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EVALUATION OF MULTIPURPOSE FODDER TREES IN NEPAL

A thesis submitted in partial fulfilment
of the requirement for the degree of
Doctor of Philosophy (PhD)

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Forestry**



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Abstract

This PhD thesis consists of nine chapters describing aspects of the subsistence farms of western Nepal in general, and a need-based evaluation of multipurpose fodder trees (MFT) as a source of dry-season forage for ruminants in particular, as a basis for mitigating the current high rate of land degradation and loss of productivity in livestock production systems in the region. Understanding the complex farming systems that provide a living for 65% of the 27.1 million people in Nepal is the key to designing effective programmes of research and development. Evaluation methods include review of past work, farmers group workshops to identify current practice in the use of MFT in Nepal, studies on biomass production of *Artocarpus lakoocha* and *Ficus glaberrima* trees older than 50 years in Nepal and the propagation of *F. benjamina*, comparison of the feeding preferences of sheep for alternative browse species, and study of the nutritive value of alternative forage diets for lactating buffalo.

Reviews showed 2.2 million cattle and 1 million buffalo are an extra burden to steep land where productivity is declining at the rate of 1.25% per year. Indigenous knowledge identified *Ficus glaberrima* with its three varieties (Maghe, Chaite and Jethe), *A. lakoocha*, *F. benjamina* and *Bassia butyracea* as the best four MFT for renovating degraded lands. A survey study showed significantly higher dry matter (DM) production by *F. glaberrima* than *A. lakoocha* (154 vs 91 kg DM /tree/year) during dry periods at low altitude (800 - 1000m). There was no significant difference in production of fat - corrected milk (FCM) between buffalos eating *A. lakoocha*, *F. glaberrima* or a diet of 53% straw and 47% *F. glaberrima* (DM basis). Metabolisable energy balance (MJ ME/day) was greater in *Artocarpus* than *Ficus*, with the mixed diet intermediate (+1.60, -0.34 and -12.94 MJ ME/buffalo/day respectively, relative to requirements, P=0.0318). When fed together in an indoor trial, poplar (48% = 106 g DM/sheep/day) and willow (43% = 95 g DM/sheep/day) were preferred to *Ficus benjamina* (8% = 18 g DM/sheep/day) by sheep, reflecting the greater maturity and structural strength of leaves of *Ficus*.

These results are used to develop recommendations for choice of MFT species and management strategies to improve the sustainability and productivity of livestock systems incorporating fodder trees.

Keywords: *Artocarpus lakoocha*, *Ficus glaberrima*, *Ficus benjamina*, rice straw, buffalo, sheep, metabolisable energy, multipurpose fodder trees.

Dedication

This PhD thesis is dedicated to Professor John Hodgson,
for his unconditional love and effort to develop pasture
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Abbreviations and Glossary

ADP	Asian Development Bank
AGDP	Agricultural Gross Domestic products
CBS	Central Bureau of Statistics
DFAMS	Department of Food and Agricultural Marketing Services
DLS	Department of Livestock Services
DOF	Department of Forest
DSWC	Department of Soil Water Conservation
FAO	Food and Agriculture Organization of United Nations
FRSC	Forest Research and Survey Centre
HLFFDP	Hills Leasehold Forestry and Forage Development Project
IAAS	Institute of Agriculture and Animal Science
ICIMOD	International Centre for Integrated Mountain Development
IFAD	International Fund for Agriculture Development
INGO	International Non Government Organization
MOAC	Ministry of Agriculture and Cooperative
NARC	Nepal Agriculture Research Council
NBPDP	Northern Belt Pasture Development Program
NEP/85/007	FAO, High Altitude Pasture Development Project
NFGRC	National Forage and Grassland Research Centre
ODA	Overseas Development Administration of British Government
PAC	Pakhribas Agricultural Centre
PTSMF	Pasture Trial and Seed Multiplication Farm
RAS/79/12	FAO, Himalayan Pasture and Fodder Research Network
UNDP	United Nations Development Program
USAID	United States Agency for International Development

CHAPTER 1

General Introduction

The farming ecosystems of Nepal constitute 35% mountains (altitude range 3000 to 8848 m), 42% hills (600 to 3000m) and 32% plains (60 to 600m) (CBS, 2002; MOAC, 2006), and are subject to a strong monsoonal influence with a nine - month dry season from late September to early June (Gurung, 2005). These conditions result in high rates of erosion (Dhakal, *et al.*, 2001; Jha, 2002; Wickramagamage, 1990). Land productivity is reported to be declining at 1.25% per year (RCUP, 1979), and vegetation diversity is predicted to decline by 43% by the end of 21st century (Sodhi, *et al.*, 2004).

The expansion of crop farming onto marginal and sloping land (Mehta, *et al.*, 2003; Rajbhandary & Shah, 1981) has resulted in widespread land degradation (Wu, *et al.*, 2001), declining soil fertility and increasing erosion (Kironchi & Mbuvi, 1996; Srivastva, *et al.*, 2003) which together threaten the sustainability of small farming systems (Sodhi *et al.*, 2004). In livestock areas, stocking rates may be 3-13 times greater than carrying capacity (Kshatri, 2000; Rajbhandary & Shah, 1981). Agroforestry, involving the integration of multipurpose fodder trees into crop and livestock systems, has the potential to mitigate these problems by improving soil fertility, limiting erosion (Neupane & Thapa, 2001), providing dry-season fodder supplements, and meeting small-wood requirements for construction and fuel (Kshatri, 2001; Kshatri, 2003).

Multi-purpose fodder trees (MFT) are widely used for livestock feeding in Nepal (Subba, 2001) and elsewhere (Delate, *et al.*, 2005; Pande, 1997; Topps, 1992), but there is limited information on their productivity and on their nutritive value for ruminant animals (Kshatri & Gurung, 1999). Also, although buffalo (*Bubalus bubalis*) are economically important animals in Nepal (Shrestha, 2003), being responsible for 70% and 65% of total milk and meat production, respectively (MOAC, 2006), information on the value of browse species in systems of buffalo production is limited (Kshatri, 2003).

A comprehensive study of the factors influencing the productivity of MFT in Nepal is beyond the scope of this thesis. Rather, the approach used is to bring together new information on:

- a) Current use and management of alternative species of fodder tree from a farmers workshop study in Nepal (Chapter 3),
- b) Fodder tree establishment and biomass production potential from a series of field studies on *Ficus* species in Nepal and New Zealand (Chapters 4, 7 and 8), and
- c) Nutritive value for lactating buffalo in Nepal (Chapter 6) and feeding preference for sheep in New Zealand of alternative fodder tree species (Chapters 5).

This information is then integrated into a set of recommendations for improving the sustainability and productivity of MFT systems (Chapter 9).

CHAPTER 2

Literature Review

2.1 Introduction

The objective in this review is to explore worldwide available data on the use of multipurpose evergreen tree fodder relevant to the mountain ecosystem of Nepal so that proposals can be developed for further research. It will critically analyse the existing knowledge on what has been done so far to feed the animals during dry seasons, how it was done and what can be done in solving the animal feed deficit problems faced by millions of remote small holder livestock owners.

The review is mainly focused on the selection of multipurpose tree varieties, farmer friendly methods of propagation, nutrition and biomass production of *Ficus benjamina* and *Ficus glaberrima* so as to renovate mountain ecosystem and raise *in situ* biomass productivity which is highly essential in the areas of poor transportation.

Geographically, Nepal is a land-locked Himalayan country located on the highest point on earth. Its northern border is with Tibet, part of China and its southern border is with Bihar, part of India. Thus Nepal lies between latitude 26° 22' N to 30° 27' N and longitude 80° 4' to 88° 12' E. Total area of Nepal is 147181 sq km with average length of 885 km east to west on the Himalayan range. The shape of Nepal is non-uniformly rectangular and has a mean width of 193 km, from north to south. Elevation rises from 60m in the river basin of the flat land areas of eastern Tarai, Nepal to 8848 *masl* at Mt Everest. Using 500m elevation as one eco-zone, Nepal can be divided into 17 altitude zones with four aspects north, south, east and west. Based on altitude, Nepal can be divided into 88 vertical eco-zones with four main aspects facing towards sun and away from sun, facing towards snow-capped mountains and away from snow. In effect Nepal has exceptionally diversified life-zones, which demands altitude-based research and development. A case study expressed similar views (Dhakal, *et al.*, 2001). Therefore, mountain ecosystems are characterised by

highly undulating terrains with densely inhabited valley zones. The habitats are greatly inaccessible as they are located beyond the reach of modern transport. They are further isolated from rest of the world by fast-flowing mountain rivers waiting for centuries to have a bridge constructed.

About a quarter of a million people particularly from urban areas and the Himalayan tourist route in Nepal have access to nearly all facilities of the modern age indicating better standards of living. Meanwhile, 90% of the population lives a life much similar to that of the 14th century, lacking anything of a modern nature. They need to walk up to 15 days up and down just to buy salt and sugar which they carry on their back to their habitat. In totality, this mountain habitat demonstrates a historical place where all stages of development from the primitive to the modern age can be seen. Life in general, away from urban areas and the tourist trek route, is barely sustainable.

The economy of Nepal is based on agriculture from which 81% of the population makes their living. From the year 1991, Nepal started importing about 1.8 million tons of cereal grain each year (CBS, 2001). This is an indication that grain produced within the country is not enough for the entire population. Current to 2003, per capita gross domestic product (GDP) is US\$238. Thus, the problem of developing this country is malnutrition due to severe lack of balanced diet as opposed to obesity due to over eating in the western world.

Despite its extraordinary diversity, Nepali ecosystem of the mountains is a home for a human population of 23.2 million (CBS, 2002), their animals and natural faunas. Ultimately, the existing population is more than the resources can feed; the human population is increasing trends whereas natural resources are declining. Density of human population is 157, cows 50, Yak 0.39, buffaloes 21.17, goat 37.47, sheep 4.09, and pigs 3.37 head per km² respectively (CBS, 2002). A rough calculation indicates that aggregated population density will be over 423 heads per km² including poultry birds, horses and elephants competing for the same resources. Similarly, Rajbhandary & Shah, (1981) reported that livestock wealth represents Nepal as having the world's highest livestock population per unit area. Likewise, stocking rate is calculated to be 9

times and 13 times higher in forests and open grazing lands in the mid-hills respectively (Rajbhandary and Shree Govind, 1981).

Table 2.1 Density of livestock population (animal km²) (calculated from MOAC, 1998/99 data).

Animal Species	On the basis of total area of Nepal 147181 km ²	On the basis of agriculture and pasture land area 59932 km ²	On the basis of agriculture land area 39459 km ²	On the basis of pasture land 17529 km ²
Cattle	47.71	117.18	177.98	400.65
Buffalo	23.95	58.83	89.35	201.14
Sheep	5.78	14.21	21.58	48.60
Goat	42.97	105.53	160.29	360.83
Pig	5.96	14.64	22.24	50.07
Fowl	126.5	310.67	426.25	1062.21
Duck	2.88	7.09	10.77	24.25

Note: For the year 2002 human population density was 157 per km². Population growth rate was 2.4 percent.

One of the current studies indicates that “while technological improvements and increase in crop prices increased cropped area, reduced population had the opposite effect. Reduced population growth rate, and increased price for major agricultural crops led to overall reduction in forest degradation. The study, therefore, concludes that family planning policies aimed at reduction of population growth rate and increase in process of major agricultural crops can be an effective policy for slowing down the process of forest degradation or even for reversing it completely to regeneration” (Sankhayan, *et al.*, 2003).

Quantity and quality of ruminants feed availability depends upon the seasons, elevations, aspects of mountains, *in situ* degree of slopes and accessibility to agrosilvopastoral systems. Table 2.2 indicates carrying capacity of various lands. For example Alpine meadow has the highest carrying capacity of 1.77 LSU, which is available only to high altitude ruminants for example Yak mountain goats and sheep. For other animals, the 30 year trends presented in

Figure 2.1 indicate feed availability is about the half of their requirements, and declining.

Table 2.2 Dry matter (DM) production potential of various feed resource components based on six categories of mountain ecosystem in Nepal (Rajbhandari *et al.*, 1981).

S.N.	Land types available with small farmers	DM/ha (MT)	TDN/ha (MT)	Carrying capacity
1	CROP LAND AREA	2.55	0.88	0.81
	Crop residues/ by products	1.86	0.53	0.49
	Grass and weeds from crop land	0.36	0.2	0.18
	Leaf fodder	0.16	0.09	0.08
	Grazing after harvest	0.17	0.06	0.06
2	ALPINE MEADOW			
	Existing grazing system	3.2	1.54	1.42
	Rotational grazing	4	1.92	1.77
3	STEPPE GRAZING			
	Existing ground coverage	0.12	0.06	0.06
	Deferred rotational grazing	0.15	0.07	0.06
	Re-vegetation up to 25 - 30%	0.18	0.09	0.08
	Re-vegetation up to 50%	0.05	0.24	0.22
4	OPEN GRAZING IN MIDHILLS			
	Existing system	1.2	0.58	0.54
	Rotational grazing	2	0.96	0.89
	Exclosure and hand cuttings	3	1.44	1.33
	Partial reseeding management	4	1.92	1.77
	Complete reseeding management	5	2.48	2.22
5	FOREST GRAZING	0.7	0.34	0.31
6	WASTE LAND GRAZING	0.5	0.24	0.22

Evergreen trees are a major feed source for animals in Nepal. However, lack of feed is the major factor limiting the animal productivity for dry periods of nine months from October to June. Therefore, this review is designed to explore possibilities of growing evergreen fodder trees good for lopping as and when required during the lean period.

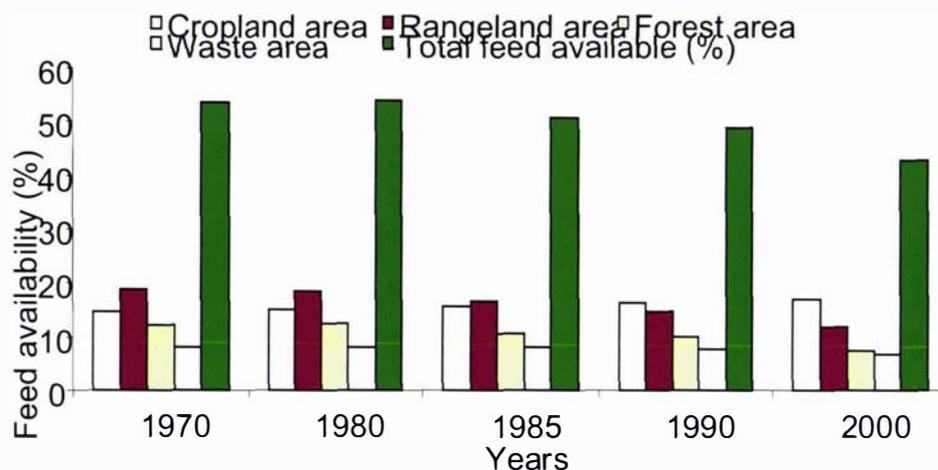


Figure 2.1 Percentage of ruminants feed availability to requirements in Nepal Figure (Modified from Rajbhandary et al., 1981).

Average households own about 8-10 trees, mostly fodder (Pokharel, and Ridish, 2002). The yield of fodder from a single tree averages 35 to 40 kg annually (Kollmair, 2004). However, Kollmair (2004) did not specify the species. Some species, for example *F. glaberrima*, are recorded to have produced 169 kg. In Nepal, tree fodder supplies 20 to 40 % of total feed during the dry winter season. However, browse production is severely limited due to combinations of factors including chilling Himalayan range, the long dry period and lack of soil moisture. Eighty five per cent of 147,181 km² total area of Nepal have high degree slope land, and fodder trees are usually planted in 30° to 70° slopes. The land which is not normally good for cultivation and cereal crops production is being used for planting multipurpose trees. Many trees grow naturally on the farms when protected from grazing animals. Seedlings of few other species are collected from nearby forest, planted on the protected slope areas of a farm and not harvested until they produce leaves. Over 250 different tree species are being used as fodder (Subba, 2001a).

The role of politicians and planners is to provide the sociological and financial structures within which adjustment of traditional management practice is

possible and also to ensure that 'it is necessary for the researcher to select carefully the objective of their investigations and to be prepared to vary management stresses in order to properly define the productivity characteristics of plant communities (Hodgson, 1993). However, with the lack of leadership and lack of pasture and fodder specialists in Nepal, our plant communities have not yet been defined properly. Therefore, in relation to existing pasture and fodder resources, we are still not aware of what potentiality and prospects exist in the mountainous ecosystem of our country. This study will explore some of the potential areas, which are not yet explored.

2.2 Global scenario of tree fodders

Use of tree fodder and browse plants by browsing animals is global in nature. However, data on quantity, quality and types of browse being used is limited. The importance of browse plants as a source of dry season nutrition is increasing. Research conducted in India indicates that fodder trees constitute a major proportion of livestock feeding in the middle Himalayan hills, to the extent of 10–15 percent green forage during monsoon; 80 percent during winter and 60 percent in summer, to the rations of ruminants in the Himalayan hills (Misri, 1998). Trees growing in the open forest and road sides are regularly lopped by the grazers. Sometimes, illicit lopping is done in the reserved forest as well (Misri, 1998). A similar situation exists in Nepal. Different species and methods of using fodder trees are practiced in different parts of the world. In Nepal for example, lopping is done by climbing the tree and branches are carried to stall fed animals. In New Zealand, poplar and willow planted for soil conservation and shelter are also potential sources of supplementary forage (Kemp, *et al.*, 2001). Planting poplars is an effective technology for controlling hill soil erosion in New Zealand pasture (Guevara-Escobar, *et al.*, 2002) However, in New Zealand, browse plants, mainly poplar and willow, are maintained in pasture to a height convenient for browsing animals.

