodder and buffalo manure (0.585), N concentration between *Ficus* fodder and cow manure (0.583), P concentration between *Brassaiopsis* fodder and buffalo manure (0.569), and K concentration between *Quercus* fodder and buffalo manure (0.501). Some relatively strong negative correlations were found for P concentration between *Quercus* fodder and cow manure (-0.544) and P concentration between *Brassaiopsis* fodder and cow manure (-0.441).

Fig and Table	Category 1	Category 2	Trends
Fig 8-4	Goat	P	The fodder nutrient and goat manure for certain fodder types a relatively clear correlation was found for P concentration in *Prunus* fodder (R^2=0.3687) and goat manure.
			If absorption of P in fodder and manure P content positively related, *Prunus* fodder has the potential to increase goat manure nutrient.
Fig 8-5	Cow	N	The fodder nutrient (*Ficus*) and cow manure for *Ficus* fodder N concentration had a positively linear correlation (R^2=0.339) as compared to the other two fodder species.
			Where N concentration is high in the *Ficus* fodder, the greater N concentration shows in cow manure.
		P	P concentration feeding with *Ficus* had lower concentration with relatively wide range of fodder nutrient than other two types of fodder.
		K	The manure concentration of K for *Quercus* fodder had the wider and higher concentration compared to other two types of fodders.
Fig 8-6	Buffalo	P	*Brassaiopsis* fodder nutrient concentration and P concentration of buffalo manure from *Brassaiopsis* fodder had a positively linear correlation (R^2=0.324) as compared to the two other fodder species
			When *Brassaiopsis* fodder is fed to buffalo, the manure P concentration is increased.
		K	A strong, linear and positive correlation (R^2=0.622) was evident in K concentration for buffalo manure from *Brassaiopsis* fodder.
			When Brassaiopsis fodder is fed to buffalo, K concentration in buffalo manure is likely to be increased.

8.3.2 Relationship between P concentration in fodder and resulting manure

The relationship between P concentration in fodder and resulting manure for three fodders fed to three livestock is shown Fig 8-2. It noted that the manure produced from three livestock fed with the *Ficus* fodder had wide and similar range of P concentration from 4,000 to 15,000 mg·kg^{-1} with narrow and low P concentration in *Ficus* fodder from 800 to 1,200 mg·kg^{-1}, may be due to the difference among the individual of livestock rather than fodder P concentration. The manure produced from cow and buffalo fed with *Quercus* fodder showed a relatively narrow range from 2,000 to 9,000 mg·kg^{-1} with narrow range of *Quercus* fodder P concentration ranged from 400 to 1,000 mg·kg^{-1}. In addition, manure produced from three livestock fed with *Brassaiopsis* fodder resulted from 3,200 to 9,000 mg·kg^{-1} with relatively wider range of *Brassaiopsis* fodder from 1,600 to 2,600 mg·kg^{-1}, unlike other two fodder species.

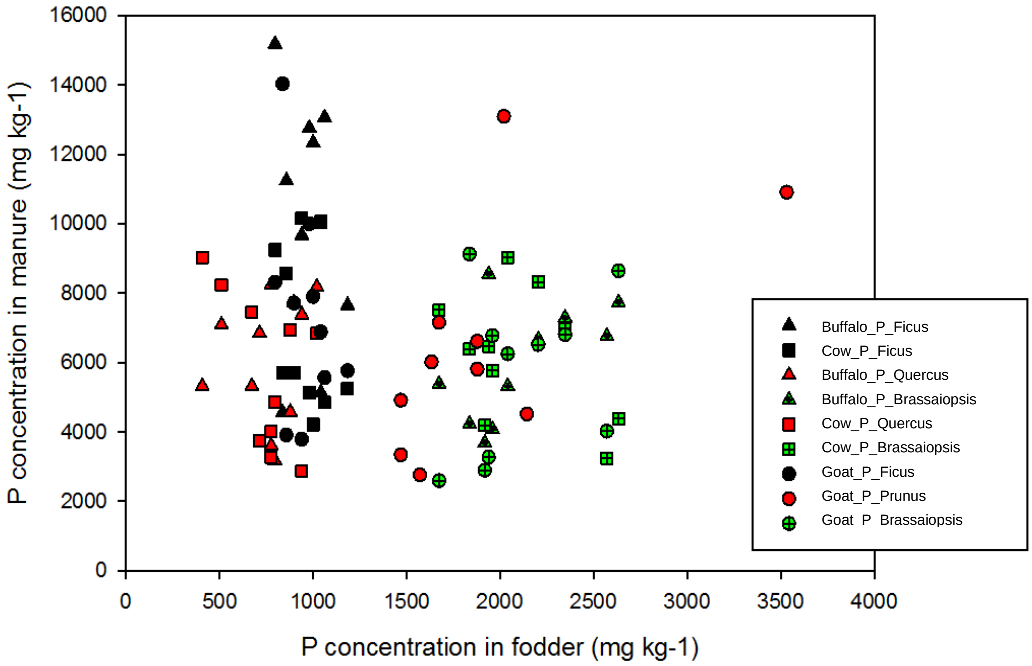

***Figure 8-2**: Relationships between P concentration in fodder and resulting manure for three types of fodder and three types of livestock*

8.3.3 Relationship between K concentration in fodder and resulting manure

The relationship between K concentration in fodder and resulting manure for three fodders fed to three livestock is shown in Fig 8-3. K concentration of manure produced from cow and buffalo fed with *Quercus* fodder resulted wider range of concentration from 2,000 to 9,000 mg·kg^{-1} with narrow and low range fodder concentration from 2,000 to 3,000 mg·kg^{-1}, which is the lowest fodder concentration among three fodder types. In addition, manure from three types of livestock fed with *Ficus* and *Brassaiopsis* fodder showed similar and spread concentrations with wide range of fodder nutrient. From these observation, K concentration manure produced by cow and buffalo fed with *Quercus* fodder may likely to be different among each individual unlike the manure fed with other two types of fodder.

The trend in goat manure fed with three types of fodder indicates relatively similar and fodder with wide range concentration. For example, manure produced from goat fed with *Ficus* and *Brassaiopsis* fodder shows a relatively similar range from 1,000 to 4,400 mg·kg^{-1} even though K concentration for these fodders are widely spread. The K concentration for manure produced from goat fed with *Prunus* fodder shows a narrow range from 1,650 to 3,300 mg·kg^{-1} even though K concentration in fodder has wide variation.

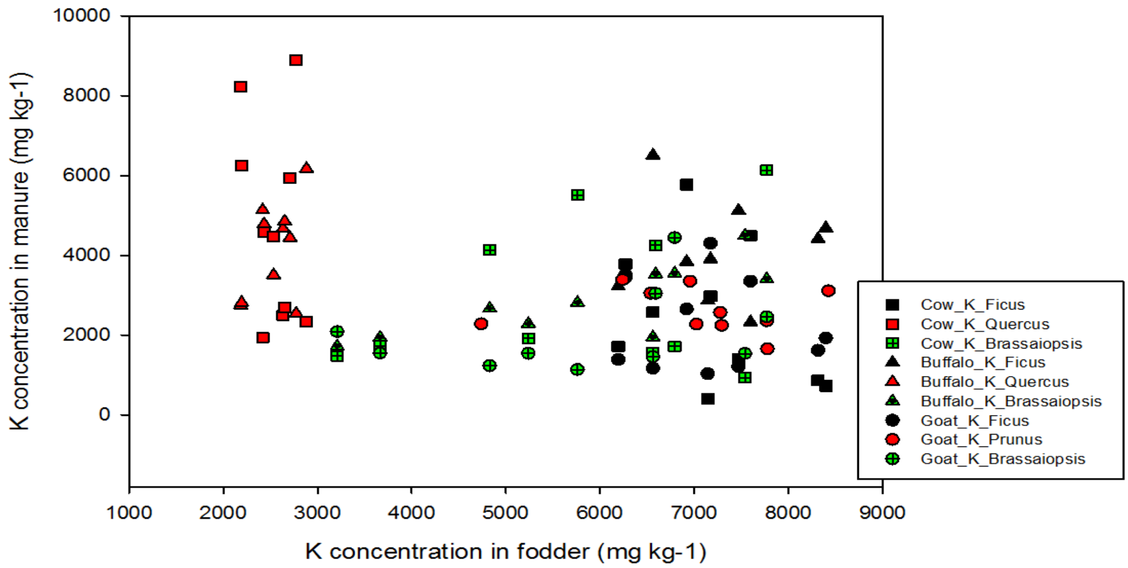

***Figure 8-3**: Relationships between K concentration in fodder and resulting manure for three types of fodder and three types of livestock*

8.3.4 Correlation of nutrients between fodder and livestock manure

In order to identify the influential fodder type for livestock manure nutrient, manure nutrients for each type of fodder were investigated using Pearson's correlation and coefficient (Table 8-2). A quite strong correlation was found for K concentration between *Brassaiopsis* fodder and buffalo manure (0.789). In addition, some relatively strong correlations were found for P concentration between *Prunus* fodder and goat manure (0.607), and N concentration between *Quercus* fodder and buffalo manure (0.585), N concentration between *Ficus* fodder and cow manure (0.583), P concentration between *Brassaiopsis* fodder and buffalo manure (0.569), and K concentration between *Quercus* fodder and buffalo manure (0.501). Furthermore, some weak correlations were identified for P concentration between *Brassaiopsis* fodder and goat manure (0.338) and K concentration between *Brassaiopsis* fodder and goat manure (0.328). On the other hand, some relatively strong negative correlations were found for P concentration between *Quercus* fodder and cow manure (-0.544) and P concentration between *Brassaiopsis* fodder and cow manure (-0.441). Besides, some weak negative correlations were recognised for K concentration between *Ficus* fodder and cow manure (-0.383), P concentration between *Ficus* fodder and cow manure (-0.350), and for P concentration between *Ficus* fodder and goat manure (-0.331).