In New Zealand poplar and willow are potential source of supplementary forage during summer, In Africa *Acacia albida* and in South Africa *Prosopis* and *Gleditsia* are used (Graham, 1998). A total of 250 different tree and browse species generally used to feed ruminants were collected from the eastern hill farms of Nepal at altitudes ranging from 1100 to 2200m masl (Subba, 2001)

This indicates that there are far more species of fodder trees above and below these altitudes in central, western, mid-western and far-western region of Nepal.

2.3 Role of browse plants in Nepal

The primary role being played by a fodder tree is to produce green and fresh foliage during the period of the dry season when there is no other alternative green feed available. By planting tree fodder, several other benefits are created which can last for many years; soil conservation, framework effect, fence material production or kitchen garden, fuel wood, windbreaks, fibre production from the bark of *Ficus glaberrima*, roadside plantation, biodiversity conservation, environmental conservation, shade, amenity and religious value and positive impact on carbon sequestration. *F. benjamina* and *F. glaberrima* are expected to produce all the above effects. *Artocarpus lakoocha* is known for its potentiality of higher milk production in buffaloes among hill farmers. However, evaluation of all those effects is beyond the scope of this PhD research.

More than 50% of the fodder for ruminant animals comes from forest resources (Kadariya, 1992). Fodder trees hold the key to one of the large constraints for improvement of the livelihood of smallholders in Nepal, and the opportunity for removing this constraint is currently not being utilised (Dhakal *et al.*, 2001). Fodder trees are lifelines for ruminants particularly during dry seasons in the hill farming system of Nepal, and are cheap sources of protein and energy. A total of 250 different trees and browse species were collected from eastern hills and analysed for the tannin content (Subba, 2002; Upreti, 2002). Above 5% tannin was found in 16% browse plants. Based on altitude and seasons the tree fodder supplies about 20 to 50% of ruminants feed, of which *F. glaberrima* is a major contributor.

2.4 Ancient history of silviculture

“Religiosa” is the species name given to one of 2000 different fig species of genus *F. religiosa* and *F. benghalensis* is the most sacred tree in Hinduism.

“Rig Vedas” the prime Hindu religious book written somewhere 10,000 to 300 B.C (Sidhartha, 2004) described how the mother goddess “Parvati” played with

Vishnu under a *Ficus religiosa* tree, while other gods spied on them. According to myths, Parvati was so angry she decided to launch a curse; thus Brahma becomes a tree in Sanskrit called Palasa, (*Butea monosperma* = *IB.froncosa*), Shiva (Rudra) the *Ficus indica* (Cactus) and Vishnu the *Ficus religiosa*. Similarly, another myth says roots of Peepal tree were believed to represent Brahma, its bark Vishnu, its branches Shiva. The three gods forming the Hindu Trinity are 1) Brahma creates the world, 2) Vishnu sustains it and 3) Shiva destroys it. Photographs and details about Hinduism and their life system can be found in (<http://www.webindia123.com/religion/hinduism/gods/trinity.htm>) Trinity using deer and tiger hide for wearing, bedding and making double headed drum ("Damma-Roo" in Nepali and Hindi language).

Accordingly, in 566 B.C Gautama Buddha was born, and the Bo tree (*F. religiosa*) under which he would attain enlightenment (Lewin & Myo Chit, 2004). It indicates that shelter importance of *Ficus* trees was recognised thousands of years ago. Regarding the care and management of trees, the watering of the Bo tree is the part of Buddhist culture in Myanmar and occurs during the hottest part of the year (Lewin & Myo Chit, 2004). Also, "the traditional tale in India is that if *Ficus benghalensis* is cut down thousands of snakes will leave and will kill everyone". This could be one of the religious strategies to protect the Banayan trees from roadside resting places. In relation to *F. benjamina* nothing was found mentioned while reviewing.

Likewise, some 246 years ago in the year 1758, Nepali poet Bhanu Bhakta Acharya (Acharya, 1758) wrote about selling of grass by a grass-vender in Tanhu district western Nepal. This indicates that some farmers have had shortage of ruminant feed at least 246 years ago.

2.5 Modern history of silviculture development in Nepal

Regarding introduction of high yielding pasture and fodder seed into Nepal, records from Ministry of Agriculture (Unpublished) indicate that Prime Minister Jang Bahadur Rana visited United Kingdom in the year 1860 and introduced white clover in the Kathmandu valley for the first time from England. Likewise in the year 1925 (2001 BS) Chitlang sheep farm in Makawanpur district was established, and in 1953 "Small Animal and Dairy Development Section" at

Singha Durbar Kathmandu and Cheese factory in Langtang, Rasuwa were also established. The New Zealand government supported the establishment of the first dairy plant at Kathmandu in 1959. The first ever agronomist of Nepal, Mr Netra Bahadur Basnyat (Pande, 1997) completed his degree of Master of Agricultural Science in February, 1957 from Massey Agricultural College, University of New Zealand (Basnyat, 1957).

2.6 Ecosystem where invasive trees find it hard to grow

In a micro-climatic condition of soil, where invasive figs fail to grow then it will be hard for any other plant to grow without altering the environmental conditions. Only the planting of multipurpose trees is expected to alter the environmental conditions.

Anecdotal evidence shows annual decline of about 1.25 % in carrying capacity of forest land in Nepal (Resources Conservation and Utilisation Project 1979). The carrying capacity of the forest land is 0.31 Livestock Unit per ha and the current stocking rate is 9 times more than the carrying capacity (Rajbhandary & Shree Govind, 1981). With the above declining trend in 80 years from 1979, the highland forest of Nepal will be completely exhausted and will turn into barren highland desert where hardly anything grows. Mountain ecosystems need a type of plant relatively capable of resisting drought and seasonal adversities. Looking at the invasive characters, root system and evergreen nature, *Ficus* species mainly *benjamina* and *glaberrima* could be the best species which can grow under harsh environments, until better alternatives are found. Those species are expected to raise mountain carrying capacity and maintain harmony with inhabitants. Invasive plants are plant species that exhibit a tendency to spread out of control in the landscape. Although not synonymous with "exotic plants" ("alien plants"), invasive plants are often plants that have been introduced from other regions. Once introduced, such plants spread quickly, because the insects which attack them in their native lands are absent in their new homes.

In this context both *F. glaberrima* and *F. benjamina* are in the invasive category, but both are expected to be a boon for renovation of degraded mountain.

2.7 Dynamic niche of livestock production

Niche is defined as the role of an organism within its natural environment that determines its relations with other organisms and ensures its survival, (Encarta dictionary).

In the mountain farming systems of Nepal several noticeable changes are taking place which have no records (Personal observation). Regarding the livestock keeping system, free grazing has completely changed to semi-intensive and stall-feeding conditions; cattle-keeping is changing to buffalo keeping. Similarly large herds were reduced to smaller size. Semi-temperate rangelands are being converted to alder based cardamom plantations. In response to the changing environment, the transhumance system of keeping sheep is in the verge of extinction (Kshatri, 1993).

Sustainable change could be a modified agro-silvo-pastoral system based on the number of animals which resources can sustain. The biomass production system involving evergreen figs i.e. *F. benjamina* and *F. glaberrima* as multipurpose trees ensures dry season nutrition should help renovation of mountain ecosystem with multipurpose fig trees focusing soil conservation and edible biomass production to provide hungry animals with fresh and evergreen fodder throughout the year. Therefore, there is need to create a database for future decisions on propagation, nutrition and biomass production of *F. benjamina* and *F. glaberrima*.

The approach used here is to bring together new information on:

- a) Current use and management of alternative MFT in Nepal
- b) MFT establishment and biomass production potential mainly on farmed land and glass house conditions.
- c) Generate knowledge on nutritive value of MFT using lactating buffaloes and sheep (large and small ruminants).

Integrated information generated will provide a set of recommendations for improving the sustainability and productivity of MFT systems.

2.8 Need for professional development in the field of tree fodders

There is no particular tree fodder specialist with Department of Livestock Services in Nepal. The Nepal Animal Science Association (NASA) is a common forum for all animal scientists from Nepal, with some expatriates. Currently it has 250 plus members including retired government officers and research scientists from the Institute of Agriculture and Animal Science (IAAS) Tribhuvan University.

The need for professional development of animal scientists was realised and NASA was established in the year 1983 in the history of organised professionalism in Nepal. Its role is to develop the capacity of the livestock industry so as to alleviate rural poverty.

The author is a life member and was, as well, an executive member of NASA for two years until August 16, 2003 and thus has had an opportunity to learn more about the livestock system in the hills of Nepal. The first NASA convention was held in Khumaltar, Nepal on 14 – 15 January 1991 and 5th convention was held on 16-17 October 2003. Likewise, the Third Livestock Development Project (TLDP), Department of Livestock Services, Ministry of Agriculture and Cooperative, Nepal held its first workshop on “Fodder and Forage Development” on November 16 – 17, 1999 and 4th Workshop on 15 to 16 January 2003, in the Vijaya Development Resource Centre, (VDRC) Gaidakot, Chitwan, Nepal. The Author has had the opportunity to read all proceedings and attend five of the nine workshops. Review found that no research was done focusing on *Ficus* as a multipurpose fodder tree for renovation of Mountain ecosystems.

2.9 Review of past work

A. lakoocha and *F. glaberrima* planted on farms for forage production, soil conservation and shelter are also potential sources for firewood, sawn wood (Joshee, *et al.*, 2002), fence material (Kshatri, 2001) and framework trees (Elliott *et al.*, 2002).

Fodder tree cultivation is a well-adopted and sustainable way to use resources. Like all other agroforestry land use systems the cultivation of fodder trees is very complex and needs a vast body of knowledge to be managed successfully (Kollmair, 2004). Also, Kollmair (2004) said that, there is no "best tree"! Only the combination of several species could cover the needs of a farm and that farmers do not plant trees on private land for "ecological" reasons - they do it for survival"

In the year 1985, the Nepal Agricultural Council (NARC) was established to investigate efficient methods and materials for higher productivity of livestock and crops. For western Nepal, Lumle Agricultural Research Centre (LARC, 1968) and for east Pakhribas Agriculture Centre (PAC, 1969) were established by Overseas Development Administration (ODA) of the British government. In the year 1985, both of them merged into NARC and were given overall responsibility of research and development in Nepal.

In general, fodder production is not a common practice in Nepal. Ruminant feed therefore varies greatly with the seasons. During wet months of June to August plenty of green grass is available. For the rest of the year, the only green foliage available is either from forest tree leaf or from tree fodder grown in the edge of the farmer's field. Recently, a few farmers have started growing oats.

In search of eco-friendly and sustainable sources of forage appropriate for smallholder farming systems throughout the year, until January 2004, over a hundred species and varieties of pasture and fodder seeds were imported and tested in various parts of Nepal. Among them, white clover, perennial ryegrass and cocksfoot are moderately successful in semi-temperate regions and on government farms. In addition to evergreen tree fodder available in their fields, less than one percent of farmers from peri-urban areas started themselves growing oats as supplementary feeding during dry seasons. Thus the major problem of finding sustainable sources of dry season feed remains unresolved.

Experiences so far suggest that growing the local evergreen tree fodder could be the best alternative to local fodder deficit problems. Among the several

evergreen trees, two multipurpose fodder trees (*F. benjamina* and *F. glaberrima*) are well adapted to mountain ecosystem and have been used by farmers from time immemorial. Both are xerophytes, epiphytes and strangling figs (Kew, 2003) which are comparatively resistant to prolonged periods of drought. For these reasons, they have been selected for further evaluation.

2.10 Reasoning for the selection of fodder tree species

Four reasons given for selection of *F. glaberrima* are; (1) its abundance in the hill farms, (2) highest biomass production among fodder trees (3) relatively unaided spreading of species and 4) resistant to continuous lopping for five or ten decades. The reason for selecting *A. lakoocha* was its quality to increase milk yield when fed to lactating buffaloes (Personal communication with workshop farmers on 12 March 2005). Planting a tree has a life long beneficial effect in the household economy of farmers. Thus, it is better to make an informed decision and plant the right species than to regret later. The meagre information available on tree fodder is not adequate to make an informed decision and farmers are planting different types of fodder trees in their farmed land (Kshatri, 2003) without knowing their quality. In contrast, *A. lakoocha* a deciduous tree is used to provide dry season fodder. This chapter explains the physical indicators such as tree trunk diameter at breast height (DBH), canopy diameter, tree height and edible biomass production per tree. In addition, there is a brief qualitative explanation on the effects of canopy on understorey forage production, which helps value judgement between *A. lakoocha* and *F. glaberrima* in the hill farming ecosystem of Nepal and decide suitable species to plant in their farms.

2.11 Ficus species

2.11.1 Distribution of *Ficus* species

Evidence from diverse sources clearly shows that most ecosystems are becoming easier to invade. One important reason for this is that potential partnerships required establishing pollination, seed dispersal, mycorrhizal and plant-bacteria mutualisms have been spread around the world by humans. Together with other changes such as altered disturbances and nutrient regimes, these are facilitating alien plant invasions worldwide (Richardson, *et al.*, 1999).

The seed of *Ficus* is most readily dispersed, because small figs can be swallowed whole by the large number of birds including migratory birds moving between continents in response to changing climate. The varieties seem to have no ecological preferences and the greater facility for dispersal seems the only explanation for the wide range of *var. microcarpa* (Corner, 1978). He further states that it not yet possible to assign geographical limits.

In New Zealand (which has no native figs), *F. macrophylla* and *F. rubiginosa* were cultivated for many years without setting seed. Both species acquired their pollinating wasps recently, apparently by long-distance dispersal by wind from their natural range in eastern Australia (Gardner & Early, 1996) Where two species are mutually dependent, the elimination of one will result in the demise of the other. In this sense they act as keystone species for each other (Payton, *et al.*, 2002).

2.11.2 Agronomy of *F. benjamina* and *F. glaberrima*

Regardless of abundance of *F. glaberrima* at household level in western Pokhara Nepal (Plates 2.1 and 2.2, their silvicultural practices have never been documented.

Therefore, information on how it grows, how much it produces, and the way it is being produced has to be documented. Within limits of this PhD time and resources, delineation with respect to its propagation, nutrition and biomass production is an important part of this research.

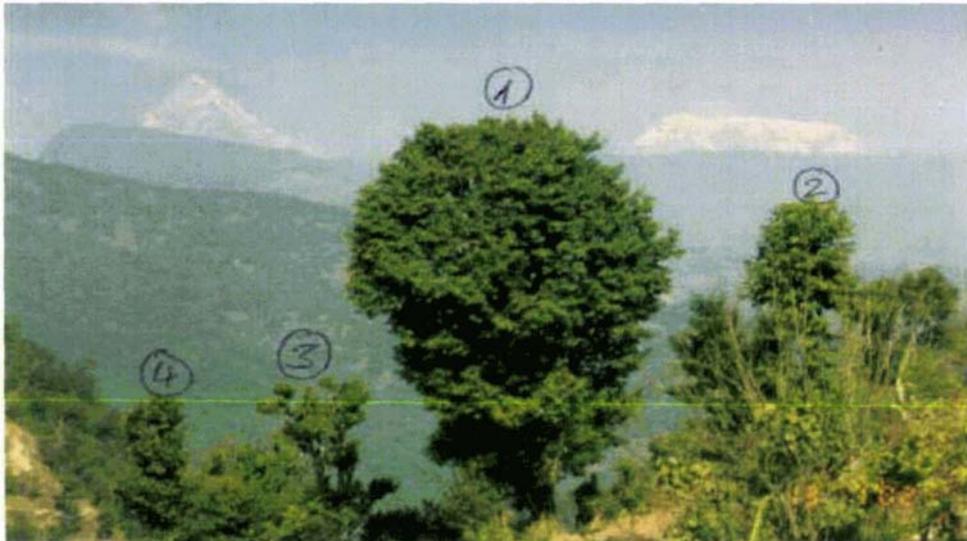


Plate 2.1 Four *Ficus glaberrima* trees heights 10m to 18m above ground Kalika-6 Sunpadalim, Kaski, Pokhara, Nepal. (Photograph by Kshatri, 2002).

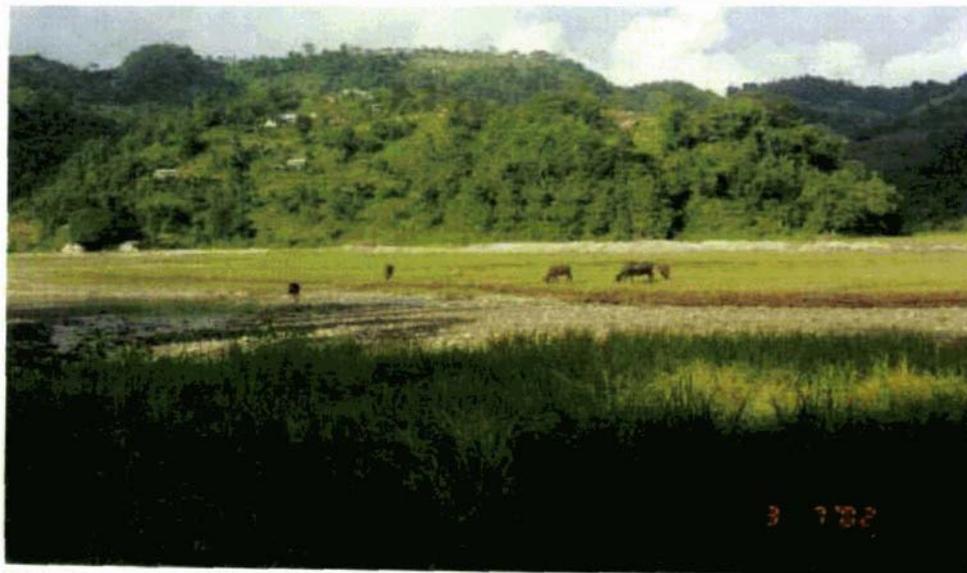


Plate 2.2 Summer greenery in farming system of Kalika-6 Sunpadali, Kaski, Pokhara, Nepal. (Photograph by Kshatri, 2002).

In many forests the fig tree is considered a keystone species since during parts of the year it is virtually the only tree producing fruit. During these lean times, many primates and birds feed almost exclusively on fig fruit (Butler, 2004). Additionally, in the hill farming system of Nepal, the fig is being considered as treasure of fodder for ruminants, which remain green throughout the year.

From the botanical viewpoint, fig trees have several beneficial inherent attributes making them the fittest of all trees existing on the deteriorating

mountain ecosystem. These attributes will provide renovative advantage under zero-grazing management arising due to loss of the traditional free grazing system. The following four main characters are responsible for making the *F. glaberrima* fit for this stressful environment:

(1) Figs as a xerophyte: A plant capable of surviving prolonged period of moisture deficiency (<http://www.afae.org>). On the other hand, it has been reported as not resistant to drought (Kayastha & Amatya, 2002)

(2) Figs as an epiphyte: There are advantages of starting from the top: glorious sunshine and by-passing dangers on the ground: flood, fire, browsing vegetarians, falling trees and branches. The epiphyte also does not have to invest in a heavy trunk before it gets to sunlight, and instead of climbing up against gravity, it simply lets its roots down. Like other epiphytes, it is not a parasite and does not take nutrients from its host. But it eventually kills its host by slow strangulation. (<http://www.szgdocent.org/fff-stfig.htm>, 2000). Royal Botanical Garden Kew report indicates that “epiphytes are not rooted in the soil nor are they parasitic” and also that the areas richest in epiphytes are the mountain rainforests at altitude around 1500 m, (Kew, 2003).

(3) Figs as a hemi-epiphyte: Perhaps the most famous hemiepiphyte is the towering strangler fig which starts life as a tiny seed in the canopy (Butler, 2004). Hemiepiphytes represent a transition between terrestrial and epiphytic growth forms; they retain hydraulic connections with the soil while using other trees as support structures.

“Hemi-epiphytes are defined by canopy to floor growth” (Fatland, 1996). After the seeds are deposited by birds or flying foxes in the forest canopy (fork and holes) and germination occurs, the figs send roots down to the forest floor and anchor in the soils. After contact with the new sources of nutrients, the growth rate increases quickly. The host tree becomes surrounded by fig roots which eventually block a majority of the light reaching the host’s crown.

(4) Figs as a strangler: Corner, (1978), said that strangling fig *F. glaberrima* is puzzling both in systematic position and geographical distribution. The host is

“strangled”, dies and decomposes, leaving the fig standing freely. Strangler fig can grow to be very large and some of the tallest trees in the forest (Fatland, 1996). This invasive nature worries many foresters if it is only the tree remaining as weed in future? However, with respect to renovating the degrading mountain ecosystem, strangling fig has been a boon and will remain so until better alternatives are found.

2.11.3 Species of *Ficus*

Ficus: Fig, a genus of about 2000 species, including the well-known Banyan (*Ficus benghalensis*) and the edible fig *Ficus carica* (Porter, 1966). *Ficus* is a large genus with some 2,000 tropical and subtropical tree, shrub, and vine species distributed around the whole world (Given, 1999). Distribution has no geographical limit (Corner, 1978).

2.11.4 Taxonomy

Current name: *Ficus glaberrima*

Authority: Blume

Family: Moraceae

Synonym(s)

Ficus bistipulata

Ficus fraterna

Ficus suberosa

Ficus thomsoni

Urostigma glaberrimum (ICRAF, 2004). It will avoid any confusion arising due many names.

F. benamina, *F. bengalensis*, *F. religiosa* and *F. elastica* are some relatives of *F. glaberrima*. *F. glaberrima* is identified as drought resistant plant, commonly being grown on hill trail platforms (locally known as “Chautari” in Nepal) for taking rest in tree shade while carrying bag packs uphill.

2.11.5 Naturalisation of *F. glaberrima*

While more evidence needs to be established, based on geographical distinction, characterized by the abundance of *F. glaberrima*, its growth, vigour and naturalized establishment in western Pokhara Nepal, the Himalayan foothill represents the original habitat. Corner (1978) wrote that, “The strangling fig *F. glaberrima* is puzzling both in systematic position and geographical distribution.”

2.11.6 Nutritional study of *Ficus* fodder

Ruminant feeding on *F. glaberrima* is a traditional practice mainly in Nepal. However, *Ficus* species are distributed all over the world. With respect to *Ficus* fodder, no data were available on nutrient content. Only two studies involving response to fodder trees of lactating buffaloes when fed with treated or untreated rice straw with Badhar (*A. lakoocha*) (Rana & Amatya, 2000), and with *F. semicordata* were found (Shrestha *et al.*, 1992). But no such studies were done with *F. benjamina* and *F. glaberrima*.

Nutritionally, clear species differences and monthly variations were observed in tannin activity (Wood *et al.*, 1992) Also monthly levels of dry matter (DM), ash, and crude protein (CP) were fairly stable except when there was new leaf growth, although year to year differences in dry matter were found. Trends in protein precipitation activity (PPA) fluctuation were generally similar for trees located at similar altitudes. Some of the fluctuations were due to changes in the extractability and quantity of condensed tannins which may affect the nutritive value of the fodders (Wood *et al.*, 1994b) Variability in leaf PPA was significant ($P < 0.05$) within trees, between trees and between bimonthly samples. Significant ($P < 0.05$) within-tree differences were found in fresh leaf samples of *Q. semecarpifolia* and *F. glaberrima*. Intraspecific differences in chemical composition may complicate the assessment of the nutritive value of tree leaf fodders (Wood *et al.*, 1995)

Intake of *A. lakoocha* increases milk yield in buffaloes (Rana & Amatya, 2000). However, it is important to note that *A. lakoocha* is a deciduous tree and possesses no leaves when they are most needed during the driest month of March to June. In my personal experience productive life of *A. lakoocha* is about 80 years compared to 100 years for *F. glaberrima*.

2.11.7 Primary planting site

Smallholders have less than 0.5 ha of degraded land available at various degrees of slopes. Steep sloped land which is not good for other purposes can be used for growing multipurpose trees. Mainly because all the small farmers want that, difficult corners of their land should be planted with multipurpose trees. This is partly because steep slopes will prevent animal access and thus

protect the trees from damage. To ease the lopping process, bamboo ladders are being used to get to the base of a tree and other ladders to climb the tree. Fodder trees can be grown effectively in any degree of slope provided temperature and moisture and nutritional condition are favourable (TLDP, 2001).

2.11.8 Slope land utilisation

For optimum utilisation of available slope land and plant resources, it is important to find out the most productive eco-belt for specific plant species. Success of fodder production, soil conservation, and sustainable development programmes relies on the identification of the best adapted multipurpose tree species. Rapid disappearance of fodder trees from natural forest and the widening gap between demand and supply of fodder (Dhakal & Lilleso, 2000) necessitate mitigation measures involving selection and planting of suitable multipurpose trees.

2.11.9 Existing variation permits selection

Intraspecific and interspecific differences in tree fodder nutrient content were observed by (Wood *et al.*, 1995). A laboratory analysis conducted to examine 250 species of tree fodders from eastern region of Nepal found existence of differences in nutrients and secondary compounds in them (Subba, 2001). However, Subba did not include *F. glaberrima* in his tree fodder list of 250 species. This indicates that a particular fodder species, suitably adapted in one location, may not be suitable for another. Therefore, an *in situ* experiment has been designed to examine and select the best fodder species for further planting, research and development (Kshatri, 2001).

2.11.10 Altitude and fodder tree species

A. lakoocha and *F. glaberrima* are found growing well in a 1000 m belt usually within 60 to 1500 masl. This belt is the densest habitat for humans and animals in Nepal. Although *F. glaberrima* may be lopped for 100 years or more after planting, they are never irrigated and fertilised. However, until their first harvest at the age of three to five years, the seedlings are protected by planting either in the vertical cliffs, beyond the reach of animals, or wrapped with some thorny bushes to avoid seedlings loss due to browsing.

2.11.11 Source of planting material for hill farmers

Small holders in particular have no reliable source of planting material of *F. benjamina* and *F. glaberrima*. Seedling production from seeds is possible; however, the tiny size of seed and seedlings at the beginning, their slow development and establishment need careful management. Propagation through air layering and branch cuttings is also possible (Kayastha & Amatya, 2002).

2.11.12 Propagation of *Ficus* species

Traditionally the only propagation methods used by farmers from hills are collection of seedlings from forest forks and holes where seeds from birds' droppings germinated. Air layering of branches measuring 10±5 cm diameter is another method hill farmers can use. No data are available to suggest the success and failure of farmers' practices. In addition to cuttings, grafting and seedlings from nursery, tissue culture methods can be used for multiplying the saplings.

The limited evidence on methods of fig propagation relevant to mountain ecosystem, meagre and inconsistent information available is presented hereunder.

Vegetative methods of propagation can be used for multiplying fodder tree species. The most common species are not usually the most valuable, but the most easily propagated (Hawkins & Malla, 1983)). This was a result of 35 households surveyed in each of three villages in Western Nepal and does not say anything about farmers' preferences on types of propagation. Farmers prefer vegetative techniques to 'improved' technologies because they are affordable, effective and often quicker to establish. However, indigenous practices are not available for all common species; they can be wasteful of material and damaging to the mother plants (Tiwari, 1994). Survival rates are given for the 6 most common species 8 and 30 months after planting: Badahar, 84 and 56%; bans, 54 and 32%; nimmaro, 46 and 32%; rai khanim, 71 and 52%; ipil ipil, 75 and 70%; and pakhuri, 57 and 26%. In general, the earlier in the monsoon season that the seedlings were planted, the better their survival.

The major cause of mortality was grazing by livestock (Balogun & Harrison, 1989).

Seeds of *F. glaberrima* were included to produce seedlings as part of propagating framework trees in Thailand. Different species produce seeds at different times of the year and they have different growth rates, yet saplings must attain a plantable size by the optimum planting time i.e. the start of the wet season. Germination percentages ranged from 38 to 89%, and the time in the nursery to reach a plantable size ranged from 119 days for *Prunus cerasoides*, when it had reached a mean height of 48.6 cm standard deviation (SD) =7.9), to 609 days for *Lithocarpus craibianus*, when it had reached mean height of 40.5 cm (SD=10.6) (Elliott *et al.*, 2002). *F. glaberrima* has typically small seeds. In many nurseries in Nepal the same techniques that are used to germinate large seeds are also used, inappropriately, for small ones. The main resulting recommendation is to use seed trays (locally and cheaply made from materials such as cooking- and motor-oil tins), which can easily be carried to the soil shed or a house for shade and protection from rain, and which can be sub-irrigated (Burslem, 1989).

Tissue culture “sand rooting technique” was used for mass production of tissue cultured trees in Nepal. Rooting is induced by inserting *in vitro* shoots directly into non-sterile sand, thus eliminating the *in vitro* rooting step (which has been reported to account for 30-70% of total production cost). Trees tested included *Artocarpus heterophyllus*, *A. lakoocha*, *Bischofia javanica*, *Dalbergia sissoo*, *Eucalyptus camaldulensis*, *F. auriculata*, *F. carica*, *F. clavata*, *F. elastica*, *F. glaberrima*, *F. lacor*, *F. nemoralis*, *F. semicordata*, *L. esculenta* and *L. leucocephala* (Rajbhandary, 1992).

2.11.13 Root Mechanism and soil conservation

Roots not only provide structural support to the plant and absorb water and nutrient from soil but also re-enforce mountain soil conservation systems. Anecdotal evidence shows that roots are the underground forest. Understanding the root morphology and growth, tree survival, root competency and role in control of soil erosion are very important.

The ability of *Ficus* ability to modify its root system to meet the needs of the micro-climatic conditions can help establishment and invasion in some cases.

2.11.14 Mini-nurseries in remote areas

Methods of transportation and transplantation have direct effect on survival of the saplings. In the areas far away from motor roads like in the hill farming system of Nepal, transportation is limited to carrying small number of saplings either by human or by pack animals. Regardless of care and management during transportation and planting, survival rate is often less than 50% (Author's experience). The major cause of sapling death is excessive loss of water from the plant during transportation for several days up and down hills. Therefore, small nurseries in the area of need will help improve rate of plant survival after transplantation.

2.11.15 Biomass production

Understanding of plant characteristics is important for selecting the best multipurpose tree within a mountain farming ecosystem. This is mainly because different trees respond differently in given climatic conditions. Data on the effect of fertilizer application, lopping management and quality and quantity of biomass production was not available. With respect to *F. glaberrima*, whatever data available up to January 2004 are reviewed and presented.

Table 2.3 Result of Participatory Rural Appraisal (PRA) and measurement of ten fodder trees (*F. glaberrima*) above the age of 50 years located at an elevation of 900mas in the mountain ecosystem of western Pokhara, Nepal (Kshatri, B. B., 2001).

S.o.	Parameters	Average value	Strategic Importance
1	Height	18.6 m	Use of space above ground
2	Diameter at breast Height	2.80 m	Good for pack-wood.
3	Canopy diameter	14.8 m	Under utilized area.
4	Canopy area	162.4 m ²	Grass and legume
5	Vacant canopy height	2 – 6 m	Bush fodder production

F. glaberrima is a potential resource for supporting livestock during the lean forage period (Rana and Amatya, 2000). Over the last five years, there have been significant changes in certain livelihood strategies, including an increase in biogas and crop residues as a fuel source, a shift from open grazing to stall-

feeding and increases in the use of fodder crops and crop residues as livestock feed and also a marked shortage of fuel-wood (Warner, *et al.*, 1999). There is a heavy dependence on 2 or 3 species and the most common species are not usually the most valuable, but the most easily propagated. Commonest species are Banjh (*Quercus incana*), Bhyaul (*Grewia optiva* [obtiva]), Pakhuri (*F. glaberrima*), Faledo (*Erythrina arborescens*), Dabdabe (*Garuga pinnata*) and bamboos. The number of fodder trees is not adequate for livestock requirements and the period of fodder shortage extends from January to June. Trees are rarely planted on irrigated fields, and the ability of the farmers to recognize valuable species is limited by their lack of experience. It is suggested that it should be possible to select species which can be lopped during the period of shortage and that regionally organized seed collection and species selection would promote the planting of valuable species (Hawkins & Malla, 1983).

Out of 33 common fodder trees under study as part of a national fodder survey, *A. lakoocha* and *F. glaberrima* were the most used species of fodder in the Jhapa and Sunsari district of eastern Nepal (Upadhyay, 1992). Native fodder tree species of Nepal, if carefully selected and planted on farmers' fields, have the potential to improve the poor fodder stands commonly found throughout the Middle Hills (Karki & Gold, 1992). In general, farmers preferred as fodder trees the species with high crude protein (CP) and organic matter (OM) contents both on their fields and in their forests (Karki & Gold, 1994).

Species of a fodder tree is one of the several factors determining the amount of fodder produced in given conditions. One of the studies found that fodder production was very variable between trees of individual species (Amatya & Lindley, 1992). Branches more than or equal to 1 cm diameter were lopped from 10 trees of each species with trunk diameter more than or equal to 30 cm in November 1990 and March 1991 (Amatya, 1992). This diameter of trees is far less than 280 cm girth recorded for 50 years old *F. glaberrima* (Kshatri, 2001).

2.11.16 Leaf morphology

A study in India and Bhutan on the morphological characters of 17 tree species revealed the highest variability for leaf dry matter and leaf area (46%) and lowest for leaf length, maximum width of leaf and perimeter (24%). In general, leaf dry matter and maximum leaf width were the most dependable characters for estimation of leaf area. Multiple regression equations improved the estimation of leaf area by 2-8% in *B. hainla* and *F. glaberrima* (Wood *et al.*, 1995).

A. lakoocha feeding trial was effectively postponed by one year due to lack of adequate information on the time of foliage availability. No literature indicates that *A. lakoocha* is not available during dry season in Nepal. Based on the information available, a project was set to start and planned to run through the driest months of the year in Nepal, that is about second week of February until June. The project was to compare the "effect of intake of *A. lakoocha* and *F. glaberrima* on milk production of buffaloes. Because, *A. lakoocha* ranked first as the best fodder tree in Nepal, in terms of palatability, nutrition and farmers' preference, *F. glaberrima* has never been considered for such evaluation in the past. The effect of feeding *A. lakoocha* was significant on fat % ($P < .01$) and TS content of milk ($P < 0.05$) (Rana & Amatya, 2000).

As a source of dry season nutrition, particularly in Sunpadali, Kalika-6, Kaski, Pokhara Nepal, (elevation 900 m) *F. glaberrima* is available 365 days in a year whereas *A. lakoocha* completes shedding its leaves generally after the second week of February and is not available when hardest dry season starts. The former is evergreen and the latter is deciduous. Just for supplying fodder leaves during dry seasons, deciduous trees cannot be compared with evergreen one. Therefore, both evergreen multipurpose trees; *F. glaberrima* and *F. benjamina* could be the most important of all fodder trees of the areas. Despite the above facts, we can see farmers and extension workers still making un-practical comparisons between evergreen and deciduous fodder.