Table 8-2*: Correlation nutrient between fodder and manure from three types of livestock fed three types of fodder (Pearson's correlation and coefficient), (bold number has higher correlation coefficient)*

Fodder		Goat	Cow	Buffalo
Ficus	N	0.082	**0.583**	0.073
	P	**-0.331**	**-0.350**	-0.164
	K	-0.075	**-0.383**	0.067
Quercus	N	-	0.181	**0.585**
	P	-	**-0.544**	0.172
	K	-	-0.285	**0.501**
Prunus	N	-0.009	-	-
	P	**0.607**	-	-
	K	-0.083	-	-
Brassaiopsis	N	0.203	0.206	0.098
	P	**0.338**	**-0.441**	**0.569**
	K	**0.328**	0.275	**0.789**

8.3.5 Correlation of nutrients between fodder and goat manure for three types of fodder

For fodder nutrient and goat manure for certain fodder types a relatively strong correlation was found for P concentration in *Prunus* fodder (R^2=0.3687) and goat manure (Figure 8-4). In other words, where *Prunus* fodder was fed to goat manure P concentration increased. Thus, if absorption of P in fodder and manure P content positively related, *Prunus* fodder has the potential to increase nutrient content in goat manure.

Overall trend is that the trend between goat manure with fodder showed quite different types of tendency in each NPK concentrations and fodder type. For example, in P concentration fed with three types of fodder showed wide range of manure with narrow fodder concentration. In K concentration fed with three types of fodder showed both narrow range of manure nutrient concentration and fodder concentration. On the other hand, N manure in N concentration showed a wide range both manure and fodder concentration (Figure 8-4).

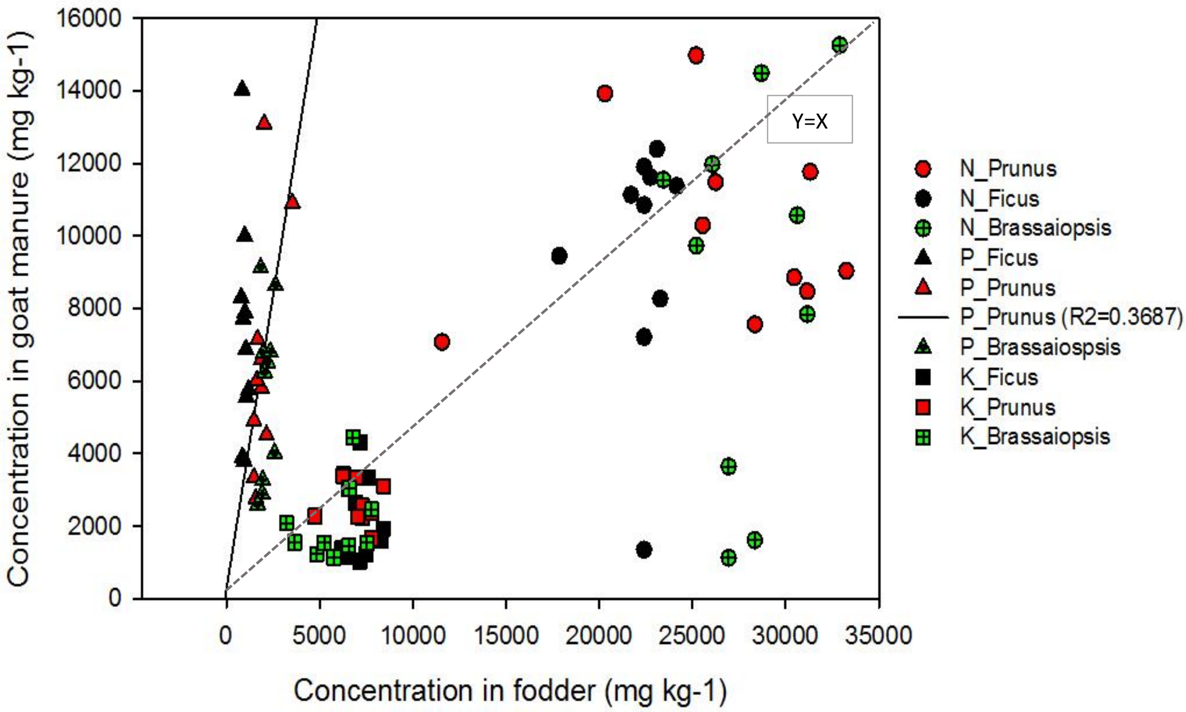

***Figure 8-4**: Correlation nutrient between fodder and goat manure fed with three types of fodder*

8.3.6 Correlation of nutrient concentration between fodder and cow manure for three types of fodder

Correlation between fodder nutrient (*Ficus*) and cow manure for *Ficus* fodder N concentration had a positively linear correlation (R^2=0.339) as compared to the other two fodder species (Figure 8-5). In other words, where N concentration is high in the *Ficus* fodder, the greater N concentration shows in cow manure. Interestingly, manure results showed a similar N concentration range between 2,380 to 5,075 $mg \cdot kg^{-1}$ in three types of fodder, even though fodder N concentrations were different (Figure 8-5).

In terms of P concentration, manure feeding with *Quercus* and *Brassaiopsis* fodder resulted wide range concentration with narrow range for fodder concentration (Figure 8-5). On the other hand, P concentration feeding with *Ficus* had lower concentration with relatively wide range of fodder nutrient than other two types of fodder. These results may be due to diversity of gut function and metabolism in cow toward fodder type. For K concentration, manure concentration fed with *Quercus* fodder resulted the wider concentration with narrow range of the fodder nutrient compared to other two types of fodders. Thus, *Quercus* fodder may likely influence in a relatively higher K concentration to the cow manure as compared to other fodders, which may likely be effected the digestion and metabolism.