2.12 Summary and conclusions

Overexploitation of natural pasture resources is seriously damaging slope land productivity, leading to serious lack of feed and thereby adversely affecting the

health and productivity of animals, particularly during the dry period of 9 months from October to June in the hill farming system of Nepal. The mountain ecosystem that provides living for nearly half of 27.1 million total population of Nepal is no longer capable of supporting ever increasing human and animal populations, and is said to be in the verge of collapse. Planting hardy multi-purpose fodder trees will help to conserve life and stabilise this ecosystem. This study will help select the best tree species suitable to supply dry season nutrition for stall feed animals.

A. lakoocha is an important fodder tree but has no leaves in the densely populated altitude of 1000±500m masl in Nepal at the time of driest month from March to June.

F. benjamina is an indoor plant available all over the world whereas *F. glaberrima* is closely related fodder tree mainly from the Himalayan foothills. Both are evergreen plants under *Moraceae* family and are potential sources of ruminant nutrition for dry seasons. This research focuses mainly on that fodder potential.

The Mountain ecosystem is a complex and highly dynamic interaction among trees, grasses, animals and birds generating energy for people who are sharing a common piece of land. Overall productivity now has a negative trend, which is commercially not viable and has fallen below subsistence. In the remote areas people are living on the margin of their existence and are migrating to seek asylum even abroad in search of food, water and better job. Thus, there is a greater need for lands of renovation of mountain so that energy keeps generation to sustain life.

Fig trees, once planted, provide nutritious fodder which can be harvested for up to 100 years. Besides, the specialised attributes of figs, such as the strangling, epiphytic, hemi-epiphytic, xerophytic and invasive characteristics of *F. benjamina* and *F. glaberrima*, they are nutritious and palatable to all categories of animals.

Finally, figs have immense potential as fodder source for dry season nutrition, soil and biodiversity conservation and also maintain ecological harmony. Thus, evergreen figs deserve more attention of researcher thus enhancing the status of multipurpose trees around the globe.

Lack of ruminant feed is not only causing severe malnutrition but also causing a greater harmful effect on health and productivity than other animal diseases. The household and national economies are being adversely affected by such situations.

The literature review provides information on existing status and potential role of fodder use in hill and mountain farming ecosystem of Nepal. In fact without multipurpose trees, the future of the whole agro-silvo-pastoral system will be in question. During dry winters, when existing pastures becomes brown and barren due to over grazing and lack of soil moisture, trees are the main source of energy and protein for animals. Virtually tree fodder has no alternatives. Thus browse species are playing an intricate role of dry season nutrition, soil conservation, biodiversity conservation and are ultimately maintaining ecological harmony. Therefore, multipurpose trees must be given due research attention.

Different species of browse supply different quality of leaves in different times of the year. However, ruminants need green and fresh fodder throughout the year. The most important browse is therefore one which can supply leaves 365 days in a year. Of the 250 plus species being used in the hills of Nepal, *F. glaberrima* and *F. benjamina* remain green all year round. Therefore, those two *Ficus* species were selected for further evaluation as multipurpose fodder trees. While focusing mainly on propagation, nutrition and biomass production of *Ficus*, data generated will be compared with that for other available tree fodder species significant to mountain ecosystem.

Data available on browse species particular to hill farming system of Nepal is meagre and also inconsistent. This could be due to extremes of variation in the elevations, seasons, climatic conditions, aspects of mountains, morphological differences and variation in the micro-climatic requirements of a particular plant

species. Natural factors including hail-storm, severe drought lead us to think twice about the highly significant variation within any research results, despite the use of proven management practice developed elsewhere. Delineation of all fodder trees particular to hill farming system needs species and variety-specific *in situ* research.

Under existing hill farming practice, a *F. glaberrima* tree grows for over 100 year. That means, once planted, nutritious fodder can be harvested for 100 years. However, traditional management practices of planting, establishment, and lopping need improvement. Provision of data on efficient management of multipurpose trees, practical means of propagation, comparative chart of nutritive values and biomass yielding species will encourage farmers to grow more plants which they need for their future generation. Besides, naturally specialised attributes of figs, such as the strangling nature, epiphytic, hemi-epiphytic, xerophytic and invasive characteristics of *F. benjamina* and *F. glaberrima* needs research. Different categories of birds after devouring on small syconium full of seeds can fly continent to continent in course of migration which might spread the fig around the globe. This is how varieties of figs have no geographical limits.

Despite the great need to gain knowledge of multipurpose trees, none of the potential trees existing in Himalayan ecosystem have been studied extensively. The target species for this research are *F. benjamina* and *F. glaberrima*, which are prime indoor plant and fodder plant respectively.

The genus *Ficus* has immense potential as fodder resources for dry season nutrition, soil and biodiversity conservation and also maintains ecological harmony. Finally, evergreen fig deserves much needed attention of researcher for enhancing the status o multipurpose trees around the globe.

Lack of ruminant feed is not only causing severe malnutrition but also casting a harmful effect on health and productivity. The household and national economies are being adversely affected by such situations.

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To achieve the broader objective, the following specific gaps in knowledge were identified on the basis of which experiments were designed to acquire the knowledge to renovate the degraded hills, supply nutrients to herbivores and help conserve biodiversity in a sustainable way.

The approach used here is to bring together new information on:

a) Current use and management of alternative MFT in Nepal

- b) MFT establishment and biomass production potential mainly on farmed land and under glass house conditions.
- c) Generate knowledge on the nutritive value of MFT using lactating buffaloes and sheep (large and small ruminants).

Integrated information generated will provide a set of recommendations for improving the sustainability and productivity of MFT systems.

CHAPTER 3

Invasive tree *Ficus glaberrima* characteristics and fodder research priorities set by users' participatory workshops in Nepal

3.1 Introduction

This Focus Group Workshop is a vital part of research for understanding natural and farmed MFT and developing a new strategy to restore and manage hill farming ecosystems.

Fodder trees are disappearing rapidly from the natural forest of the mid-hills which was source of 35% of the annual livestock feed. Estimated 5 – 6 million tons of dry matter equivalent, are met from forage coming from natural forest (Dhakal & Lilleso, 2000). Farmers possess an extensive ecological knowledge of tree crop interactions, fodder quality evaluation and tree fodder management techniques, which they used in management of tree fodder on farmland and in formulating feeding strategies (Gurung, 1999). Varying degree of access to off-farm fodder sources and the number of livestock kept by different households also seems to affect fodder management decisions (Vickers & Rekha, 2000). Farmers are planting an increasing number of *F. glaberrima* trees as a cheap and simple solution to counterbalance the declining forest resources in Nepal; however, its usefulness has never been verified. Selection and planting of trees depends on what the farmers like (Bista, 2000). Thus, to start with the selection process using farmers' indigenous knowledge two focus group workshops were conducted in the field in western Pokhara, Nepal.

Based on traditional farmers' practices, *F. glaberrima* was classified on the basis of test (bitter and sweet), thickness of leaves (thick and thin) and size of leaves (big or broad and small or narrow) and lustre of leaves (black or dark green or light white).

The integration of trees with agronomic crops has been actively promoted throughout the world to increase biodiversity, to optimise production and

resource conservation, and to improve wildlife habitat (Delate *et al.*, 2005; USDA, 2006). In Nepal, increase in forage demand and decreasing trend of soil productivity in the hill farming system has led to irreversible damage to the local biodiversity and hence chronic lack of animal feed (Kshatri, 1993; Rajbhandary & Shah, 1981). To cope with the declining forest resources small farmers in the hills are planting increasing numbers of tree species on their farmed land (Thapa, *et al.*, 1997). Trees, crops and animal husbandry are three main interdependent components generating living for 65.5% of 27.1 million people in Nepal (CBS, 2002; Pokharel, 2005). Livestock play a key role in providing draught power for crop production, manure for maintaining cropland fertility, farm income and protein for household nutrition (Sherchand, 2001; Tulachan, 1998). One pre-condition for raising livestock is fodder production which is severely lacking in the hills of Nepal. Recently, there has been a decrease in animal numbers and farm income, with severe consequences for human nutrition (Thapa, *et al.*, 1997a). Farmers depend on tree resources to maintain livestock numbers particularly during the dry season when other feed is in limited supply more than 75% of the fodder that is fed to livestock is used during the period from November to June (Panday & Nosberger, 1985). Fodder production is the main aim of growing trees, followed by firewood, fence material and minor timber use.

Selecting and planting invasive but multipurpose trees could form the basis for renewal of degrading hill farms and provide durable ecological services (Kshatri, 2003). *F. glaberrima* (FG) is one of 5000 to 7000 plant species available in Nepal (Bajracharya, *et al.*, 1988). Only 23 species of trees were found to be domesticated of which *F. glaberrima* and *A. lakoocha* are the most commonly used species in the research area. *F. glaberrima* provides supplementary nutrition to lactating animals particularly during the dry period from October to June. Leaves of the locally well-known, palatable and nutritious fodder tree; *A. lakoocha* start shedding from February, which makes it unfit as fodder source until September, whereas *F. glaberrima* is an evergreen multipurpose tree and available for lopping throughout the year. About a million households around western Nepal are using both trees as fodder, firewood, fence material, minor timber and conservation purposes. However, their performance and usefulness has never been investigated.

3.1.1 Background

Nepal is a landlocked country of 147181 square km area and located at 26°22" to 30°27" N latitude, and 80°4" to 88°12"E longitude, lying on the Himalayan range between China in the north and India in the south. Eight of 10 highest peaks of the world including Mt Everest are in Nepal. Also there are some 200 peaks more than 6000 meters. The width of Nepal varies from 120 km to 240 km. Within one degree latitude (27° N) there is a great variation in altitude, where the lowest elevation is 60 m at 26° 22" latitude and highest is 8848 m Mt. Everest. Due to steep slopes and small terraces, use of advanced technology is limited by poor access to roads, rugged terraces and high cost. High altitudes also have its role to complicate the crop production. Based on altitude, Nepal can be easily stratified into 88 bands of 100 metre elevation, where each stratum forms a specific agroecosystem. Aspects of hills, elevations, distance from the oceans and distance from the chilling Himalayas have a direct effect on primary production and daily chores on small farmers, thus it is relevant to describe the background of geo-climatic conditions of the research area. The Research site is located at 84° to 85° longitudes, 27° -28° latitude and 700 – 1500 m elevation (Gurung, 2005) in the central hill farming system of western Nepal. It is about 10 km away from the 8167 m high Annapurna range.

A major methodological advance in rural development research in recent years has been the recognition that rural households are not necessarily focused exclusively on increasing crop or livestock production, whether for subsistence farming or the market, but undertake a range of activities, both on- and off-farm, depending on the resources to which they have access and the livelihood strategies they choose to pursue at any given time (Twomlow, *et al.*, 2002).

3.1.2 Collapsing hill farm ecosystem: A review

Overexploitation of plant resources is causing severe damage to the hill pastures (Sharma & Kayastha, 1998) of the Mt Everest country of Nepal. The problem of animal feed deficits and desertification was apparent by 1950 when sheep herders started giving-up the transhumance system of producing sheep (Kshatri, 1993, 2003; Mishra, 1998; Pande, 1997b). Forage deficits triggered the agreement to ban cross border grazing between Nepal and Tibet. When forest depletes, livestock suffer. When livestock suffer, cropland, in turn loses

and food security is threatened and ultimately the economy suffers (Sherchand, 2001). Thus, by 1956 The first five year plan was started as a series of mitigation measures to overcome the crisis (Mishra, 1998). Then, to detail the trends and projections of livestock production in the hills, a special “seminar on Nepal’s experience in hill agriculture development” was organised by the Ministry of Food and Agriculture, in cooperation with “The Agricultural Development Council, Nepal” (Rajbhandary & Shah, 1981). Subsequently, several long term (20 years) sectoral master plans were formulated: Forest Master Plan, Agricultural perspective Plan (APP), Livestock Master Plan, Irrigation Master Plan, Horticultural Master Plan and so on (Sherchand, 2001). None of the projects was focused on the importance of *F. glaberrima*, despite it’s use by millions of small farmers.

3.1.3 Evaluation of fodder trees by chemical means

Selected trees need to be resilient to local factors influencing plant production, liked by farmers, nutritious and palatable to animals. Evaluating fodder species using chemical methods is widely adopted (Subba, *et al.*, 1994). Intraspecific and inter-specific differences in leaf chemistry of the fodder trees from the hills (Wood *et al.*, 1995; Wood *et al.*, 1994b), makes the available knowledge far from conclusive and often contradictory between different laboratories (Mahato & Harrison, 2005; Subba, 1998; Thapa *et al.*, 1997b). In some cases chemical explanations are similar to farmers preferences in other cases there is no explanation for them (Subba, *et al.*, 2002). Proximate analysis and other methods of analysis are used in which digestibility, crude protein, crude fibre, lignin, cellulose and tannin content provide as indicator of fodder quality. Many studies carried out based on these indicators have produced widely differing results for the same species (Subba *et al.*, 1994). Review of literature clearly indicates that evaluating fodder trees by chemical means alone is not enough. There is a need for composite methods including a better understanding of the factors influencing fodder quality, farmer’s preferences and conformation with chemical methods.

3.1.4 Role of forest resources and stall feeding animals in the hills

About 50 % of animal feed comes from the forest. The forest resources in Nepal are not only important from the view point of conserving the natural

environment, particularly land degradation, loss of habitat or wild flora and fauna, maintaining balance of hydrological cycles and natural disasters, but also as a major source of livelihoods of the people (Mishra, 1998) .

There is a general trend toward declining cattle populations in Indian Himalayas, Nepal and Bhutan. This could be mainly because of decreasing feed resources and a decline in areas for open grazing (Tulachan, 2000). Major concern is the declining soil productivity due to rampant erosion leading to desertification (Mishra, 1998). As a result 99 % of hill farmers lack animal feed and are trying hard to find sustainable solutions to feed their animals in landlocked mountain terrains.

3.1.5 Lack of feed and consequences at small farm level

To overcome the constant lack of animal feed, the farmers themselves are making changes in the traditional farming system which includes:

- (1) Complete abandonment of the nomadic system of keeping sheep, in response to lack of grazing pasture
- (2) Migration of rural population to urban areas and outside the country.
- (3) Change in free-range system of keeping livestock during 1940s to semi-intensive system until 1980s and stall-feeding from the year 2000.
- (4) A reduction to 2 to 4 animals per house hold from 10–12 animals during 1940s.
- (5) An increasing number of farmers are keeping buffaloes compared with 50 years ago.
- (6) In response to lack of meat, increasing number of new generation Hindus of occupational cast, are secretly eating beef, buffalo and pork, where slaughtering a cow is punishable both by religion and by law in Nepal.
- (7) Owing to decreasing carrying capacity of land, over 2.4 million small farmers were displaced during 1991 to 2001 and they are the cheap source of unskilled labour for any country around the world. The percentage of population dependent on agriculture dropped sharply from 81 % to 65.6 % during 10 years period 1995-2000 (Census, 2001). It is not because industries are growing but because of lack of hope to make a living from small farming.

- (8) During the past ninety years, the human population has grown from 5.6 million in 1911 to 27.1 million in 2005 with a consequent population density of 38.3 to 184 per square km respectively, whereas land areas remain constant and land productivity is declining at the rate of 1.25 % per year. Now small farmers realise that any continuation of the generations old practice of making living by felling trees for fodder, firewood and timber purposes will prove to be suicidal and hence they need to think seriously about reclamation.

3.1.6 Farmers Participating Workshops

The group approach to development was invented and adapted as a principle method for solving these common problems, where experienced farmers conduct a monthly participatory meeting to decide the suitable course of action required for conservation, innovation and changes needed to sustain life in hill farms. Based on interest, socio-economics and geographical locations, a group is composed of 5 to 30 members (Kshatri 2000). Federation of community forest user groups Nepal (FECOFUN) recorded 13000 user groups involving 35 % of the total population who are managing 1.1 million hectare of forests (Pokharel, 2005). However, such groups are lacking scientific backup to enhance their efficiencies. Community forest refers to a part of national forest, which is handed over to forest user groups for its development, protection, management and utilisation for collective benefits to locally selected communities. In other words a group of people called a "Forest User Group (FUG)" is given rights by the Forest Department to manage, use and protect an area of forest land or an area of land for growing trees (Shrestha, 2002).

Obviously, lack of feed particularly during October to June is the major problem for small farmers limiting livestock health and productivity. Planting a multipurpose tree is a solution for the renovation of hill farms. Finding the best adapted multipurpose trees capable of producing a diversified benefit for the poor inhabitants of rugged terrain is a challenging question. Farmers' participatory workshops can form the basis for pooling the indigenous technical knowledge for planning, implementation, monitoring and evaluation of the components supporting their living in the local environment (Cramb, *et al.*, 2004; Subba, *et al.*, 2002). Therefore, with the objective of selecting suitable

multipurpose species, two workshops of local farmers were conducted to discuss aspects of tree fodder production in the hill farming system of Nepal.

Specific objectives were to verify:

- Key research questions: other species better than *F. glaberrima*?
- Participatory methods of selecting multipurpose trees.
- Tree species prioritised for detailed investigations

3.2 Methodology

To conduct a focus group workshop successfully, it is crucial to decide the right date, day, time, venue and right duration for the resource-poor farmers to gather in workshops without compensation. Any holidays are suitable as children will be off school and available for household chores, while parents will be available for the workshop. The important job of milking needs to be done by adult members and completed by 7 am, therefore 7 – 11 am is found to be a suitable time and duration. A common gathering place such as school, tea-shops or Chautaree (resting platform for trekkers) is a convenient venue for the workshop.

A proposal was developed to conduct preliminary research on *F. glaberrima* in complex small farming systems in the hills of Nepal and presented in a series of seminars for comments. The first presentation was done at the seminar organised by the Institute of Natural Resources (INR) at Massey University on 14 August 2003. After incorporating the comments from scientists in INR, the modified proposal was presented at the 5th National Animal Science Convention on 15 – 16 October 2003 in Kathmandu, organised by Nepal Animal Science Association (NASA). This provided an opportunity to incorporate any comments from Nepalese researchers.

Lastly, two workshops were conducted with small farmers at the research site in western Nepal. Workshop-1 was conducted on 13th October 2004 at the beginning of the on-farm research and workshop-2 was conducted five months later (on 12 March 2005). After visiting farmers' homes and discussing with farmers, a suitable common gathering place was fixed. A "Chautaree" with large *F. benjamina* tree adjoining the trekking road at Garkate of Sunpadali village,

Kalika-6, Kaski, Pokhara Nepal was used as venue for both workshops. Chautaree is a platform for porters resting for short time, generally planted with *F. benghalensis*, *F. benjamina* and *F. religiosa* trees for shade.

To conduct the Focus Group Workshop (*F. glaberrima*) by creating respectful environment, among farmers' participants, ensuring equal participation to capture diverse views and consensus as appropriate, the following chronological steps were adapted before, during and after the workshops:

Six months before the first workshop (19 April 2004), approval from Human Ethics Committee, Massey University, New Zealand was obtained to conduct the focus group workshops in Nepal.

One month before the workshops, door to door visits were made to contact small farmers to share their views and ask if they were interested to participate in the workshop to evaluate the importance of fodder trees. A suitable time, date and venue were decided and informed well in advance to all participants. Venue was fixed to be an open area suitable for gathering all participants. Twenty mats made of rice straw that are good for sitting 40 participants and stationeries for recording outcome of the workshop were arranged.

During the workshop users' group members were welcomed; seats were arranged in semi-circular manner so that each participant would be able to contact eyes while sharing their experiences. Then, an introduction outlining steps to be taken and the community participatory rules applicable during workshops. Purposes and the methods to be used during the workshops process were reiterated to the participants. The participating farmers were allowed to share and express their views freely and get clarification of questions and options. The same farmers were regularly interacted with for five months to share the research results for optimum participation. Care was taken to avoid biases and establish harmony with social environments. Focus group Workshops lasted for 3 hours from 008–1100 hours, on both occasions.

3.4 Results

3.4.1 Background

The major land use problems identified by members of the Workshop are outlined in Table 3.1. The three main determinants of the numbers and species of trees on farmed land were; farmers' experience of the effects of trees on under - storey crops, the amount and quality of the tree fodder produced, and the availability of land.

Table 3.1 Livelihood strategies of small farmers: problems and consequences.

S.N	Problems	Consequences
1	Long drought period of nine months (October to June) prevents primary production.	Soil moisture drops below critical level and trees start shedding leaves prematurely. Fodder crop that need frequent irrigation cannot be grown. Green and fresh fodder availability is limited to evergreen trees that are already lacking.
2	Land productivity is decreasing and ranged from 1.2 - 5 dry matter per hectare for existing ground cover and complete reseeded management respectively (Rajbhandary and Shah, 1981).	Straw based, poor quality cereal by products is being supplemented with 2 - 10 kg per day fresh fodder twigs for a buffalo maintenance and production. Malnourished oxen are the only source for field traction as use of tractors is constrained by lack of motor roads, narrow terraces and high cost.
3	Adverse effects of lack of soil moisture on deciduous fodder tree causes lengthening of period of dormancy whereas an evergreen tree starts senescence and abscissions prematurely.	Reduced quantity and the quality of edible biomass per tree and per hectare and hence less feed is available for animals' consumption. Under feeding of animals is the single most serious cause for deterioration of health and productivity and thereby worsening economy of small farmers in Nepal.
4	Children spends more time to collecting fodder from forest and less time for school homework and finally dropout from school before they develop ability to read and write	Similar to their ancestors, hill farmers in 21 century Nepal, tend to be of the same uneducated and traditional type and hence continue to farm in a vulnerable condition with limited hope for any improvement in their standard of future living.

5	Livelihoods strategies of hill farmers are complex, diverse, doubtful and fragile.	Vicious circle of poverty continued until some special, (magical, or blissful) changes takes place.
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Note: Land holding 0.54 ha per capita, two buffaloes, two cows and two goats and five members in the family.

3.4.2 Inventory of multipurpose fodder species

A total of 1575 trees were found to be domesticated and used on the 30 small farms. Inventories of the number and species of forage trees per farm and of the host trees of *F. glaberrima* while in the epiphytic stage of development are shown in Tables 3.2 and 3.3 respectively. Although 27 species were used as fodder trees the mean number of species per farm was relatively small, and only *F. glaberrima* exceeded mean number greater than 3.8 trees per farm (Table 3.2).

Table 3.2 Types and number of fodder trees per farm.

Nepali name of Trees	Number		Mean	Std. Error of Mean	Std. Deviation	Range	Sum
	Valid	Missing					
Badhar	30	0	3.76	.49	2.71	11.00	113.00
Bans	28	2	2.14	.23	1.23	4.00	60.00
Bar	6	24	1.00	.00	.00	.00	6.00
Bedulo	29	1	3.34	.28	1.51	5.00	97.00
Chilaune	30	0	3.43	.35	1.94	8.00	103.00
ChipleKaulo	9	21	1.55	.24	.72	2.00	14.00
Chiuree	4	26	1.25	.25	.500	1.00	5.00
Chuletro	7	23	1.28	.18	.48	1.00	9.00
Dabdabe	16	14	1.43	.12	.51	1.00	23.00
Gindari	27	3	2.48	.20	1.05	4.00	67.00
Ipillpil	6	24	2.83	.70	1.72	5.00	17.00
Kathar	7	23	1.14	.14	.37	1.00	8.00
Katus	30	0	3.53	.27	1.50	5.00	106.00
Kavro	28	2	2.14	.20	1.07	4.00	60.00
Khanayo	28	2	3.17	.34	1.82	7.00	89.00
Khari	20	10	2.20	.32	1.43	5.00	44.00
Khirrow	30	0	2.76	.37	2.06	10.00	83.00

Kimbu	20	10	2.10	.28	1.25	5.00	42.00
Kutmiro	26	4	1.80	.15	.80	2.00	47.00
Nimaro	11	19	1.45	.24	.82	2.00	16.00
Pakhuri	30	0	7.63	.90	4.97	19.00	229.00
Peepal	9	21	1.00	.00	.00	.00	9.00
Phaledo	25	5	2.24	.25	1.26	5.00	56.00
Sami	15	15	1.13	.09	.35	1.00	17.00
Suntala	30	0	3.56	.40	2.20	10.00	107.00
Tanki	27	3	2.03	.17	.89	4.00	55.00
Thotne	27	3	3.44	.28	1.50	5.00	93.00

Note: E= Evergreen; Farmers (N) = total no of respondents participated in workshop; Min=minimum number of fodder trees; Max = Maximum number of fodder trees, SD= Standard deviation, Valid = number of farmers with respective tree species, Missing= number of farmers without having respective tree species

Table 3.3 Host trees of *F. glaberrima* in forest and farms while in epiphytic stage.

Sn	Local name	Botanical name	Advantages	Deleterious characters
1	Khirror or Khirra	<i>Sapium insigne</i>	Goat feed, mulch, kitchen cabinet, wood good for making musical instrument (Sarangi, Madramootoo, & Cox)	Some people are allergic to milky sap.
2	Pakhuri	<i>Ficus glaberrima</i>	Evergreen: grows in poor management, have sweet and bitter types with small, medium and large leaves. Produce up to 800 kg biomass/years /tree	Grows slowly on tree forks as epiphytes.
3	Kavro or Kauro	<i>Ficus locar</i>	Deciduous fodder available during drought period	Available only for a short period of 3 months (Apr – Jun)
4	Bedulo or Berulo	<i>Ficus subincisa</i> <i>Syn: clavata</i>	Grows in poor soils and slopes. Liked by	Small tree of 4 m high., produce about 50 kg

			animals	fodder /tree/year
5	Nevaro or Nyaro	<i>Ficus roxburghii</i> Syn: <i>auriculata</i>	<i>F. glaberrima</i> can be used as vegetable	Better in north aspect of hills at 1000 to 2000 m altitude.
6	Thotne or Tote	<i>Ficus hispada</i>	Bushy fodder, no need for climbing	Rough broad leaves
7	Peepal	<i>Ficus religiosa</i>	Religious trees, <i>F. glaberrima</i> all year round	New sources of fodder
8	Bar	<i>Ficus benghalensis</i>	Evergreen trees	
9	Sami	<i>Ficus benjamina</i>	Medium size tree	
10	Khanyuoo	<i>F. semicordata</i>	Medium size tree	Rough leaves, produce only about 100 kg fresh leaves.
11	Chiuree	<i>Bassia butyracea</i>	True multipurpose tree, made butter oil out of seeds, fruits good for eating and making wine. Leaves are good fodder.	Difficult to propagate by vegetative means.
12	Faledo	<i>Erythrina spp.</i>	Good fence for the farm. Easy to propagate by cuttings pole size up to 3 cm dia and 200 cm long.	Upper trunk and branches have conical prickles.
13	Suntala	<i>Citrus spp.</i>	Too many branches and forks to hold the Ficus seed and moisture	Orange tree was strangled within 30 years of <i>Ficus glaberrima</i> growth.
14	Katus	<i>Castonopsis indica</i>	Rough bark with ridges. Leaves can be eaten mainly by goats	Liked by goats. Buffaloes can eat when nothing available.
15	Chilaune	<i>Schima wallichii</i>	Rough bark with ridges. Leaves can be eaten mainly by goats	
16	Kutmiro	<i>Litsea monopetala</i>	Good fodder tree	Termite attacks the trunk which looks dry.

17	Badhar	<i>Artocarpus lakoocha</i>	The best tree fodder, in terms of animals liking and milk production. About 20 m tall tree.	Need higher management to get first harvest of leaves at 5 years of age.
18	Khari	<i>Celtis australis</i>	Medium size tree 8 m high	Sensitive to drought
19	Tanki	<i>Bauhinia purpurea</i>	Medium size tree 12 m high.	Not competitive with other trees
20	Gidari or Ganhaune	<i>Premna barbata</i> Syn: <i>P. integrifolia</i> <i>P. latifolia</i>	Medium size tree 12 m high	Unpleasant odour
21	Chiple-Kaulo	<i>Machilus odoratissum</i>	Medium size tree 12 m high	Less palatable
22	Kathar	<i>Artocarpus heterophilus</i>	Medium to large tree	Fruit tree, fodder is available only when thinning is done.
23	Ipillpil	<i>Leucaena leucocephala</i>	Nutritious and easy to cut and carry	Need higher management and irrigation
24	Chuletro	<i>Brassiopsis hainla</i>	Medium tree easy to climb	Too much shade underneath
25	Dabdabe	<i>Garuga pinnata</i>	Medium tree	Comparatively less foliage production
26	Kimbu	<i>Morus alba</i>	Small to medium tree easy to climb	Pest problems and low foliage yield
27	Bans	<i>Dendrocalamus spp.</i>	About 10 metre tall column and palatable leaves	Nothing grows underneath

Note: Suntala and Kathar are fruit trees and not fodder trees. Leaves, fruit peel and bark preferred by goats.

The seasonality of availability of the 27 fodder species is shown in Table 3.4, listed under the Nepalese calendar, and Table 3.5 indicates the relationship between Nepalese and English calendars. The year-round availability of leaves from two *Ficus* species (*F. benjamina* and *F. glaberrima*) and two additional groups of species (Citrus and *Dendrocalamus spp.*) is clearly seen.

A. lakoocha, *A. heterophilus* and *F. semicordata* are grown in commercial nurseries from seed. *S. insigne* and *E. arborescens* are used as poles for fencing and become established trees. *F. glaberrima* and *F. benjamina* are collected from the forest when still in the epiphytic stage.

Farmers' experience of the effect of *A. lakoocha* intake in increasing milk yield of buffaloes was verified during the Workshop.

F. glaberrima was further classified by farmers on the basis of taste (bitter and sweet), thickness of leaves (thick and thin), size of leaves (large and broad, small or narrow), and leaf lustre (dark and light). Farmers' perception was that the smaller and darker the leaves the more they were palatable.

Table 3.4 Calendar of availability of tree leaves at Sunpadali, Kalika-6, Kaski, Nepal.

Botanical name	Nepali name	Nepali Months starting A = Asoj (15 Sep-16 Oct)											
		A	K	M	P	M	F	C	B	J	A	S	V
<i>A. heterophyllus</i>	Kathar	x	x	x	x	x	x	x				x	x
<i>A. lakoocha</i>	Badhar	x	x	x	x	x	x				x	x	x
<i>Bassis butyracea</i>	Chiuree				x	x	x	x	x	x	x		
<i>Bauhinia purpurea</i>	Tanki	x	x	x	x						x	x	x
<i>Brassiopsis hainla</i>	Chuletro	x	x	x	x						x	x	x
<i>Castonopsis indica</i>	Katus	x	x	x	x	x				x	x	x	x
<i>Celtis austrles</i>	Khari	x	x	x						x	x	x	x
<i>Citrus spp</i>	Suntala	x	x	x	x	x	x	x	x	x	x	x	x
<i>Dendrocalamus spp</i>	Bans	x	x	x	x	x	x	x	x	x	x	x	x
<i>Erythrina arborescens</i>	Phaledo	x	x	x	x						x	x	x
<i>F. benghalensis</i>	Bar	x	x	x	x	x					x	x	x
<i>F. benjamina (E)</i>	Somi	x	x	x	x	x	x	x	x	x	x	x	x
<i>F. glaberrima (E)</i>	Pakhuri	x	x	x	x	x	x	x	x	x	x	x	x
<i>Ficus hispida</i>	Thotne	x	x	x							x	x	x
<i>F. locar</i>	Kavro	x	x	x						x	x	x	x
<i>F. religiosa</i>	Peepal	x	x	x	x	x					x	x	x
<i>F. roxburghaii</i>	Nemaro	x	x	x						x	x	x	x
<i>F. semicordata</i>	Khanyo	x	x	x								x	x

<i>F. subincia</i>	Bedulo	x	x	x							x	x	x
<i>Garuga pinnata</i>	Dabdabe	x	x	x							x	x	x
<i>L. leucocephala</i>	Ipil ipil	x	x	x							x	x	x
<i>Litsea monopetala</i>	Kutmiro	x	x	x	x							x	x
<i>McChilus odoratissum</i>	Chiple-kaulo	x	x	x	x	x						x	x
<i>Morus alba</i>	Kinbu	x	x	x						x	x	x	x
<i>Premna barbata</i>	Gindari	x	x	x	x							x	x
<i>Sapium inseeigne</i>	Khirrow	x	x	x						x	x	x	x
<i>Schiuma wallichii</i>	Chilaune	x	x	x	x					x	x	x	x

Table 3.5 Linkage of Nepali and English calendar in relation to fodder lopping cycle and months in dry seasons in the northern hemisphere, Nepal.

Months	Fodder supply period			Equivalent date in English Calendar
	<i>A. lakoocha</i>	<i>F. glaberrima</i>	Pasture	
Baisakh	x	√	x	B = 13 April to 13 May
Jestha	x	√	x	J = 14 May – 12 June
Asar	x	√	√	A = 15 June to 15 July
Shrawn	x	x	√	S = 5 July to 16 August
Bhadau	x	x	√	B = 17 August to 16 September
Aswin	√	√	√	A = 15 September to 16 October
Kartik	√	√	√	K = 17 October to 15 November
Mangsir	√	√	√	M = 16 November to 15 December
Poush	√	√	x	P = 16 December to 13 January
Magh	x	√	x	M = 14 January to 11 February
Fagun	x	√	x	F = 12 February to 13 March
Chaitra	x	√	x	C = 14 March to 13 April

√ = months of harvesting *A. lakoocha* and *F. glaberrima* pasture in farmed land of mid hills Nepal; x = months when fodder and pasture is not available for cut and carry system

Note: This information is applicable to 600-1500 masl altitude in hill farming system of Pokhara.

3.4.3 Research recommendations

Four forage tree species (*A. lakoocha*, *F. benjamina*, *F. glaberrima*, *B. butyracea*) were selected for further study, with the expectation that other species could be studied later depending on resource availability. Table 3.6 lists the characteristics used in making this selection, and the species ranking in each category. Six tree species (*F. glaberrima*, *A. lakoocha*, *Citrus* spp,

Castanopsis, *Schima wallichii* and *Sapum insigne*) were grown by all farmers, but only the first two species were considered for priority research as the other four were not important as fodder for buffaloes.

Table 3.6 Purposely selected multipurpose fodder tree species and criteria applied by farmers for selection.

Desirable attributes	Fodder tree species			
	Al	Fb	Fg	Bb
Year round fodder supply	3	1	1	4
Soil conservation properties	4	2	1	3
Propagation through seeds	1	4	2	3
Propagation through cuttings	3	1	2	4
Biomass (kg)/ year	3	2	1	4
Preferred by farmers	1	4	3	2
Liked by animals	1	4	2	3
Raise milk yield in buffalo	1	4	3	2
Ease of lopping	4	1	2	3
Growth rate	1	4	3	2
Hardy to adversities	4	2	1	3
Overall score and Rank	26=B	29=C	21=A	33=D

Note: Rank by number: 1=Best, 2=Better, 3=Good, 4=Fair

Al = *Artocarpus lakoocha*; Fb = *Ficus benjamina*; F. *glaberrima* = *F. glaberrima*; Bb = *Bassia butyracea*

3.5 Discussion

3.5.1 Use of forage trees by farmers

Participatory workshops were instrumental for selecting suitable multipurpose trees for future research and development. Farmers' perceptions were based on centuries old experience of using fodder trees and hence useful for evaluating the trees species in required detail. It was concluded that palatable, nutritious and drought hardy evergreen fodder tree species will be helpful for the renovation of degrading hill farms. Before deciding to invest in large scale planting, it is important to prove comparative benefits of the different trees available. Farmers' methods of comparing the fodder trees are based on the effect of planted trees on understorey crops (Douglas *et al.*, 2006), animal intake of a particular fodder species and its effects on quality of health and

productivity. Quality factors known to farmers' were leaf age, season, texture, bitterness, toxicities, values, tree-crop interaction and degree of management needed to grow a tree to its full maturity. It was also apparent that some species were preferred by small ruminants while others were preferred by large ruminants. Therefore, species of animal and stage of lactation were important factors when deciding which tree species were to be harvested for the day. For example *Artocarpus lakoocha* is given only to lactating animals while *Sapium insigne* is given only to goats.