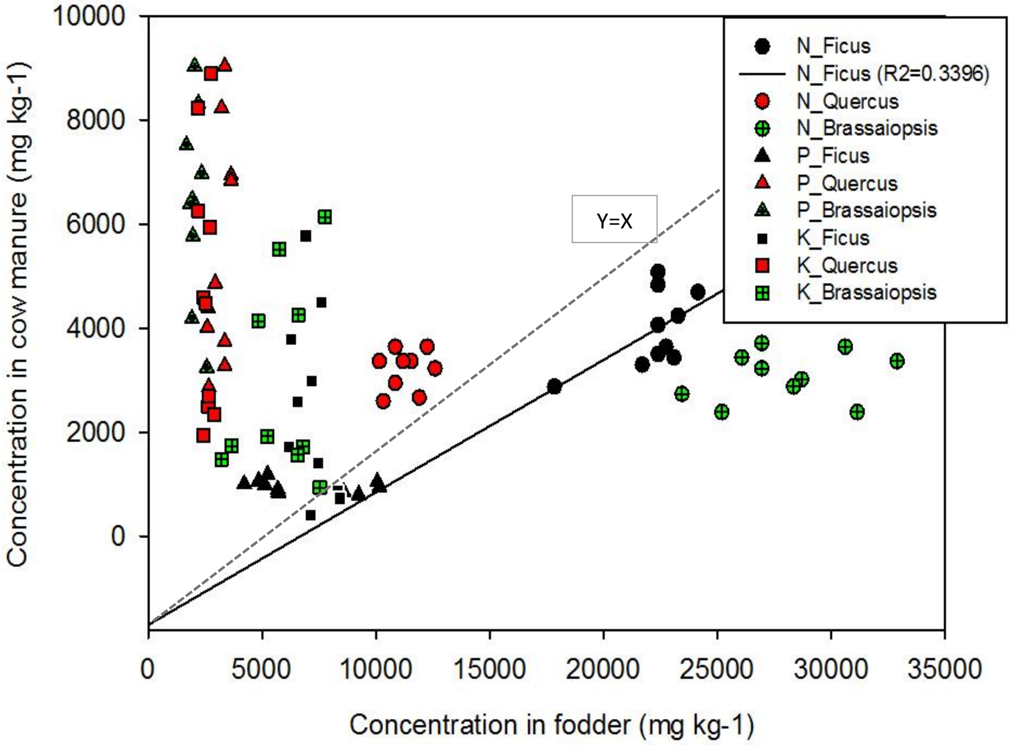

***Figure 8-5**: Correlation nutrient between fodder and cow manure fed with three types of fodder*

8.3.8 Correlation nutrient between fodder and buffalo manure fed with three types of fodder

P concentration of buffalo manure fed with *Brassaiopsis* fodder had a positive linear correlation (R^2=0.324) as compared to the two other fodder species (Figure 8-6). In other words, when *Brassaiopsis* fodder is fed to buffalo the manure P concentration increased. In addition, a strong, linear and positive correlation (R^2=0.622) were evident in K concentration for buffalo manure from *Brassaiopsis* fodder. In other words, there is a correlation that when *Brassaiopsis* fodder is fed to buffalo, K concentration in buffalo manure is likely to increase. Therefore, *Brassaiopsis* fodder increases P and K concentration in buffalo manure. In addition, manure N concentration fed with three types of fodder ranged relatively similar concentrations with different ranges of three types of fodder N concentration.

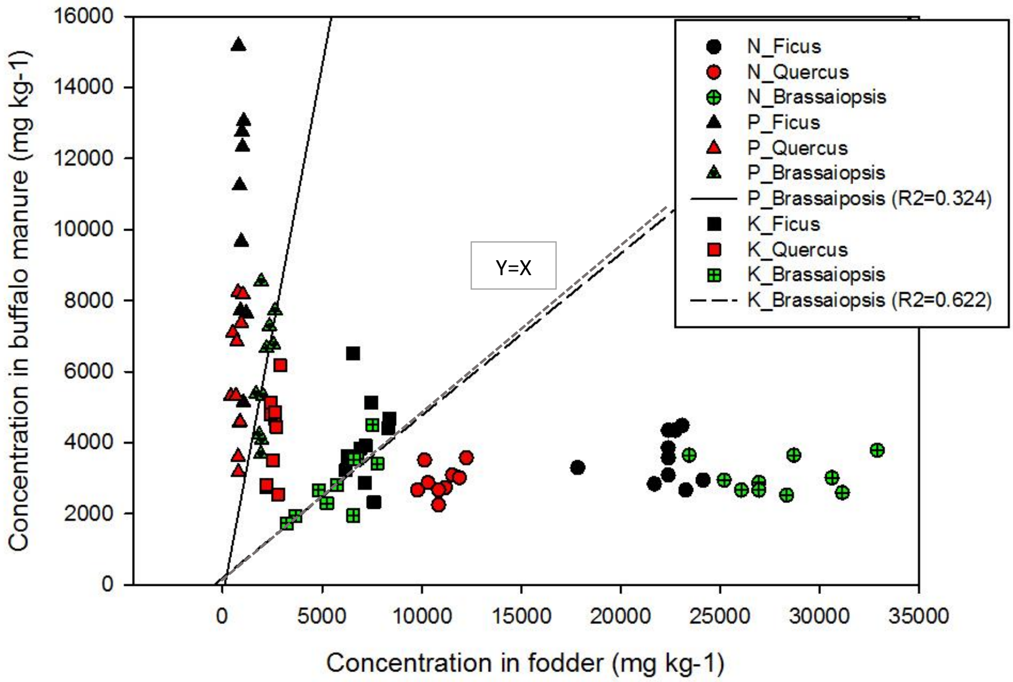

Figure 8-6*: Correlation nutrient between fodder and buffalo manure fed with three types of fodder*

8.4 Chapter conclusions

Nutrient trends in fresh manure and fodder show no significant difference between N in manure and fodder N concentration among three types of livestock. The P concentrations in cow and the buffalo manure are higher and wider range for *Ficus* fodder than other two types of fodder, even P concentration in *Ficus* fodder is narrow and low. The K concentrations in cow and buffalo manure likely to positively impact with *Quercus* fodder even though the K concentration in fodder ranged narrow and low.

A positive relationship was found for P concentration of goat manure from the *Prunus* fodder experiment (R^2=0.3687). Therefore, if *Prunus* fodder had high P concentration, P concentration in goat manure also increased. For cow manure, N concentration for *Ficus* fodder was found a positive linear correlation (R^2=0.339). Thus, when *Ficus* fodder had high N concentration, the N concentration in manure correspondingly increases. For buffalo manure, P concentration from *Brassaiopsis* fodder had a positive linear correlation (R^2=0.324). Furthermore, K concentration in buffalo manure for *Brassaiopsis* fodder also had positive correlation (R^2=0.622). This means that when *Brassaiopsis* fodder fed to the buffalo, P and K concentration in manure increase.

Chapter 9: Discussion

9.1 Introduction

The aim of this chapter is to discuss the key results and to create an integrated understanding the value of nutrients provided with fodder trees in the mid-hills farming system of Nepal. This new knowledge will be published in the context of the international literature.

This chapter presents a sequence of subsections: ‘Interviews in Chaubas and Dhunkharka villages’, ‘FYM sampling’, ‘Fodder nutrient’, ‘Manure nutrient’, ‘Recommendation fodder type’, ‘Equivalent to monetary value NPK status in FYM’, and ‘Overall context of forest-farming systems’. This chapter also discusses the limitations of this study and implications for further studies.

9.2 Interview in Chaubas and Dhunkharka villages

Interviews with farmers showed that there are preferable fodder species differences in the two villages. This difference is due to diversity in altitude, climate, geological features, soil type and soil fertility that influence fodder vegetation types in each sites. Consequently, fodder availability influenced farmer choice of fodder varieties for livestock and participation in this experiment. For example, in Chaubas the altitude range is from 1,385 to 2,020 m and Dhunkharka is from 1,600 to 2,150 m. Thus, elevation may influence the selection of fodder species. In Chaubas, the main fodder species were *Ficus auriculata* (habitat: 100-1,700m) and *Ficus semicordata* (habitat: 600-1,900 m) which inhabit a lower altitude compared to the species grown in Dhunkharka.

The preferred species in Dhunkharka were *Saurauria nepaulensis* (750-2,100 m) *Brassaiopsis hainla* (1,300-2,100 m) and *Quercus lanata* (1,900-3,000 m) which inhabit a higher altitude as compared to the species in Chaubas. In Gorkha district (altitude 1,135 m), the preferred fodder species for goats with farmers are *Ficus semicordata*, followed with *Listea polyantha*, *Bauhinia purpurea*, and *Terminolia* *belerica* (Degen 2010). In addition, the choice of fodder types may have been derived from farmers' empirical practices with long time trials in which their ancestors have been choosing to achieve their objectives towards livestock traits such as increased weight, meat, amount of milk and health.

In the FYM production practice, the mean amount of making FYM per hectare per household per year in Chaubas is 9.3 $t \cdot hh^{-1} \cdot year^{-1}$ and in Dhunkharka is 18.5 $t \cdot hh^{-1} \cdot year^{-1}$ (Table 4-4), which are higher than the former research range from 3.23 to 4.56 $t \cdot year^{-1}$ (Dougil et al. 2001). However, the study results in Dhunkharka is consistent to the former research and result in Chaubas is less than the former research to 26 $t \cdot hh^{-1} \cdot year^{-1}$ (Pilbeam et al. 2000).

9.3 FYM sampling

In this experiment, P was higher in concentration in FYM in Dhunkharka than shown in most previous studies, whereas N and K concentrations were lower than former studies (Aryal & Tamrakar 2013; Dougil et al. 2001; Karki et al. 2008). This trend related to the higher proportion of manure in the FYM material in this study because manure has a higher P concentration than green foliage, leaf litter and dried plant materials. In other studies, manure has higher P composition than green weed and dried rice straw (Das et al. 2010).

When decomposition commences, FYM containing green foliage, leaf litter and dried plants material has higher P than FYM composed of manure solely. Hence, the higher proportion of leaf and other dried materials influence a higher P concentration, which consists of large amount of woody materials. For example, woody mixed compost has higher P concentration in FYM (Fujiwara 2008; Keityou et al. 2005). Additionally, the study result of N concentration (%) in Chaubas and Dhunkharka, 0.496% and 0.513% are regarded as a low ratio manure in the former research that low and high manure ratio (%) in N are 0.51% and 1.36% (Masaka et al. 2013).

9.3.1 Consideration of proportion of coarse and fine and SOC of FYM

Normally, when the decomposition of FYM proceeds, the fine particles matter increase and mineralisation of nutrients in FYM occurs. The result of a higher rate of fine particle of FYM in both two villages informs that the FYM in two villages decomposed and decayed the composting process (Table 4-5). SOC relates to the total organic matter in the soil that the SOC ratio is about five percentage in the total organic matter in the soil (Department agriculture and food 2015). In a mean time, one scholar reports that soil organic carbon content in FYM is positively and significantly correlated to the soluble organic nitrogen (SON) content in FYM (Mastuda 2007). In further study, it is interesting to know whether there is a significant correlation between SOC and SON.

Similar rebels of SOC concentration in both villages contribute for nutrient mineralisation and mobilisation to the microorganism. That contribution increases the nutrient absorption in plants. In the meantime, there are lot of issues have not been investigated related to SOC, which is still difficult to fully understand. For example, measuring the compost mineralisation index, further studies are necessary to determine the ash content that is subtracted by oxidisable carbon (Bera et al. 2013; Seal et al. 2012). Another example is that one study shows that concentrations of SOC improved during decomposition time at 0, 30, and 63 days (Duong et al. 2013). Contrary, one study investigated the SOC concentration during decomposition period from 0 to 250 days that it decreases as the composition time proceeds (Said-Pullicino, Erriquens & Gigliotti 2007). In addition, there are many methods to acquire the water extractable carbon solution from organic matter or soil, which is not standardised. For example, the shaking time of soil organic matter samples varied to the former studies. One study shake the solution for 30 minutes, 1 hour, 18 hours (Hishi et al. 2004), whereas another study shook for 2 hours (Hagedorn, Blaser & Siegwolf 2002).

9.3.2 Consideration of FYM condition in both two villages

The climatic conditions, in Chaubas is warmer (Figure 4-1) and the mean altitude is lower than in Dhunkharka (Table 4-2) which implies the decomposition and mineralisation process in Chaubas may be accelerated even though the precipitation rates are similar in both villages. The number of time making FYM and month kept in piling FYM in a year in Chaubas, 1.3 times and 10.0 months, and Dhunkharka, 1.5 times and 9.5 months (Table 4-4) are consistent to the former research reports, the time for kept piling range from 1.5 month to a year in Kavre district (Kaneko 2014). The reason of this result difference probably derived from the frequency of cultivation cropping pattern. It is reasonable to imagine that farmers in Dhunkharka cultivate more vegetables, which need large amount of FYM, so they make it frequently in short time. The month start piling and the month apply the FYM to the crop field in Chaubas, February to March and January to February, and in Dhunkharka, November, and September to October are also may derive from their cropping pattern. For example, farmers in Chaubas apply FYM before the maize and potato cultivation, which starts in March. On the other hand, the month applying the FYM to the crop field in Dhunkharka is in September to October, which they cultivate the profitable vegetables such as, cauliflower and radish for sales. It imagines that Dhunkharka is close to the large markets such as Kathmandu and Banepa, the vegetable cultivation is more popular than in Chaubas where the farming system is the subsistence-based system.

Regarding FYM material, the larger proportion of material in Chaubas is green fodder which is biodegradable and for Dhunkharka the larger proportion of material is litter and plant residual composed of woody materials, including lignin and hard to degrade materials (Figure 4-3). During FYM sample collection in the field experiment, FYM in Dhunkharka included a large amount of litter and humus. On the contrary, FYM in Chaubas involved larger amounts of white fungus, likely to be mycorrhizal fungus or root fungus. The presence of fungi in FYM in Chaubas implies that appropriate decomposition is in process.

N fixing amount (kg·ha^{-1}·year^{-1}) in the study in Chaubas, 29.0 kg·ha^{-1}·year^{-1} showed relatively lower amount to the former research in dry land fallow-maize-wheat system in Nepal in Kavre district, 53 kg·ha^{-1}·year^{-1} (Brown 1999). However, that in Dhunkharka, 139.6 kg·ha^{-1}·year^{-1} was higher amount than former study (Table 4-6). Brown et al. (1999) surveys the N fixation in the soil 0 to 15 cm of the biological N fixation intake, fertiliser input, and organic residuals input, then calculated total deficit in N is 142 kg·ha^{-1}·year^{-1} in Jhikhu Khola water shed area in Kavre district. This longitude study reported the nutrient budget input and loss in N, P and Ca fixation to which can be able to compare the study nutrient N fixing data. However, some of the parameters were collected from the secondary data and they published from 1989 to 1994. Giri and Katzensteiner (2013) estimate the N fixing from FYM production, 45.6 kg·ha^{-1}, loss of volatilisation and denitrification, 6.4 to 6.6 kg·ha^{-1}, and manure application, 19.0 to 39.6 kg·ha^{-1}. The study data in Chaubas is relatively less than this FYM production amount whereas data in Dhunkharka is higher than this report (Table 4-6). However, the former research conducted in Solkhmbu district, where mountain climate and the fodder species and the amount collection of FYM may differ. Pilbeam et al. (2000) estimate the average N application from the FYM to the field is between 25 to 100 kg·ha^{-1}, which is consistent to the research data in Chaubas whereas it is less amount than in Dhunkharka. However, the report data referred from the former literature reviews and made the hypothetical household data for N input and output.

9.4 Fodder nutrients

For N and CP concentration, fodder *Brassaiopsis* and *Prunus* was determined to be higher in nutrient content than *Ficus* and *Quercus* fodders. Similarly, *Brassaiopsis* and *Prunus* show outstanding differences in P concentration, which are likely to influence P concentration in manure. Furthermore, *Ficus* and *Prunus* fodders had a higher K concentration. This finding especially in N concentration in fodder correlates with a former study which found a high correlation between dietary concentration of CP in fodder and N concentration in manure (Burgos et al. 2010; Frank, Persson & Gustafsson 2002; Hristov et al. 2004; James et al. 1999; Yan et al. 2006). High P content in fodder increases milk yield of the lactating cow. One study reports that low calcium and phosphorus content in fodder is likely to reduce the absorption of a protein phosphorus complex due to low phosphorus concentration (Osti et al. 2009).

In addition, the digestibility dry matter (DDM) of four types of fodder was derived from secondary data from Upreti and Shrestha (2006) and is shown in Table 9-1. Again, the data of *Quercus lanata* is unavailable, so the data of *Quercus incana* was used. From the secondary data (Upreti & Shrestha 2006), the most digestible fodder species was *Prunus*, followed with *Ficus*, *Brassaiopsis*, then the lowest digestible fodder was *Quercus* fodder.

Table 9-1*: Digestibility dry matter (DDM) of four types of fodder (Source: Upreti (2006))*

Item	*Ficus nemoralis*	*Quercus incana*	*Prunus cerasoides*	*Brassaiopsis hainla*
DDM	61.4	49.5	64.5	56.7

For K concentration, K in fodder and dietary intake correlates to K content in manure (Nennich et al. 2005), however K concentration is mostly extracted in urine (National Research Council 2001). Observing the research NPK nutrient data in fodder and secondary data of fodder digestibility (Upreti & Shrestha 2006), *Prunus* has the highest digestibility which may reflect to the higher N and P in the research data nutrient (Figure 9.1). Conversely, the low nutrient NPK status in *Quercus* fodder corresponds to lower digestibility, supporting findings in a former study (Osti et al. 2009).

9.5 Manure nutrient

9.5.1 Goat manure

This study results show that the nutrient ranking status in fodder do not reflect the similar nutrient ranking for goat manure. Nutrient status in goat manure did not show statistical significant difference after different fodder species were administered as feed. On the other hand, the ordering the highest NPK nutrient in fodder and goat manure fed with three types of fodder differed. For example, the relationship between fodder nutrient and goat manure, although the highest N concentration fodder was *Brassaiopsis*, followed with *Prunus*, the highest N concentration in manure was *Prunus*, followed with *Ficus* and *Brassaiopsis*. For P concentration, although the highest fodder was *Brassaiopsis*, followed with *Prunus,* the highest P concentration in manure was *Ficus*, followed with *Prunus*, and *Brassaiopsis*. Besides, the highest K concentration in fodder was *Ficus*, followed with *Prunus*, whereas the highest K concentration in manure was *Prunus*, followed with *Ficus*, and the least was *Brassaiopsis*.

The correlation between P nutrients in fodder and manure, remembering P content in fodder and digestibility (Osti et al. 2009) in this study determined that it is acceptable that higher digestibility fodder resulted in higher P content.