Price of browse is an important factor to be considered during the selection process, though buying and selling of fodder is a new practice at the research site. Browse is sold while on the trees and generally it is the responsibility of the buyer to climb the trees and cut and carry branches to required destinations where stall feeding is the main practice. Price is fixed by the number of Bhari's (approximately 30 kg bundle) of browse produced last year as it is difficult to estimate just by looking at the trees. Distance from the tree to where it is being used, quality and approximate weight of leaves, lopping dates and how easy it is to climb the tree (tree architecture) are the factors associated that affect the fodder price. Traditional practice of exchanging tree browse with 1 – 5 kg of ghee based on the size has now been replaced by selling in cash. Until 1990 only *A. lakoocha* was in high demand but, it was revealed at the workshops that after 1990 *Ficus glaberrima* also started fetching a commercial price.

Managing fodder tree on the risers and bunds of farmed land is complicated by wide differences in tree-crop interactions as crops under some species of tree canopy will be reduced in quality and quantity. Also, not all the domesticated trees have desirable attributes. Consideration of criteria in tree selection programmes based on farmers knowledge can be envisaged as resulting in explicit selection of species and genotypes that may be compatible with requirements for incorporation of trees into local farming systems (Thapa *et al.*, 1997b).

The great majority of tree species used by farmers are new to research and therefore, lacking in scientific data. Farmed land alone in Kalika-6, Sunpadali, Kaski, Pokhara recorded 27 species and the vast majority of other species are

in the forest which is beyond the scope of this study. Given the resource constraints, it was agreed by the workshop participants it is practical to select the top four species that have required characteristics for further research and development. By way of “learning by doing”, more species could be tested and promoted to establish trees in risers, bunds and degraded hills. High potential for further selection research is indicated by the existing biodiversity in the hills.

For selection and prioritisation of multi-use trees, most of the indicators of fodder quality were based on the applied environmental physiology of trees. These indicators were easily observed by farmers in the context of their experience, climatic stress and extreme environmental conditions. Some fodder quality characteristics defined by farmers can be easily inferred (for example coarse leaves and fodder palatability), while others could not (for example leaf bitterness and milk and/ or ghee production). *F. glaberrima* alone was classified by farmers on the basis of taste (bitter and sweet), thickness of leaves (thick and thin) and size of leaves (big or broad and small or narrow) and lustre of leaves (dark and light). Farmers’ perception was that smaller and darker leaves were the most palatable. This suggests a high degree of empiricism in farmers knowledge and that the indicators of tree fodder that they use may not be capable of differentiating new types of tree fodder or how to use existing types in different ways, therefore there is a need for alternative methods of evaluation involving use of animals for selecting the fodder and advanced chemical analysis to enhance the quality of selection (Thapa *et al.*, 1997b).

Multiuse is the main reason for preferring *F. glaberrima*. Over one million small farm families (Total: 4.98 million people) located mainly around western Pokhara Nepal are using *F. glaberrima* trees as fodder, firewood, fence material, fibre, furniture, minor timber, erosion control and conservation of soil nutrients. Thus, farmers started planting *F. glaberrima* to compensate for the fading forest resources and to renovate the degrading hill farming system. Traditionally, bigger size poles of *F. glaberrima* collected from tree forks in the forest while in the epiphytic stage of growth or rooted by layering (Tiwari, 1994) were planted along with fencing poles for lasting results.

Aiming to reduce the effects of land slides within the farm terraces in the hills, *F. glaberrima* is also planted on the risers and bunds. Land which is the neglected part of farm and generally not fit for repeated cultivation and other purposes is being used for planting *F. glaberrima*. Planting is common on areas that are steep and narrow and where it is difficult to make terraces using two bullocks harnessed with a wooden plough (Kshatri, 2003). Another reason for planting trees on steep land is to avoid fencing practices as the slope is too steep for large animals to reach.

During the 1970s all fodder tree plants were sourced from naturally grown seedlings from the forest. With declining forest and increasing demand for seedlings, some farmers have started nursery businesses.

Farmers have certain preferences regarding the fodder trees based on availability and quality of fodder during the dry season (Kharel, et al., 2000). *F. glaberrima* seedlings grown on a fork or holes of *A. lakoocha* (Al) and the *F. glaberrima* itself were uprooted and replanted. A tiny seed of *F. glaberrima* germinates on the fork of any tree and starts its life as an epiphyte (Kew, 2003) and establishes naturally after strangling the host trees. Host tree can be a common fodder tree or other species (Table 3.3). *F. glaberrima* is such an expertly epiphytic tree that it is selected by nature and thriving well in Himalayan foothills. So far no research has been done on any aspects of *F. glaberrima* and hence this is a pilot project to explore and describe the potential of *F. glaberrima* and open the door for further research on its multipurpose uses. The ultimate aim is to find ways and means of raising the primary production in hill farms.

3.5.2 Relevance of invasive species in restoring productivity of degraded hill farms

Some trees are better than others in terms of adapting to adverse climatic conditions and their multipurpose uses in resource poor areas of Africa and Asia. *F. glaberrima* is one such promising tree contributing to the household economy of small farmers. With respect to surviving and establishing by itself in adverse conditions, *F. glaberrima* clearly demonstrates its ability as the “Fittest tree in the poorest terrain”. However, *F. glaberrima* is said to be an invasive tree

within the forest. Those trees that are able to survive reproduce and spread unaided, and sometimes at alarming rates, across the landscape are said to be invasive (van Wilgen *et al.*, 2001). However, in Nepal farmers are getting more benefit than harm from epiphytic or invasive attributes of *F. glaberrima*. This study aims to evaluate and prioritise those trees that are commonly available in small farms, easy to grow and establish and are good for fodder, firewood, and natural conservation particularly in the harsh hill farms of Nepal.

Results clearly indicate that 100% of the focus group workshop participants representing resource poor small farmers from the hill farming system of Nepal are growing several kinds of trees for fodder, firewood, fencing material and minor timber purposes in their farmed land. It is obvious that without trees they cannot cook food and they cannot feed their stall confined animal as there is no alternative source available. Stall feeding has been the only option to keep animals in the hills of Nepal for the past three decades.

F. glaberrima is a “double standard tree” because it is a multipurpose tree for millions of farmers in Nepal (Kshatri, 2001), whereas for western ecologists, it is an invasive and strangling *Ficus* species (Corner, 1978). Invasive species and the ensuing homogenization of the world's biota, form a global problem with consequences ranging from the decline and extirpation of native species to threats to human health (Puth & David, 2005). However, as realised by the hill farmers in Nepal, it does not say anything about life saving properties of *F. glaberrima*. Thus it is hard to recognize and understand the differences between an invasive *F. glaberrima* tree becoming a multipurpose one. Advocating promotion of invasive *F. glaberrima* tree helps support the cause of generating livelihood in degraded hill farms. Therefore, this study focused mainly on comparisons of beneficial aspects of *F. glaberrima* with other fodder trees.

Establishing multipurpose trees is a low cost answer to the problems of degrading hill pasture that is leading to a chronic lack of animal feed. To provide lasting ecological services, users' involvement is vital at all steps of restoring productivity of degraded hill farms

Despite its multi-use, *F. glaberrima* potential for fodders has never been investigated; as a result no basis is available for comparing and prioritising the usefulness and research need of different trees being domesticated. Thus, knowledge gaps still remain as to what to plant, how to plant, where to plant and for whom to plant. These need to be solved before deciding further investment on large scale planting. Animals are ultimate users of selected tree fodder and poorly preferred species could decrease animal performance (McKinnon, *et al.*, 2000). Therefore, this research is a pilot project aiming to answer those primary questions during PhD study and open the door for further research on the usefulness of *F. glaberrima* and its role for revitalizing the collapsing hills and mountain ecosystem.

Animals, particularly buffalo in this case, are the end users of trees being selected. As a result sustainable production of milk, meat, draught-power for field traction and manure for fertilising the hill terraces is maintained. Thus, a buffalo is the most precious multipurpose animal in Nepalese households. The number of buffaloes owned by a farmer is indicative of his socio-economic status in the community.

Among several fodder trees naturally being grown in Sunpadali village of Kalika-6, Pokhara Nepal, a single tree of *F. glaberrima* can produce 800 kg fresh edible biomass per year inclusive of branches, twigs and leaves and continue to produce for over a 100 years. It takes 5 to 10 years before farmers can get their first lopping from a tree. Starting from a tiny seed in the nursery planting, protecting the seedlings, transplanting management and final establishment of an evergreen fodder tree takes time and money. A transect walk showed that about 50% *F. glaberrima* trees in Kalika-6, Sunpadali, Pokhara, Nepal were growing and establishing unaided. Also, farmers are actively participating in selection of suitable trees for reclamations of eroded land. At this point a simple modification of the traditional practice of growing *F. glaberrima* will hasten the efficiency of ecosystem reconstruction.

Based on farmers classifications and visual observations of clear differences in growth of new leaves in a particular date three distinct varieties of *F. glaberrima* were identified. These *Ficus* varieties imply that they can be lopped at different

dates supplying relatively balanced quality of leaves in terms of leaf age over a longer period of dry seasons.

3.5.3 Farmers views on time of lopping.

Workshop discussions on the time of lopping of tree fodder is as follows:

Table 3.7 Farmers perception of the time of lopping within a day and quality of fodder.

Farmers usually found to be lopping their fodder trees between 5am in the morning to 7pm in the evening. But there is no fixed time for lopping.

During the dry season when dry winds dehydrate tree leaves, time of lopping within a day has its role on health of standing tree and quality of browse lopped.

Farmers select a suitable time for lopping branches based on several factors which have direct effect on daily chores, such as cooking, sending children to school, fetching water and collecting firewood etc.

Browse lopped before noon (05 to 1200 hrs) lose considerable leaf moisture by evening which may change palatability, intake and possibly nutrients. If branches are lopped 5 am and given to buffaloes at 7pm, it exposes the leaves to dehydration for 14 hours making leaves very dry. Covering branches with straw mats soaked in water and also spraying water on fodder leaves will prevent such drying to some extent.

Afternoon (1200 to 1900 hrs) lopping reduces the leaf water loss by reducing exposure to the dry air.

In most cases freshly lopped branches are palatable and preferred over dried ones, whereas in cases of *Machilus odoretissima* (Kaulo) wilted leaves were preferred over fresh ones. It indicates that some species are preferred by ruminant animals after a period of wilting or seasoning.

To avoid the daily risk of climbing trees for lopping, *Artocarpus lakoocha* branches can be lopped once a week and continue to feed for 7 days to lactating buffaloes. However, browse needs to be stored in a relatively cold and protected area beyond the reach of dry wind and direct sunlight. Spraying of water on leaves and than covered with wet straw mat or gunny bags will prevent moisture loss from browse.

3.6 Conclusions

Focus group workshops were helpful to use farmers' indigenous knowledge for selection, identification and prioritisation of multipurpose fodder tree for further research and planting to provide lasting ecological services to them. The research recommendations based on the outcomes of the workshop discussions are summarised in Table 3.8.

Table 3.8 Practical research ideas identified during farmers participatory workshops for evaluation of fodder trees.

Method Evaluations based on users participations (Chapter 3)	1	Focus group workshops; Participatory Rural Appraisal (PRA) Farmers experience on multipurpose role of <i>Ficus browse</i> , its nutrition, biomass production and ease of propagation were discussed recorded.
Method Evaluation based on adoption to local environment (Chapter 4)	2	Biomass production: A comparison between <i>Artocarpus lakoocha</i> and <i>Ficus glaberrima</i> biomass in the hill farming system around Pokhara Nepal. 3 elevations x 2 species x 5 tree as replication.
Method Evaluation based on cheap and simple media for propagations (Chapter 5)	3	Low cost rooting media for propagation: coarse sand, commercial media and 50% by volume mixed sand and commercial media = 9 treatment combinations. 3x3 factorial RCBD. Effect of rooting media on rooting of <i>F. benjamina</i> cuttings and biomass production of two year old trees.
Method Evaluation using small ruminants' sheep (Chapter 5)	4	Sheep as ultimate users of browse selecting their best feed. <i>F. benjamina</i> , Poplar, and Willow as supplementary nutrition during drought. 3 species x 4 time offered unbalanced Latin square design. Leaf age and senescence of <i>F. benjamina</i> will be analysed against rooting media used for propagation
Method 5 Evaluation using large ruminants (Chapter 6)		Effects of <i>F. glaberrima</i> intake on milk quality of buffalo. Six lactating buffaloes will be fed on 3 treatment diets involving adlib amount of <i>F. glaberrima</i> (T1) adlib

	amount of <i>A. lakoocha</i> (T2) and 3kgDM <i>F. glaberrima</i> + rice straw up to appetite (T3), will be alternatively for three periods of 10 days with 10 days adoption for a total period of 60 days. Concentrate @ 1.5 kg/day will be given to all. Research Design: 2(3x3) Latin square for milk yield comparison.
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Most of the indicators of fodder quality were based on applied environmental physiology of trees which were easily observed by farmers during generations of practice in the context of their experience, climatic stress and extreme environmental conditions. Plant hardiness, ability of plants to produce higher biomass during the dry season, ease of propagation (epiphytic types) and effect of intake on quality of livestock product were basic indicators with a high degree of empiricism based on practice.

In conclusion, the top four fodder tree species prioritised for detailed study were: *F. glaberrima* (Fg), *A. lakoocha* (Al), *F. benjamina* (Fb) and *Bassia butyracea* (Bb). Research can be focused on the detailed study of these selected species so that millions of farmers practicing stall feeding with a cut and carry system will benefit.

CHAPTER 4

Evaluating fodder trees in Nepal after five decades of lopping

4.1 Introduction

This chapter is based on the users' participatory workshops and evaluation of nutritious fodder species described previously (Chapter 3), where the community need for selecting and prioritising the adapted multipurpose trees was highlighted. This study verified the farmers experience and evaluation of *A. lakoocha* and *F. glaberrima* by empirical means. Overexploitation of natural forest is creating havoc in the hill farming ecosystem in Nepal (Rajbhandary & Shah, 1981). Degrading land productivity has resulted in a severe lack of animal feed that has led livestock and forest researchers to search for and develop new methods of reviving the productivity of existing land (Banstola, *et al.*, 2003; Kshatri, 2003). Among 27 species found planted sparsely in the farmed land, the top two species selected for this study were, *A. lakoocha* and *F. glaberrima* as they are grown by almost 100% of small farmers in western hills (Chapter 3). To make sure that a tree can be lopped for 100 years, trees already lopped for the last 50 years or more and expected to live as many years more were evaluated using farmers workshops (chapter 3).

Therefore, this study will provide information to farmers, planners and decision makers that will assist in the judgment of the value of different fodder tree species. It will also identify the key factors on which decisions can be based to qualify tree species suitable for planting in the specific locations and quantify the proportion of species to be planted for reconstruction of the hill farming ecosystem. The aim here is to document the effects of altitude on diameter at breast height (DBH), canopy diameter (diameter = radius x 2), height of the tree and the edible biomass production and crude protein production per tree per year of established *F. glaberrima* and *A. lakoocha* trees aged 50 years and older in mountain ecosystems of Nepal. The result can be used to compare values of *F. glaberrima* and *A. lakoocha* and other fodder tree species available in the farmed land.

Specific objective: Comparisons of edible biomass production potential of *F. glaberrima* and *A. lakoocha* at different altitudes in Pokhara Nepal. This objective will be used to answer the following questions:

Are there any differences between two species in terms of quality, quantity and period of fresh biomass produced at different altitudes around Pokhara, Nepal?

Does *F. glaberrima* produce significantly higher edible biomass and crude protein in comparisons to *A. lakoocha* particularly during the driest months of March to June?

4.1.1 Reasoning for the selection of fodder tree species

The need for natural resource management and the challenge to feed the increasing population brings forward fodder trees as nature's sustainable alternative to livestock feeding (Kaphle & Devkota, 2000). In the farmland of eastern plain area of Jhapa and Sunsary district of Nepal, *A. lakoocha*, *Dendrocalamus* spp and *F. glaberrima* were among the top three preferred species (Upadhyay, 1992). Four reasons given for selection of *F. glaberrima* are ; 1) its abundance in the hill farms from time immemorial, 2) highest biomass production among fodder trees 3) relatively unaided spreading of species and 4) resistant to continuous lopping for five or ten decades. The reason for selecting *A. lakoocha* as the most preferred fodder species (Upadhyay, 1992) was its ability to increase milk yield when fed to lactating buffaloes (Personal communication with workshop farmers on 12 March 2005). Planting a tree has a life long beneficial effect in the household economy of farmers. Thus, it is better to make informed decisions and plant the right species than to regret it later. The meagre information available on tree fodder is not adequate to make informed decisions and farmers are planting different types of fodder trees on their farmed land (Kshatri, 2003) without knowing their quality. This chapter explains the physical indicators such as tree trunk diameter at breast height (DBH), canopy diameter, tree height and edible biomass production per tree. In addition, there is a brief qualitative explanation on the effects of canopy on understorey forage production, which helps value judgement between *A. lakoocha* and *F. glaberrima* in the hill farming ecosystem of Nepal and decide farmers to suitable species to plant in their farms.