9.5.2 Cow manure

This study examined effectiveness of *Quercus* and *Ficus* fodders as a feeding diet for cow. There was a higher K manure concentration for *Quercus* fodder, which was similar for buffalo manure than other two types of fodder. The highest K content in manure was found in *Quercus*, followed with *Brassaiopsis* and *Ficus*. *Ficus* fodder, which has a lower P concentration than *Brassaiopsis* fodder, had the highest P concentration in the cow manure. The reason of the result is probably the variation between digestibility and absorption in a cow's gut of each fodder may have caused this difference.

9.5.3 Buffalo manure

This study revealed that *Ficus* fodder had a significant impact on P and K concentration and *Quercus* fodder impacts on K concentration in buffalo manure. Interestingly, even the lower nutrient concentration of *Quercus* fodder contributed to increased K concentration in manure.

The result of high K concentration in manure fed with *Quercus* fodder is difficult to explain in terms of the fodder nutrient. For example, *Quercus* has the lowest DDM (Table 9-1) among the four types of fodder tested, and lowest K concentration that is supportive. However, the K concentration in manure fed with *Quercus* fodder resulted in the highest concentration. One reason this is likely is that the *Quercus* fodder has an ability to raise nutrient absorption in buffalo or enhance the function of the enterobacteria in the buffalo's gut. This is further discussed in the next sections.

9.5.4 Overall manure nutrient related to fodder

Overall, the higher nutrient status in fodder does not correspond to the similar nutrient status to the manure fed each types of fodder. In other words, the nutrient content of NPK in manure varied according to the livestock type. This result contrasted to previous studies where the N, CP, and gross energy (GE) dietary intake significantly corresponded to the N content in manure (Yan et al. 2006). The reason may be derived from the physiological characteristics of ruminant (Esse et al. 2001), digestibility and assimilation ability and the differences of ruminant intestinal microbial metabolism in individual livestock. Besides, the reason may likely to be less proportion of feeding ratio of fodder (23%) comparing to the other feed such as grass (46%) and maize and dried plant leaves (20%).

One key factor is related to the unique tannin content in *Quercus* fodder when combined with fodder and other feed materials. Tannin is one of the plants secondary metabolism (PSM) (Villalba, Provenza & Bryant 2002). Minor nutrient, tannin causes both positive and negative impacts to the ruminant on the nutrient absorption, utilisation of ruminant energy and excrete nutrient. For example of negative impact, tannin inhibits the nutrient utilisation (Robbins, Hegerman & Austin 1991; Robbins et al. 1987). In the study case, the *Quercus* fodder with tannin as toxic component may negatively affect absorption of nutrients into the body, thereby excreting as manure. In other studies with lambs, a tannin-enhanced diet in combination with another high energy feed can stimulate intake and thereby overall nutrient ingestion (Villalba, Provenza & Bryant 2002). Therefore, it is feasible, but not tested, that in the current study tannin may enhance cow and buffaloes' diets to absorb more nutrients as well as increase nutrient contents in manure.

The combination of dietary intake may impact the tannin influence, for example, if the tannin has a higher lignin content in the fodder, the ruminant diet intake will be minimised because of the special function of combination between lignin and tannin (Skarpe 2007). One former study reports that when the feeding rate of Stylo grass (*Stylosanthes guianensis*) mixed with fodder feed was fed to goats the rate of fodder intake was reduced (Pandey et al. 2013). However, this study demonstrated that the increase of the P and K in manure was attributed to *Quercus* fodder.

Feeding varieties of diet materials to herbivores effectively impact on the absorption of biochemical diversity of the body (Tilman 1982). Additionally, mixed feeds are preferred by the herbivore because of the combinations of mixed chemical component that helps to dilute toxicity. If livestock consume the tannin included fodder, *Quercus* with other feed, tannin in *Quercus* detoxifies the toxic components in the feed in the livestock organs (Freeland & Janzen 1974). Therefore, the dietary intake rate of mixed feeds of *Quercus* fodder, grass and other materials presumably impacted in the manure nutrient.

An important point is that the study did not investigate the correlation between total GE and ADF in each feed intake, which could measure and predict the digestibility of fodder and relationship with N concentration in manure. Furthermore, the study may have potential bias from factors related to the fodder sampling season, location, age of the tree varieties and the unmeasured nutrient quality of additional feeding materials, such as maize stem and leaves, fresh grasses, maize wheat powder and manure sample numbers. Therefore, further studies are recommended to gain more data.

9.6 Recommended fodder types

Although, the fodder types fed to goats did not significantly influence the manure nutrient, recommended fodders for cow and buffalo manures were identified. *Quercus* fodder effectively increased the K concentration in cow and buffalo manure and *Ficus* fodder improved P and K concentration in buffalo manure. A further important point is that feeding rate of fodder types and other feeding materials should be well balanced and appropriate due to the side effects on livestock. For example, *Ficus* fodder has relatively higher saponin content which may cause inhibition of microbial fermentation and synthesis in the ruminant (Lu 1987). Alternatively, *Quercus* fodder has a relatively higher tannin content which may induce a low growth rate (Tanner 1990) and decrease the feed intake

(McSweeney 1988) in sheep. It also has been shown to induce the anthelmintic effect, that increases protein supply and reduce health disorders in sheep and goats (Westendarp 2006).

9.7 Equivalent monetary value of NPK in FYM

The equivalent monetary value of NPK in FYM in Chaubas is 4.4 NRs· doko^{-1} and in Dhunkharka is 6.6 NRs· doko^{-1}. These values are less than the trading value of FYM, 45 NRs· doko^{-1} in Chaubas and 35 NRs· doko^{-1} that are shown in detail in Chapter 7. Therefore, there is large potential to improve the nutrient value as well as nutrient quality of FYM. These techniques enhance the nutrient quality and maintain the nutrients in FYM during the decomposition period. During decomposition, FYM normally piled close to the cattle barn without cover, and it exposed to strong sun light, rain, and wind temperature every day of the year. As a result, most of the urine cannot be used for making FYM but leaches into the soil uselessly. Urine is important because 50 to 90% of N originates from in the dietary N intake (Dijkstra et al. 2013). The useful method to store urine N is to use the straw for bedding for livestock which absorbs the N in urine (Rufino et al. 2007). The stall-feeding system in these studied villages has the advantage of storing urine N, because tethered livestock excrete manure in the barn. It also implies that the significance of utilising urine and blending straw with other materials will be able to make a nutritious high value FYM. That FYM made of mixed urine straw and other materials convinces high nutritious monetary value of FYM.

The equivalent monetary value of FYM gained from this research can be utilised for NGOs and *EnLiFT* project to understand the forest-livestock-farming system at target sites. Besides, determining the baseline data of the FYM value, *EnLiFT* project activities can use this information to increase the nutrient cycle within the forest-livestock-farming system. It provides the basis of a discussion to increase the nutrient value by identifying every nutrient value within the system for farmers and other stakeholders, and points out where and how the nutrient status can be improved. Furthermore, those baseline nutrient values are useful to compare to the value after a few years of improvement of practices. After the FYM values shared and understood among stakeholders, the effectiveness and cost of improved practices can be evaluated and amended for the next project stage to enhance their livelihood.

9.8 Overall context forest-farming system

9.8.1 Consideration fodder, manure and FYM

As it is mentioned former section, the feeding result shows that *Ficus* fodder improves the highest P concentration in buffalo manure. *Quercus* fodder helps to develop the K concentration in cow and buffalo manure among three types of fodder (Fig 6-2 and 6-3). Therefore, it is recommended *Ficus* fodder for buffalo and *Quercus* fodder for buffalo and cow, which will increase nutrient status in manure and, subsequently, in FYM, when it is incorporated with other materials. The fodder normally fed in winter when the grasses are unavailable, and is important for livestock health. If nutrient rich fodders were fed, the livestock would be healthy during the dry period. In the mid-hills, *Ficus* fodder inhabits on agroforestry land whereas *Quercus* fodder inhabits in the forest or on communal land. This study recommends that these fodder species become silviculture forest activity as part of future agroforestry and community forestry programs.

Additionally, the high content of P and K in FYM may possibly to enhance the soil nutrient status after FYM applied to the field. Farmers in Dhunkharka therefore can consider that the choice of fodder type may improve their FYM quality as well as strengthen the crop production, thus enriching their food security and saving their livelihood.

9.8.2 Choice of fodder as a feed for livestock

In Dhunkharka village, there are many milking processing factories which everyday produce fresh milk and sell to the nearest market such as Banepa, or Kathmandu. A key area of interest among farmers is the increase the milk yield and fat rate, which directly reflects to the sales price every day. If the study demonstrates that dietary nutrient intake impacts the weight gain and milk yield, farmers would be very interested the result that directly reflect on the daily profit of milk sales. As this research focused on the fodder intake and manure nutrient as well as FYM nutrient, it is necessary to research further these topics. Similar to Dhunkharka, the further study in Chaubas is necessary in order to determine milk yield and gain body weight feeding with fodder species such as *Ficus nemoralis*, *Morus alba*, *Ficus auriculata*, *Ficus semicordata* favoured by farmers. Then, where the research yields positive outcomes, recommendations can promote to farmers for nutrient rich fodder trees. Consequently, the improved productivity of profitable agricultural products, milk and meat will contribute remarkably influence the national GDP (FAO 2010b, 2014b).

9.8.3 Sustainability in forest-farming system

To discuss about sustainability of this forest-farming system in mid-hills, it is necessary to survey nutrient input and output in each component. They are such as use of fodder, manure, each FYM material such as litter and grass, plant residuals, soil, yield, plant residuals, as well as loss by erosion and volatilisation in Kavre district per household and per year. As this research focused only on the nutrient status of fodder, fresh manure, and FYM, it is not sufficient data to determine the entire cycle of nutrient flow from fodder to FYM. If the research is conducted in each component of forest-farming system flows, the result would provide clearer information about the nutrient flow as well as the degree of dependency of farmers on community forestry and agroforestry practices in Kavre district.

In the meantime, the results of this research on the amount of FYM input to the field show consistency with the works in the past. For example, 9.3 tons in Chaubas and 18.5 tons in Dhunkharka are within the suggested range of 3 to 21 $t \cdot ha^{-1} \cdot year^{-1}$ (Heuch 1986) and 15 to 20 $t \cdot ha^{-1}$ (Balogun 1989; Upreti 1989). Masaka et al. (2013) reports that application of manure in low quality (0.5% in N of 15 to 30 $t \cdot ha^{-1}$) to the field increased the tomato and rapeseed yield as well as reduced the N leachate that causes ground water contamination. Considering this article, the FYM in both studied villages may influence the crop yield as well as reduce the risk of drinking water contamination. However, further study needs to be conducted to understand the impact of application of FYM on the crop yield and ground water quality.

Considering the forest-farming system, Balla et al. (2014) reports interesting result to identify the amount of NPK fixation from the fodder and grass for the FYM, which enables to understand the forest to FYM nutrient flow in Kaski and Mustang districts (Table 2-3). The article stated the status of NPK of the composting materials such as leaf litter. According to the study, 50% of the leaf litter is derived from the forests in mid-hills every year (Balla et al. 2014), which is a significant contribution to the forest-farming system.

Similarly, the results on the amount of N fixation to the field from FYM, 29.0 $kg \cdot ha^{-1} \cdot year^{-1}$ in Chaubas is lower and 139.6 $kg \cdot ha^{-1} \cdot year^{-1}$ in Dhunkharka is higher than the recommendable amount of N fertiliser for rice and maize cultivation i.e. 100 and 120 $kgN \cdot ha^{-1}$ (LARC 1997) respectively. Therefore, the soil nutrient balance in Chaubas is likely to be insufficient, whereas the amount of N-level in Dhunkharka is sufficient.

Regarding soil fertility, it is attention to state that intensive cultivation which may be accelerated by the market demand in Dhunkharka should be careful the use of mineral fertiliser. Because the use of increase amount of mineral fertiliser may cause the soil degradation and erosion. For example, Tiwari et al. (2008) express the caution of intensive cultivation, which is induced by use of agrochemicals and hybrid seeds, resulting to decline in the soil fertility. It threatens the sustainability of mountain farming where locates sloppy terraces and high precipitation. In addition, Brown et al. (1999) warn that introduction of triple cropping system including rain-fed maize cultivation resulted deficit of the soil fertility in 95% of the farms which nutrient balances in soil remains in low level in Nepal. Therefore, farmers in Dhunkharka who apply the mineral fertiliser for vegetable cultivation should thoroughly consider the amount and the times of application that may induce to decline the soil fertility.

9.9 Limitations and justification for method

Ideally, the objective of this study could have been accomplished with robust methods. Here are some options to be considered for further study as in follows.

9.9.1 Sample regime of Fresh Manure

The examination of NPK value of fresh manure in the fodder-livestock experiment (Chapter 5) would ideally be conducted over a longer period and with livestock permanently housed in stalls and greater control over the mixture of fodder and other feedstuffs (e.g. green grass and crop residue). The day of feeding experiment was nine days, which is relatively inappropriate to obtain the most accurate nutrient status in the manure. Pitchford (2014) recommends that pre-feeding day for two weeks should include at least one week of before sampling period. In addition, the sample number of feeding fodder type to the livestock experiment was five in each livestock. If the number were more, the more confident data would be acquired, which related to construct the succinct analysis and evaluation of fodder feeding impact for two research sites. Thus, if the field condition, time, and economical opportunity allow, the large sample number of livestock for feeding experiment would conduct in the future.

9.9.2 Field research duration and the time undertaken

The researcher was not in Nepal long enough, or at the right time, to organise and implement such a field trial across a cropping season. Furthermore, there are significant logistic hurdles implementing such a trial on farmers' fields in Nepal, not the least being interference either through mischief or mistake.

This experiment relied on the good nature and flexibility of participating farmers. Taking further control of the experimental situation would impose an unacceptable interruption with daily practice. There are no government research station facilities where this research could be undertaken even if funds were available.

The study conducted in rainy season from July to September, which is not optimal for the fodder feeding experiment. Because the normal fodder feeding season for livestock is in winter or the dry season from November to February. If, the time for feeding experiment were arranged in the dry season, the result of feeding experiment and nutrient status would be more appropriate to fit to the actual farmers' practical field situation.

9.9.3 Future research recommendations for investigating nutrient status of other feed and FYM materials

The nutrient component in the diet intake of livestock only examined fodder, which was approximately one quarter of the proportion of all livestock feed intake. Ideally, other nutrients of feed materials such as the dried plant residual, wheat powder, leaf litter and foliage grass would need to investigate to acquire more accurate data. In addition, each nutrient of material in FYM such as litter, grass should be able to determine. To identify the nutrient status of each intake material of further research will be able to understand the relationship between the nutrient intake and output and loss through forest-farming system.

9.9.4 Feeding experiment in Chaubas

Due to the time limitation for the research student for whole program for two years, the feeding experiment fodder to the livestock conducted in Dhunkharka village, part of two potential research sites. If time allows and had an opportunity, the feeding experiment for four types of fodder tree to the livestock would conduct in Chaubas village. The result of nutrient status of fresh manure fed with the favourite fodder species would provide interesting outcomes, which can compare to the result of experiment in Dhunkharka. Those research results and outcomes would make robust consideration and recommendation of fodder to the farmers and stakeholders of *EnLiFT* project.

9.9.5 Analytical method for SOC

Even though the supportive instruction and information provided to the researcher from the university professors in KU, the analytical method of SOC for the researcher was the first experience, which was quite challenging to the experiment. In addition, for the laboratory technician in KU, the utilising the FYM for determining the SOC with the machine was the first experience. For example, firstly the understanding the process of determining the SOC with the machine was difficult. Secondly, extracting the SOC solution from the FYM sample needed the effort. Thus, it needed quite a lot of time to familiar to the machine and skill to conduct the laboratory test for SOC.

9.9.6 Field trial to justify the FYM treatment

The valuation of the FYM (Chapter 7) would ideally be a replicated field trial where crop yields and soil nutrient status measure under treatments with FYM and commercial fertiliser. For example, each studied village, the field experimental trial cultivating crop with FYM application could result the significant difference comparing to mineral fertiliser application to investigate the crop yield whole the year. The different amount of FYM application would result the different crop yield. Then the crop yield can apply to the market price to comparing to the amount of NPK nutrient in FYM. That difference will be more robust explanation to understand the FYM value.

9.9.7 Soil fertility is determined by more than NPK

The estimation of the monetary value of FYM is limited to the NPK content. FYM has significant amounts of which is very important for soil fertility. In this study, SOC of FYM has been measured which is only less than five percentage of the total organic matter in the soil. When the more soil organic carbon soil includes, the more accelerated the microorganism mobilisation that enhances the soil aeration, decomposition, bio element circulation, and mineralisation. Then, the existence of soil organic carbon in the soil can be fertile. In this study, the contribution of SOC in the FYM to soil fertility is not accounted. Ideally, if there were some methods to determine the monetary value of SOC or soil organic carbon according to the scientific criteria, it would be more appropriate to evaluate the value of FYM. For example, to compare the crop yield applied with FYM in different ratio of organic carbon contents and without soil organic carbon content would gain the clear result of the contribution of soil carbon content in FYM.