4.1.2 Location

The research site was located 210 km west of Kathmandu, about an hours walk from the gravel road. The precise address is Sunpadali, Kalika-6, Kaski Pokhara Nepal. Elevations covered by this research were 800 to 1440 masl (1000 ± 500m). This midhills area has a concentrated population of humans and animals (Rajbhandary & Shah, 1981). Traditional manual cultivation is a common practice and there is no mechanisation of any kind at the research site.

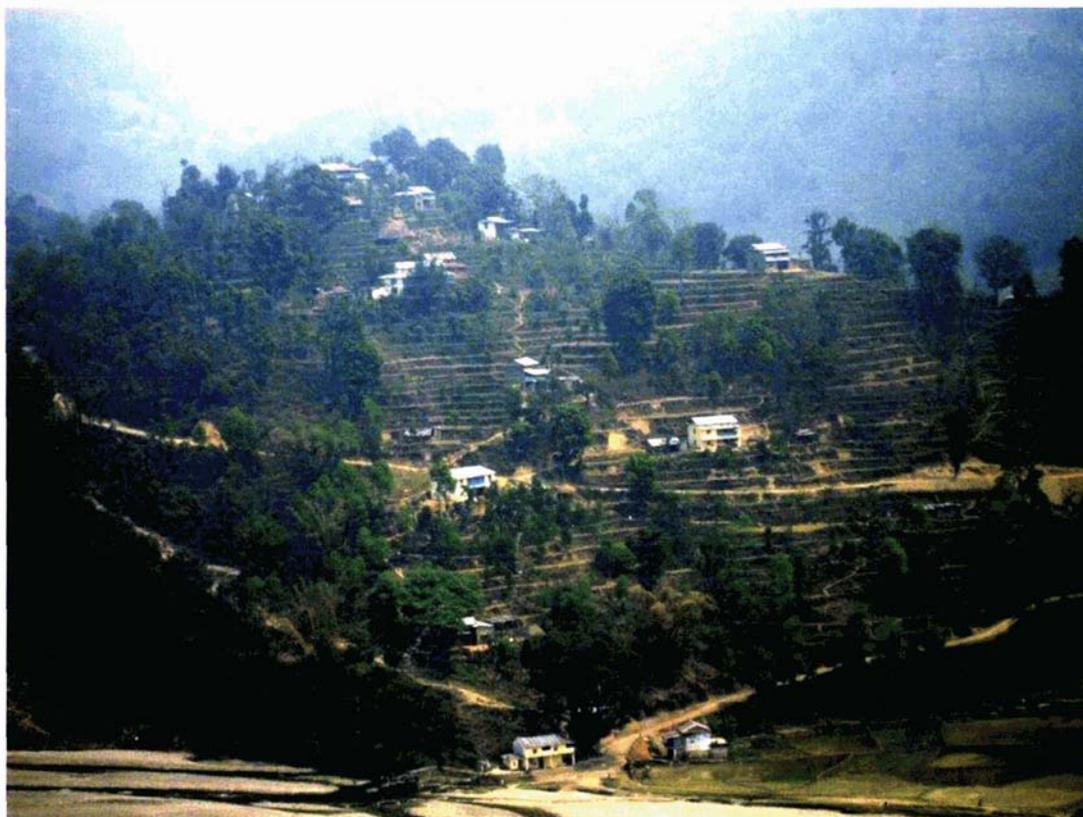


Plate 4.1 Research site, Sunpadali village in Kalika-6, Pokhara, Nepal located at 800 to 900 masl. Sparsely planted fodder trees can be seen in terraced farm.

4.1.3 Soils

The surface soil and subsoil is red greyish-brown fine sandy loam but compact. Organic matter is low and fertility is low. The soil is mainly acidic and pH is less than 5 in most areas. Rainwater run-off is a problem, which does not allow time to percolate water to root zones. Erosion is a serious hazard.

4.1.4 Climate

Average annual precipitation in Pokhara Nepal is based on time of arrival of monsoon and varies with months (see Map 2 in Appendix 2). In the years 2000

to 2003, most rain was found concentrated in six month from May to October. Highest rainfall of 89 cm was received in August and lowest of 17 cm was received in October. Pokhara receives the highest annual rainfall in Nepal. The average annual rainfall is about 3,580 mm and it occurs mainly from May to September (Bogati, 2006). Likewise lowest and highest yearly average temperature varied between 3 to 37° C in Pokhara. The experimental area receives some frost each year. Temperature in landlocked mountain terrain is a determinant of biomass production (see Map 5 in Appendix 2 0). A difference of 100 m in altitude yields $\pm 0.5^{\circ}$ C difference in environmental temperature. Winter is cold and dry and summer is hot and wet.

4.2 Methods

4.2.1 Altitude stratifications

Three altitude strata were identified in the hill farming system each strata having 200 masl differences (see Map 2 in Appendix 2). The highest and the lowest altitude where both species of trees were found were 1440 m and 800m, respectively. Thus the experiment was scattered over 640 m altitude in the hill farming ecosystem of Pokhara. Altitude strata were divided as follows with highest strata having 240 m compared to 200 m for medium and lower strata (Table 4.1).

Low altitude below 800 to 1000m

Medium altitude 1000 to 1200 m

High altitude 1200 to 1440 m.

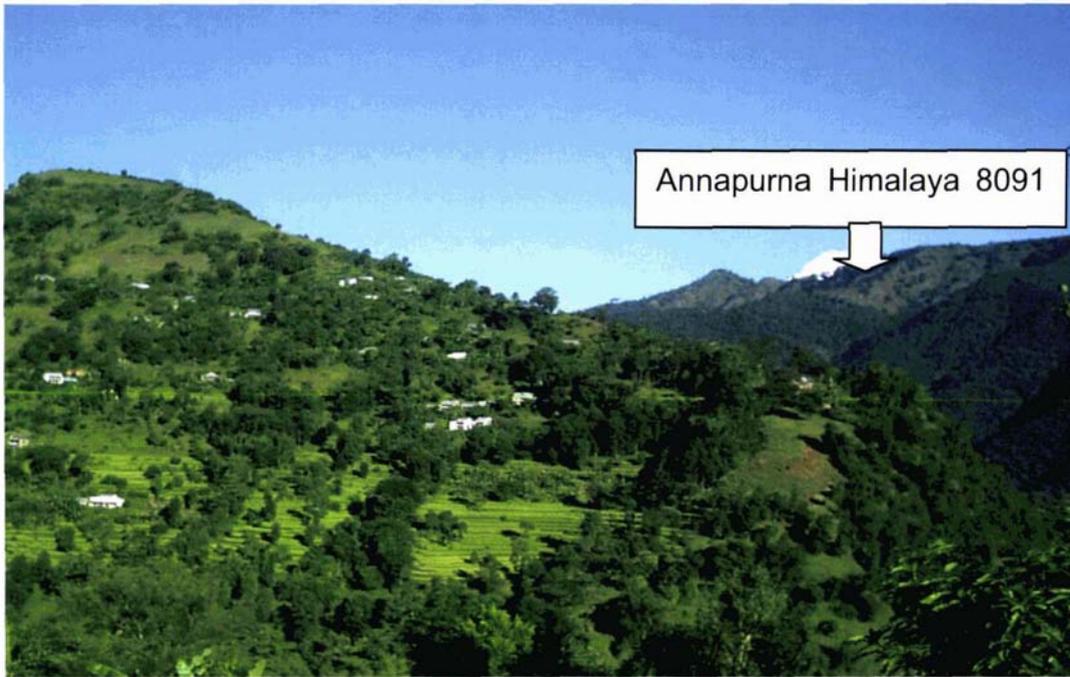


Plate 4.2 Silvipastoral system facing Southeast in western hills of Arba-6, Amalachaur, Kaski, Pokhara Nepal.

4.2.2 Survey in Pokhara Nepal

Survey area selected was ward no-6 of Kalika, Village Development Committee (VDC). Midhill farms represent the common hill village conditions typical to hill farming system of Nepal (Pariyar, 2006). Average population and area of Kalika VDC is 4428 and 24.7 square km (Bogati, 2006), respectively. The difference in elevation from Garkate, Bijayapur Khola (800m) Kalika-6 to the top of Kalika-Kot (1440m) was 640m. To stratify the altitude into three belts, with equal number of *F. glaberrima* and *A. lakoocha*, a survey was conducted by trekking and visits to farmers' homes from all strata of the hill farming ecosystem. The visits were continued until 27 trees of *F. glaberrima* and 27 trees of *A. lakoocha* were identified and procured for the experiment.

A total of 54 trees (9 trees x 3 altitudes x 2 species of fodder trees) were procured. All trees identified were above the age of 50 years in the mountain ecosystem of Pokhara Nepal. Tree fodder selection criteria associated with year round supply of fodder, higher DM production per tree per year and ease of lopping were highlighted in chapter 3. Tree age was determined by the farmers' discussion in workshops.

4.2.3 Experimental design

Table 4.1 Trial arrangement in split plots with three blocks (altitudes) for evaluation of edible biomass production from 50 years old trees growing in 30° – 70° slope land between 800 – 1440 m (metre above sea level = m) in the hill farming system of Nepal.

Altitudes	Trees	Block-A	Block-B	Block-C
1200 to 1440	<i>A. lakoocha</i> (Al)	Al1,Al2,Al3	Fg1,Fg2,Fg3	Al1,Al2,Al3
	<i>F. glaberrima</i> (Fg)	Fg1,Fg2,Fg3	Al1,Al2,Al3	Fg1,Fg2,Fg3
1000 to 1200	<i>A. lakoocha</i> (Al)	Fg1,Fg2,Fg3	Al1,Al2,Al3	Fg1,Fg2,Fg3
	<i>F. glaberrima</i> (Fg)	Al1,Al2,Al3	Fg1,Fg2,Fg3	Al1,Al2,Al3
800 to 1000	<i>A. lakoocha</i> (Al)	Al1,Al2,Al3	Fg1,Fg2,Fg3	Al1,Al2,Al3
	<i>F. glaberrima</i> (Fg)	Fg1,Fg2,Fg3	Al1,Al2,Al3	Fg1,Fg2,Fg3

Note: Al1, Al2, Al3 and Fg1, Fg2, Fg3 indicates three trees in each plot

4.2.4 Data analysis

The data collected were analysed by simple split-plot analysis of variance (ANOVA) using RCBD with fixed blocks in the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 2001). A split plot design, with three replicate blocks; comprising altitude as main plot and species as subplot was used to analyze the effect of altitude on tree diameter at breast height, canopy radius (diameter = radius x 2), tree height, yield of edible biomass and crude protein per tree. Separation of means was based on altitude and species and subjected to test at 5 % level using least significance difference (LSD) technique. Also, Microsoft Office Excel was used to prepare and manage the data before analysis using SAS. A total of 54 sample observations that including 27 each for *A. lakoocha* and *F. glaberrima* were taken for analysis.

4.2.5 Lopping period

Generally, lopping of trees for fodder purpose is a year round activity of rural farmers in Nepal with low frequency during summer when grass is abundant (Chapter 3). The main lopping period starts from 30 September (15th Asoj = Nepali month) this is when monsoon rain stops and dry and cold winter starts. Pastures and farms in the hills become brown and dry and hence nothing green is left on the ground for grazing animals. Farmers need to manage animal feed resources based on what is available. Then farmers start lopping deciduous

fodder tree first, saving the evergreen tree as a future security to be used during the driest months of March to June in the following year.

Since the feeding value (Chapter 6) of evergreen *F. glaberrima* is being compared with deciduous *A. lakoocha*, this experiment had to be completed before February. After February leaves of the deciduous browse species *A. lakoocha* will not be available. Therefore, lopping period for *A. lakoocha* is limited to 6 months between September to February, whereas *F. glaberrima* can be available for rest of the dry period.

4.2.6 Quantification of edible fodder biomass per tree

Quantification of browse produced by each fodder tree was by weighing the fodder lopped for stall feeding animals. In case of *A. lakoocha*, leaves dropped while lopping were collected in a gunny bag and recorded as part of edible biomass produced per tree. There was no problem of collecting dropped leaves in evergreen *F. glaberrima*.

In this experiment the lopping of *A. lakoocha* was started on 23 November 2004 (08 Mangsir) and continued for 110 days until 12th March 2005 (29 Phagun) beyond which the nutritional quality of leaves will be inferior as they mature. Normally shedding of *A. lakoocha* leaves is completed by the end of March. For efficient utilisation of leaves, farmers finish lopping and feeding one month before 12th March (29 Falgun).

4.2.7 Identifying the age of the trees for research

Age of the tree was identified based on owners report and those farmers older than 60 years of age as witnesses; no records were available as to when the trees were planted.

4.2.8 Measurements of tree components

Five main components of tree architecture were measured: trunk diameter at breast height (DBH), branch extension (canopy radius), tree height, edible biomass and crude protein production per tree per year were measured.

Edible biomass of the tree mainly includes small twigs with leaves, figs and bark on them. Large ruminants such as lactating buffaloes can eat thick diameter

twigs. Length and diameter of twigs considered edible in this case vary from 30 to 100 cm in length and 0.2 to 1.9 cm in diameter, respectively. As per prevailing common practice in the midhills of Nepal, lopping percent varies with species where 100% twigs of *A. lakoocha* and 80 to 90% twigs of *F. glaberrima* will be lopped. A fodder tree could be lopped over a day or it may take a couple of weeks or a month depending upon the size of fodder tree and the number of animals to feed on the browse. Diameter at breast height (DBH) was measured at 4.5 ft (1.37 m) above ground level. Specially calibrated tape called a diameter tape supplied by Global Supply Ltd; Germany was used.

4.2.8.1 Branch extension

Extension of tree fodder branches was measured as a radial distance from the base of the tree to the perimeter of the canopy. Measuring tape (100 m capacity) was used for this purpose. "Canopy diameter" and "diameter = radius x 2" were used to express the horizontal growth of branches.

4.2.8.2 Height of the fodder tree

Slope/height of the tree was measured using a clinometer (SUUNTO Tandem combination compass/clinometers). Upper and lower angles observed on top and base of the tree were recorded. Also distance between centre of the base of tree trunk and feet of the observer was taken. Then the heights (H) of the tree were calculated using Pythagoras formulae (Figure 4.1).

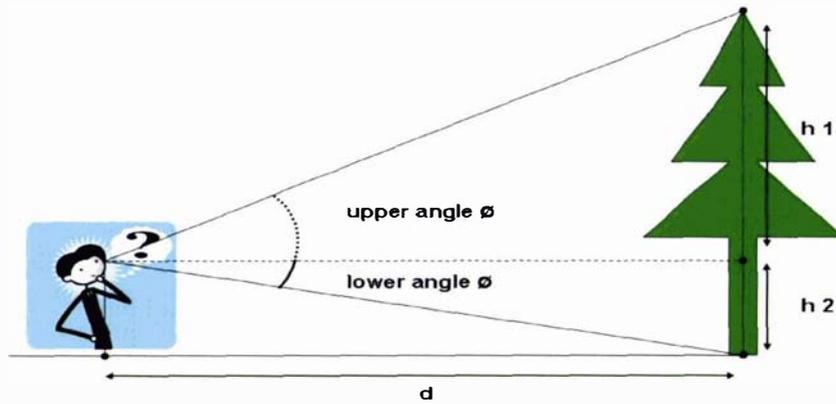


Figure 4.1 Measurement of tree height and formulae used.

Where,

$$\tan \text{ upper} = \frac{h1}{d}, h1 = \tan \text{ upper} \times d$$

$$\tan \text{ lower} = \frac{h2}{d}, h2 = \tan \text{ lower} \times d$$

h1	=	tree height above the eyes of the observer
h2	=	tree height below the eyes of observer
d	=	distance from the observer to the centre of the trunk
H	=	tree height
tan	=	table value of clinometers reading (upper or lower angle)

4.2.8.3 Edible biomass production per tree

Weight was taken using a spring balance with capacity to weigh up to 100 kg. Fifteen samples from each species were oven dried and weighed for DM analysis (ISO-6496, 1999). Total browse that included leaves and edible small branches and figs produced by each tree were lopped, weighed and recorded before feeding to buffaloes.

4.2.8.4 Crude protein (CP) production per tree

Fodder samples were collected from 15 trees each from *A. lakoocha* and *F. glaberrima* species and analysed using Kjeldahl methods (ISO-8968-1, 2001). Means of 15 observations were used to convert the DM of 27 trees into CP production kg/tree.

4.2.9 Manpower for lopping

Cut and carry and stall-feeding is the current system for keeping animals and needs a considerable number of skilled farmers for lopping. Lopping is a day-to-day chore of hill farmers in Nepal. For many generations until today, manual lopping is done by climbing the tree. Generally, climbing a tree is a job of a young and skilled man, because, women,+ children and elderly farmers cannot climb the trees. In absence of lopping manpower, fodder in the trees becomes useless. Use of harness for safety reasons is not known in the area. In many cases a single pole of bamboo used as a ladder to climb the first three to six meters of the tree which is difficult part of tree to climb. A tree growing in the hill slope needs specialised skills, for climbing and lopping safely. An experienced farmer takes eight hours to lop a 50 years old tree.

4.2.10 Transporting the browse by farmers

Transporting browse from trees to the animal shed was done by carrying on the back of the farmers. Edible portion of fodder branches with leaves were bundled into 20 to 60 kg packs based on the interest and the carrying capacity of a person and put on the back with a supporting flat rope (Namlo) on the head (Plate 4.3). Distance between trees to the shed varied from 2 to 20 km both ways walking generally up and down hills. Women and men are involved in the transportation.