9.10 How to improve FYM and research questions

The lower nutrient status except the P concentration in Dhunkharka needs to improve more nutritious FYM. The important action to build nutrient status of FYM is to use nutritious materials to develop the FYM quality. In addition, techniques making nutritious FYM need to apply to protect nutrient loss, such as leachate and volatilisation during decomposition. Furthermore, to upgrade the nutrient decomposition effectively, it is necessary to utilise a fermentation accelerator.

Firstly, utilising nutritious materials is effective to improving nutritious livestock manure, and discussed in ‘Section 9.8. Overall’, this study finds that *Ficus* fodders raise P and K concentrations in buffalo manure and *Quercus* fodder increases K concentration in cow and buffalo manure. In addition, high CP feed materials such as rice bran (13.9%), maize leaves (13.3%), cowpea leaves (12.9%), sweet potato leaves (11.8%) and nutritious grass such as oats, (*Avena sativa L.*), Napier grass (*Pennisetum purpureum*), stylo grass (*Stylosanthes guianensis (Aubl.)*), Guinea grass (*Megathyrsus maximus*), and joint-vetch grass (*Aeschynomene americana L.)* are recommended species for grass fodder for livestock in mid-hills of Nepal (Yadav & Devkota 2005).

Secondary, practical techniques that protect the nutrients loss such as leachate or volatilisation to maintain the appropriate moisture are crucial. For example, covering manure by black plastic sheet, making pit, constructing greenhouses, a compost shed using plastic or galvanised sheet iron are effective techniques to enhance the appropriate decomposition and keep nutrients. Covering FYM from direct sun light, rain run-off, and utilising the cattle urine to incorporate to FYM or direct application to the field will effectively improve the soil physio-chemical fertility in Kavre district (Shrestha 2009).

Thirdly, employment of the fermentation accelerator is also a useful method to enhance the decomposition process. For example, utilising the effective microorganism (EM) is one of the fermentation promoters to speed-up the decomposition. EM is composed of approximately 80 species of microorganisms, such as photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes, and fermenting fungi like Aspergillus and Penicillium (Higa & Parr 1994). The effectiveness of EM utilised with other materials for making FYM improves the photosynthesis, promotes bioactive substances and hormone enzymes, and accelerates the decomposition of lignin (Daly & Stewart 1999).

Similarly, another useful technique is to make 'Bokashi' FYM, meaning 'fermented' in Japanese. The 'Bokashi' organic fertiliser is a type of fermented organic fertiliser blended with rice bran, rice or wheat straw, mountain soil, livestock manure, oil cake, rice husk charcoal, fishmeal and occasionally with indigenous bacteria, which is available in the forest or bamboo thicket. The unique characteristic of 'Bokashi' FYM is to have a rapid fertiliser response (Shimane prefecture 2015), and enhances the rate of organic decomposition and absorption of nutrients by plants (Boechat, Santos & Accioly 2013).

Indirectly, other techniques are to be utilised to improve the soil fertility. For example, intercropping with legume in the conventional crop field helps to fertile the soil in nitrogen. The planting legume coexists with root Rhizobium which fixes the nitrogen from the air to ammonia and stores nitrogen in the root around the legume plant (Shrestha 2008). Inter-copping black gram (*Vigna mungo),* soybean *(Glycine max),* lentil *(Lenus culinaris)*, and cowpe*a (Vigna unguiculata*) with rice or maize system enables to gain extra yield fixed by Rhizobium coexists with those crops and yield those product 1 to 600 $kg \cdot ha^{-1} \cdot y^{-1}$ (Sthapit 1988). In addition, the parallel use of Rhizobium and fertiliser enhances the soil. Therefore, inoculation of Rhizobium with plant seedlings may solve the current problematic soil situation (Roshetko 2015; Shrestha 2008). Thus, the use of legume and fertiliser efficiently develops the low level of soil fertility in mid-hills.

Chapter 10: Conclusions

The highlights of this study are shown in the Table 10-1. The best finding of the study is firstly that the fodder species have different nutrient values. For example, every species of four types of fodder has different nutrient status in terms of NPK. Secondly, this study identified that some of the fodders have a value, which influences cow, and buffalo manure nutrient. For example, *Quercus* fodder significantly impacts on K concentration in the cow and buffalo manure. In addition, *Ficus* fodder significantly impacts on P and K concentration in the buffalo manure. However, high nutrient value fodder does not simply necessarily impact on the manure nutrient. This study demonstrated that even though some of the fodders have with a lower nutrient component, they are easily absorbed by livestock, leaving the manure nutrients showed notable higher concentrations of nutrients in cow and buffalo manure. As mentioned above, these fodders are *Ficus* and *Quercus* fodders. In the mid-hills, *Ficus* fodder inhabits on agroforestry land whereas *Quercus* fodder inhabits in the forest or on communal land, it is recommended to promote *Ficus* and *Quercus* plants to commence the silviculture forest activity as part of future agroforestry and community forestry programs.

Thirdly, P concentration FYM in Dhunkharka village is significantly higher than that in Chaubas village, which derived from the high proportion of livestock manure. In addition, SOC concentration in FYM does not differ in two village sites. A relatively strong correlation was found in goat manure in P concentration with *Prunus* fodder. In addition, a relatively strong correlation was identified in cow manure in N concentration with *Ficus* fodder. Furthermore, a strong correlation was recognised in buffalo manure in K concentration with *Brassaiopsis* fodder and a relatively strong correlation was discovered P concentration in buffalo manure with *Brassaiopsis* fodder.

The situation in Dhunkharka influenced by the high demand of intensive commercial crop production requires nutritious fertiliser. The situation in Chaubas, on the other hand, is subsistence based and farmers should be able to improve crop productivity and food security levels. Even with a lower nutrient concentration of FYM, farmers ought to be able to mix the synthetic fertiliser with FYM to increase soil fertility.

Importantly, the market value of FYM is five to ten times greater than the nutrient monetary value of FYM measured by NPK concentration. In other words, the NPK nutrient content of FYM does not retain the same monetary value in the price which farmers sell the FYM in the market. The low monetary value of FYM implies that more attention needs to be paid to increasing the quality of FYM through improved composting practices in studied villages. In order to enrich those values, the feeding materials of livestock should be chosen to reflect nutritious sources with a high protein, and promising fodder species and grasses that increase the manure nutrient. Accordingly, when incorporating nutrient rich manure and other materials of FYM, effective techniques such as covering plastic, roofing FYM shed, utilising the urine, effective micro-organism, and 'Bokashi' are applied to maintain those nutrients and encourage decomposition and fermentation. There are possibilities to ameliorate the FYM nutrient quality using locally available materials and techniques mentioned in this study in Chapter 9.10.

Additionally, there are inherent limitations of using FYM in every household in mid-hills Nepal. Firstly, most of farmers do not have easy access to the main road, which can have better transportation of materials of FYM. Secondly, they have a limited land holding size that reflects to a limited resource of materials. Thirdly, there is a rule and regulations of community forest management to limit the entering time and utilise the forest that related to limitation of using forest resource for using FYM materials such as litter and fodder. Fourthly, there is a labour limitation in the rural village, which influences the labour shortage of making sufficient amount of FYM for their crop cultivation. Finally, there is a limitation for information and extension for sharing to make efficient nutritious FYM such as pit method and vermi-composting method through the government sector and NGOs.

To maintain the sustainability of farming system in mid-hills, some options are thought. They are, 1) to wisely use community forest as a source of material for

FYM, fuel-wood, medical plants, cash crop, value added crop such as herb and spices, 2) to plant useful fodder tress and fruits trees in their agroforestry field for their livestock and food security, 3) to plant nitrogen fixing plants which fertilise the nutrient in the soil and protect the soil erosion, and 4) to utilise appropriate techniques to enhance the FYM quality and crop productivity with locally available materials. These options ensure to secure their life and raise their economic situation which enhances their food security.

Farmers, policy makers and promoters of organic agriculture should not assume the quality of existing FYM is of an acceptable standard for a productive, sustainable agriculture. There is the potential for farmers in mid-hills to improve soil fertility and crop productivity and positively impact on their livelihood if more attention is paid to the quality of FYM, and by being open to the judicious use of synthetic fertilisers as well.

Table 10-1: Study highlights of findings

Study	Subject	no	Trends
Fodder		1	Nutrient NPK in four types of fodder differ each other.
		2	In N, pairs of *Ficus* and *Prunus, Ficus* and *Brassaiopsis, Quercus* and *Prunus, Quercus* and *Brassaiopsis,* and *Ficus* and *Quercus* are significantly different.
		3	In P, pairs of *Ficus* and *Prunus, Ficus* and *Brassaiopsis, Quercus* and *Prunus, and Quercus* and *Brassaiopsis* are significantly different.
		4	In K, pairs of *Ficus* and *Quercus, Ficus* and *Brassaiopsis, Quercus* and *Prunus, Quercus* and *Brassaiopsis, and Prunus and Brassaiopsis* are significantly different.
Manure		1	Goat manure, the highest nutrient is N, followed by P and K.
		2	Cow manure, *Quercus* fodder significantly impacts on K concentration than fed by *Ficus* fodder.
		3	Cow and buffalo manure, the highest nutrient is P, the second highest nutrient differ to the manure fed fodder types.
		4	Buffalo manure, *Ficus* fodder significantly impacts on P and K concentration in the manure.
		5	Buffalo manure, *Quercus* fodder significantly impacts on the K concentration in the manure.
FYM		1	P concentration in Dhunkharka village is significantly higher than that in Chaubas village, which derived from the high proportion of livestock manure.
		2	Soluble organic carbon concentration is similar status in two villages as no difference found.
		3	In P and K concentration between coarse and fine particles of FYM, there is no significant difference both two villages.
		4	Proportion material of FYM, the green foliage for bedding materials for livestock is the highest in Chaubas village whereas the leaf litter and other dried materials is the highest proportion in Dhunkharka village.
Monetary value of FYM		1	The monetary value of FYM in Dhunkharka, 0.35 NRs·kg^{-1} is 48% higher than in Chaubas, 0.23 NRs·kg^{-1} due to a higher P concentration in Dhunkharka village of FYM.
		2	The NPK content equivalent monetary value of FYM per doko (18.9 kg, dry matter) in Chaubas is 4.4 NRs· $doko^{-1}$ and in Dhunkharka is 6.6 NRs· $doko^{-1}$.
		3	The monetary value of FYM for Dhunkharka is 48% higher than in Chaubas due to a higher P concentration in FYM.
		4	The market trading price value of FYM in Chaubas is ten times and in Dhunkharka is five times higher than the equivalent nutrient monetary value.

Study	Subject	no	Trends
Correlation nutrient fodder and manure	Overall	1	A quite strong correlation was found for K concentration between *Brassaiopsis* fodder and buffalo manure (0.789). Relatively strong correlation was identified for P concentration between *Prunus* fodder and goat manure (0.607). Relatively strong correlations were recognised for N concentration between *Quercus* fodder and buffalo manure (0.585), and N concentration between *Ficus* fodder and cow manure (0.583). Relatively strong correlation was identified for P concentration between *Brassaiopsis* fodder and buffalo manure (0.569). Relatively strong correlation was identified for K concentration between *Quercus* fodder and buffalo manure (0.501). Relatively strong negative correlation was recognised for P concentration between *Quercus* fodder and cow manure (-0.544). Relatively strong negative correlation was found for P concentration between *Brassaiopsis* fodder and cow manure (-0.441).
	N concentration	2	The trend for cow and buffalo manure showed low N concentration for the three types of fodders with similar ranges.
	P concentration	3	The manure produced from three livestock fed with the *Ficus* fodder had wide and similar range of P concentration with narrow and low concentration.
	K concentration	4	K concentration of manure produced from cow and buffalo fed with *Quercus* fodder resulted wider range of concentration with narrow and low range fodder concentration.
	Goat manure	5	A relatively clear correlation was found for P concentration in *Prunus* fodder (R^2=0.3687) and goat manure.
	Cow manure	6	Correlation between fodder nutrient (*Ficus*) and cow manure for *Ficus* fodder N concentration had a positively linear correlation (R^2=0.339).
	Buffalo manure	7	K and P concentrations fed with *Brassaiopsis* fodder in buffalo manure had a positively linear correlations (R^2=0.622 and R^2=0.324) as compared to the two other fodder species.

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Appendix 1: Questionnaire for farmers' interview

2.10 Introduction

This interview is related to the activities the *EnLiFT* project which attempt to establish the nutrient flow model forest/farming system among the whole nutrient system, forest/livestock/farming system in the Mid-Hills of Nepal. The objectives of this interview are to identify the main fodder types for livestock, materials and the volume of the applied farm yard manure (FYM), and the cropping pattern of cultivation. The personal information, only age (e.g. range between 20 to 30 years old) is asked. The data is to be used to improve the *EnLiFT* project activities. The interview approximately takes 1 hour. If you do not want to be interviewed, you can withdraw.

Age range: 10-20, 21-30, 31-40, 41-59, 51-60, 61-70, 71-80, 81-90 Sex: (M.F)

1. Farming and Livestock Sector

Q1: How many areas (ropani) do you have? bari ropani and khet ropani?

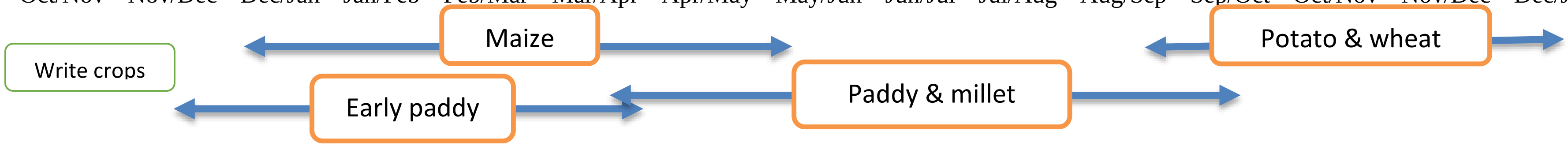
Q2: How many no of cow, BF and goat (no of adult and young) you have? Cow: (M,F),(M,F),(M,F) Buffalo: (M,F,(M,F), (M,F) Goat: (M,F), (M,F), (M,F)

Q3: What kinds of crops do you cultivate?

Q4: What kinds of animal feeding materials (fodder, litter, grass, and crop residuals) do you collect every season?

Cropping pattern reference (Source: Shrestha, 2008)

Autumn			**Winter**			**Spring**			**Summer(monsoon)**						
Asoj	Kartik	Mansir	Pus	Mag	Fagun	Tsaitra	Baisak	Jest	Asad	Sraun	Badu	Asoj	Kartik	Mansir	Pus
Sep/Oct	Oct/Nov	Nov/Dec	Dec/Jan	Jan/Feb	Feb/Mar	Mar/Apr	Apr/May	May/Jun	Jun/Jul	Jul/Aug	Aug/Sep	Sep/Oct	Oct/Nov	Nov/Dec	Dec/Jan



Q5: Tree preference

No	**Name of fodder**	**Ranking every purpose**	**Milk weight (1-5)**	**Gain weight (1-5)**	**Dry dung amount (1-5)**	**Growth rate of leaves (1-5)**	**Propagation (1-5)**	**Availability (1-5)**
1	(CF, Pri)							
2	(CF, Pri)							
3	(CF, Pri)							
4	(CF, Pri)							
5	(CF, Pri)							
No	**Name of fodder**	**Ranking every purpose**	**Milk weight (1-5)**	**Gain weight (1-5)**	**Dry dung amount (1-5)**	**Growth rate of leaves (1-5)**	**Propagation (1-5)**	**Availability (1-5)**

6	(CF, Pri)							
7	(CF, Pri)							
8	(CF, Pri)							

Ranking can be written as F-1: fodder the most preferable, L-1: litter most favoured up to 4th.

Q6: Asking feeding materials types and amount (no of 'doko' (basket)) to livestock in summer

No.	Fodder Name (source	Litter name	Grass name	Crop residual	Other material	No of doko for Cow	No of doko for BF	No of doko for goat
1	(CF, Pri)	(CF, Pri)						
2	(CF, Pri)	(CF, Pri)						
3	(CF, Pri)	(CF, Pri)						
4	(CF, Pri)	(CF, Pri)						

CF: source form Community forest, Pri: private land

2. Compost (applied FYM) Sector

Autumn			Winter			Spring	Spring		Summer (monsoon)						
Asoj	Kartik	Mansir	Pus	Mag	Fagun	Tsaitra	Baisak	Jest	Asad	Sraun	Badu	Asoj	Kartik	Mansir	Pus
Sep/Oct	Oct/Nov	Nov/Dec	Dec/Jan	Jan/Feb	Feb/Mar	Mar/Apr	Apr/May	May/Jun	Jun/Jul	Jul/Aug	Aug/Sep	Sep/Oct	Oct/Nov	Nov/Dec	Dec/Jan

Q7: How many times do you make compost, applied FYM in a season (or in month)?

Q8: How many months do you keep on piling compost, applied FYM? : months.

Q9: If you have piled FYM (compost), when did you start piling? month.

Q10: When do you apply this compost, applied FYM to the field?

Q11: What are materials of compost, applied FYM and what are materials?

Manure; doko, fodder name; doko, Litter; doko, Crop residual; doko, Grass; doko, Other ; doko /1 pile

Q12: What do you think good organic fertiliser of its quality?

Thank you very much.

If there are any complaints, feel free to tell to us or project coordinator or send it by mail to this address.

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