Only a few fodder trees were located near the shed. Most of them were scattered over farms. Typically, farmers holding a hectare land may have his land scattered over 10 different areas with a 1000 square meter land in each place. Holding scattered pieces of land is a traditional common practice in the hill farming ecosystem.



Plate 4.3 Carrying *A. lakoocha* fodder from tree to buffalo shed.

4.3 Results

Table 4.2 Diameter at breast height (DBH) of *A. lakoocha* and *F. glaberrima* at different altitudes in a hill farming ecosystem of Nepal.

Tree Species	Altitude (masl)	Mean DBH (cm)
<i>Artocarpus</i>	1200 - 1440	52.6
<i>Artocarpus</i>	1000 - 1200	46.5
<i>Artocarpus</i>	0800 - 1000	43.3
<i>Ficus</i>	1200 - 1440	73.3
<i>Ficus</i>	1000 - 1200	73.2
<i>Ficus</i>	0800 - 1000	94.9
SEM (Species x altitude)	5.4	
		Probability
Species		0.0001
Altitude		0.231
Species x altitude		0.0168

SEM: standard error of the least square means

4.3.1 Diameter at breast height (DBH) + Carrying diameter

There was a significant interaction between species and altitude on DBH of the fodder trees ($P=0.0168$). *F. glaberrima* at lower altitude had a significantly higher DBH ($n = 9$) than the DBH of *A. lakoocha* (Table 4.2).

There was a significant ($P=0.0001$) effect of species on DBH with a mean DBH of 80.5 cm for *F. glaberrima* compared to DBH of 47.5 cm for *A. lakoocha*. There was no significant effect of altitude on DBH growth of fodder trees. The main effect is species related.

Table 4.3 Canopy radius of *A. lakoocha* and *F. glaberrima*.

Tree Species	Altitude (masl)	Canopy radius (Mean Branch Ext. (m))
<i>Artocarpus</i>	1200 - 1440	3.8
<i>Artocarpus</i>	1000 - 1200	4.1
<i>Artocarpus</i>	0800 - 1000	3.5
<i>Ficus</i>	1200 - 1440	4.7
<i>Ficus</i>	1000 - 1200	5.7
<i>Ficus</i>	0800 - 1000	7.2
SEM (Species x altitude)		0.5
		Probability
Species		0.0001
Altitude		0.1275
Species x altitude		0.0327

SEM: standard error of the least square means

There was a significant interaction ($P=0.0327$, Table 4.3) between species and altitude on the canopy radius of trees during the survey period. Significantly, a wider canopy diameter was found for *F. glaberrima* trees at low altitude whereas similar canopy diameter was found for *A. lakoocha* trees at mid and high altitudes.

There was a significant effect of species on branch extension (diameter = radius x 2) of tree species ($P=0.0001$). The mean canopy radius ($n=27$) of *Ficus* was 5.9 m compared to 3.8 m for *Artocarpus*.

There was no significant effect of altitude on canopy growth of species of fodder trees ($P=0.1275$).

Table 4.4 Tree height of *A. lakoocha* and *F. glaberrima*.

Tree Species	Altitude (masl)	Fodder tree height (m)
<i>Artocarpus</i>	1200 - 1440	16.7
<i>Artocarpus</i>	1000 - 1200	17.9
<i>Artocarpus</i>	0800 - 1000	17
<i>Ficus</i>	1200 - 1440	13.4
<i>Ficus</i>	1000 - 1200	16.5
<i>Ficus</i>	0800 - 1000	16
SEM (Species x altitude)		0.8
		Probability
Species		0.0094
Altitude		0.0422
Species x altitude		0.3818

4.3.2 Height of the tree

No significant interaction effect between altitude and species was found (Table 4.4) on the height of the tree during the survey conducted within September 2004 to March 2005.

There was a significant effect of species on height of the fodder trees ($P=0.0094$). For example, *A. lakoocha* was significantly taller than *F. glaberrima* trees with a mean tree height of 17.2 m and 15.3 m respectively (LSD = 1.3 m, and, $n=27$).

Altitude had a significant effect on tree height ($P= 0.0422$). Mid and low altitudes had taller trees compared to high altitude ($17.2=16.5 > 15.0$ m, ($n=18$) respectively).

Table 4.5 Edible biomass production of fodder trees (DM kg/trees).

Tree Species	Altitude (masl)	Mean Biomass (DMkg/tree)
<i>Artocarpus</i>	1200 - 1440	84.9
<i>Artocarpus</i>	1000 - 1200	86.3
<i>Artocarpus</i>	0800 - 1000	90.8
<i>Ficus</i>	1200 - 1440	84.4
<i>Ficus</i>	1000 - 1200	106.6
<i>Ficus</i>	0800 - 1000	154.4
SEM (Species x altitude)		14.3
		Probability
Species		0.0225
Altitude		0.0347
Species x altitude		0.0864

4.3.3 Biomass production (Dry matter (DM) kg/tree)

There was no significant interaction effect between altitude and species on the fodder biomass production ($P=0.0864$, Table 4.5).

There was a significant difference in biomass production between tree species. *F. glaberrima* produced significantly more ($P=0.0225$) biomass than *A. lakoocha* (Table 5). Overall mean ($n=27$) fodder biomass per tree per year from *F. glaberrima* was 115 kg compared to 87 kg for AI (LSD = 12.13 kg).

Table 4.6 Crude protein (CP) production kg/tree/year.

Tree Species	Altitude (masl)	Mean CP (kg/tree)
<i>Artocarpus</i>	1200 - 1440	10.9
<i>Artocarpus</i>	1000 - 1200	11.1
<i>Artocarpus</i>	0800 - 1000	11.6
<i>Ficus</i>	1200 - 1440	8.1
<i>Ficus</i>	1000 - 1200	10.3
<i>Ficus</i>	0800 - 1000	14.9
SEM (Species x altitude)		1.5
		Probability
Species		0.9549
Altitude		0.0545
Species x altitude		0.1499

Altitude had a significant effect on biomass production of fodder trees. Low altitude produced significantly higher overall mean compared to high altitude (122.6 > 84.7 DM kg/tree/year). DM production of 96.4 kg per tree per year at mid altitude was statistically similar to DM production at low and high altitude (n=18 and LSD = 27.79).

4.3.4 Crude protein (CP) production per tree

There was no significant interaction between altitude and species on CP production (Table 4.6) by the fodder trees (CP kg/tree).

There were no significant differences in the amount of CP produced by a tree of *A. lakoocha* (11.23 kg CP per tree/year) and *F. glaberima* (11.15 kg CP per tree/year). There was a significant difference in the CP production (kg/tree/year) between low and high altitudes. However, CP production was statistically similar for low and mid altitudes (Table 4.6).

Contrasts in species and altitude explained from 29% (CP production) to 68% (DBH) of the observed variation in tree characteristics (Table 4.7.)

Table 4.7 Dependent variables, means, R-square values and coefficient of variance calculated by SAS GLM procedure (n=54) using independent variable altitude and species (altitude = high, mid and low and species = *Artocarpus* and *Ficus*).

Dependent variables	Mean	Standard deviation	r ² value (*)	Coefficients of variance
DBH (cm)	63.9	23.9	0.68	25
Canopy radius (m)	4.8	1.9	0.54	32
Tree height (m)	16.3	2.6	0.38	15
Edible biomass (DM kg/tree)	101.2	45.0	0.38	42
Crude protein (CP kg/tree)	11.2	4.5	0.29	41

* Proportion of total variation explained by species and altitude contrast.

Table 4.8 summarises the species and altitude contrasts in canopy area per tree, together with calculations of the potential number of trees per hectare for each species / altitude combination assuming complete canopy cover.

Table 4.8 Canopy radius, tree/ha, perimeter, canopy area, and kg DM/tree of *A. lakoocha* and *F. glaberrima* in the hill farming ecosystem of Nepal

Species	Altitude	tree/ha	C-Area
<i>Artocarpus</i>	1200-1440	222	45
<i>Artocarpus</i>	1000-1200	189	53
<i>Artocarpus</i>	0800-1000	263	38
<i>Ficus</i>	1200-1440	145	69
<i>Ficus</i>	1000-1200	98	102
<i>Ficus</i>	0800-1000	61	163

C-Radius = Canopy radius, C-Area = Canopy area in square meter (see map 3 & 4 in Appendix 2).

4.4 Discussion

Edible biomass productions reported in this study are based on kg DM/tree because there is less than 0.5 ha per capita and trees sparsely planted in farmed land in the hills of Nepal. Review shows that 250 species (D. Subba, 2001) of fodder tree were used in Nepal followed by 84 species in India (Misri, 1998), and 28 species in Bhutan (Roder, *et al.*, 1998). In Greece, the species studied included six shrubs: *Amorpha fruticosa* L., *Carpinus orientalis* Mill, *Colutea arborescens* L., *Corylus avellana* L., *Fraxinus ornus* L. and *Ostrya carpinifolia* Scop.; and four trees: *Pirus amygdaliformis* Vill., *Quercus pubescens* Wild., *Quercus sessiliflora* Salish. and *Robinia pseudoacacia* (Papanastasis, *et al.*, 1997). Total edible biomass was about 50% and decreased as the age of plants increased. Repeated annual cutting resulted in significant reduction of both height and total biomass by 51% and 88%, respectively, as compared with uncut plants at the end of the eighth year, and hence cutting or grazing should not start earlier than the third year after establishment (Papanastasis, *et al.*, 1998). In New Zealand browse blocks are created by planting poplar and willow resulting in double storey fodder production systems involving understorey pastures and upper storey browse trees (Sulaiman, 2006).

Planting trees in farmed land creates a new set of ecosystem services for stall feeding animals and generates jobs of skilful climbing and lopping in a way that a tree keeps producing edible biomass for longer than 100 years. Anecdotal evidence, existing farmers practices and author's 30 years experiences in hill

farming system of Nepal suggest that *F. glaberrima* and *A. lakoocha* can sustain the first lopping when tree gets about 3 to 5 m height at 3 to 10 years of age. Age difference at first lopping depends on the plant species and soil resources available to a newly planted sapling. Lopping 50% to 100% crown height of three year old *F. semicordata*, *Litsea monopetala*, *F. auriculata* and *A. lakoocha* did not effect the total fodder and wood production (Karki & Gold, 1994). This indicates that three years is old enough to sustain lopping. The purpose of the first lopping is to provide the desired shape and also to induce foliage growth and lateral branching (Karki, 1994). Tree research particularly in the diverse conditions of Nepal is complex, time consuming, expensive and generally comes with a high degree of variation that discourages researchers and hence no information is available to compare edible biomass yield of trees older than 50 years. Coefficient of variation (CV %) in this study varies from 15 to 42 % (Table 4.7) for tree height and edible biomass production, respectively. Another biomass yield study of *F. glaberrima*, *F. semicordata* and *Gauzuma ulmifolia* found that the CV varies from 33.8 to 85.5 % (Amatya, 1992).

Reports available in Nepal use fresh matter (kg/tree/year) instead of dry matter (DM) without specifying the age and the size of the trees. Some reports do not even specify the fresh or dry matter produced by a tree species. For example, leaf biomass yield of 50–90 kg per tree per year with *Ficus locar* producing considerably more (150 kg/tree/year). In this thesis biomass production is reported on a dry matter basis.

In Bhutan *F. auriculata* fodder yield increased with age and at four years it produced 25 kg fodder/tree whereas at 25 years of age fodder and fuel wood production was 210 kg and 145 kg fresh weight/tree/year found respectively (Pariyar, 2006). Similarly, average annual fresh yield per tree was reported as 200, 120, 112, 108, 108 and 96 kg for *F. auriculata*, *A. lakoocha*, *Gmelina arborea*, *F. cunia*, *Litsea monopetala* and *Stereospermum suaveolens*, respectively (Roder, et al., 2003). These results are not reliable for comparison to the results presented here because Roder et al., (2003) ignored DM, edible twigs and age of the trees while quantifying the tree fodder production.

Regarding the growth rate, the earliest empirical accounts of ten commonly grown fodder tree species in Nepal that includes *A. lakoocha* and *F. glaberrima* are those given by Karki and Gold (1992) for three year old trees. Results from Karmaiya, Hetauda, Rampur, Pokhara1 and Pokhara2 suggest that *A. lakoocha* and *F. glaberrima* rank 9th and 10th out of ten species tested mainly for their growth, biomass, height and diameter. *F. semicordata* (FS) was tallest with 4.8 m followed by *Leucaena leucocephala* (LL) 4.5 m, *Bauhinia variegata* (BV) 3.6 m, *Morus alba* (MA) 2.9 m, *Bauhinia purpuria* (BP) 2.9 m, *Litsea monopetala* (LM) 2.3 m, *F. auriculata* (FA) 2.3 m, *Premna integrifolia* (PI) 1.8 m, *A. lakoocha* (AL) 1.8 m and *F. glaberrima* (GG) 1.8 m (Karki & Gold, 1992). For *F. glaberrima* tree height growth of 1.77 m at the age of 17 month was achieved in Thailand (Elliott *et al.*, 2003), whereas, in four years *F. glaberrima* grew more than 2 m high in Adhabar Bara district, Nepal (Amatya, 1992).

Edible fodder biomass production of trees is a new concept in Nepal and elsewhere. Foliage biomass of 0.4 kg and 0.6 kg and wood weight of 0.7 kg and 1.0 kg for *F. glaberrima* and *A. lakoocha*, respectively, and the highest foliage weight of 4.9 kg and wood weight of 9.9 kg for *F. semicordata* was reported (Karki & Gold, 1992). A study conducted in Montreal Botanical Garden to study the biomass production of *Salix* species found that, trees harvested two years after planting produced about twice the total biomass of trees harvested twice, that is, at the end of each growing season, suggesting that a two-year cycle is more productive than a one-year cycle (Labrecque, *et al.*, 1993). Common farmer practice in Nepal is one cut per tree per year for both. *F. glaberima*, an evergreen tree lopped as and when needed, and *A. lakoocha*, not available during the deciduous period that includes dry months of March to June. Farmers with lactating buffalo lop the *A. lakoocha* tree first as it is considered to be more nutritious and to raise the milk yield, particularly when there is no green grass available.

Farmers without a lactating buffalo will sell the *A. lakoocha* tree to a farmer who has lactating buffalo. Farmers decide date of early and late lopping of *A. lakoocha* based on (a) having and not having a lactating buffalo (b) date of calving of buffalo (c) availability of farmers interested to buy fodder. Farmers

consider *A. lakoocha* as nutritionally superior fodder for lactating animals and hence rarely feed it to sheep, goat, dry cows and buffaloes.

A. lakoocha (Al) and *F. glaberrima* (Fg) trees lopped for 50 years and expected to last for another 50 years were evaluated in this study. Analysis of five dependent variables, DBH, branch extension (canopy diameter = radius x 2), total biomass production per year per tree, and crude protein (CP) production kg per tree clearly showed that *F. glaberrima* was superior in terms of greater DBH ($P=0.0001$), canopy extension ($P=0.0001$) and biomass production ($P=0.0014$) to *A. lakoocha* across the three altitudes under study.

The DBH of *F. glaberrima* was nearly double that of *A. lakoocha* across the hill farming ecosystem. Within species, the DBH of *F. glaberrima* was highest at lower elevation but was not significantly different at mid and high altitude 800 and 1440 masl. Contrastingly, the DBH of *A. lakoocha* at higher altitude was significantly greater whereas there was no difference in DBH of *A. lakoocha* at mid and low altitude. This is a pioneering study and no literature was available to compare these results. The shapes of tree trunk at breast height were cylindrical and regular for *A. lakoocha*, whereas for *F. glaberrima* the trunks were mostly irregular in shape which may result in an over estimation of DBH. Those *F. glaberrima* trees, which established as an invasive epiphyte, in particular, have irregular limbs as contributed by aerial roots that develop into trunks over a period of five or more decades.

Number and length (canopy) of branches contributed positively to a significantly higher DM content but a similar amount of CP production per tree in *F. glaberrima* than *A. lakoocha*. Intraspecific and interspecific differences in CP and other nutrients in fodder trees have been reported (Tiwari, 1994; Wood *et al.*, 1995; Wood *et al.*, 1994). During the dry months of Chaitra and Baisakh CP was 10% and 8% in *F. glaberrima*, whereas no CP was available from *A. lakoocha* due to its deciduous character (Kaphle & Devkota, 2000). Visual observation suggested that the number of branches in *F. glaberrima* was considerably greater than that on the *A. lakoocha*.

Fodder trees lopped over 50 years have nearly similar features. The shape, size and longevity of farmed fodder trees depends partly upon the position of roots, distance from moisture, frequency and quantity of biomass removed by lopping each year from a tree and the quality of lopper used during past 50 years. A blunt sickle used for lopping is likely to cause more damage to the trees than a sharp lopper.

In this experiment the lopping of *A. lakoocha* and *F. glaberrima* was started on 23 November 2004 (10 Poush) and continued for 110 days until 12th March 2005 (29 Falgun). For efficient utilisation of leaves before the start of senescence, farmers finish lopping and feeding of *A. lakoocha* one month before 12th March. Original farmer's practice was to finish *A. lakoocha* lopping before 12 February (within Nepali month of Magh), after that considerable number of leaves will fall off due to the impact of striking while cutting branches using a sickle for lopping. The whole tree will be shaken to some degree during cutting. Main causes of losing leaves from branches being cut off are, 1) Impact of sickle and branches while lopping, and 2) impact of falling on the ground from fodder tree up to 15 or 20 meter high above ground level and the 3) impact of cut off branches hitting understorey branches on the trees.

Late lopping of *A. lakoocha* needs extra labour to collect dropped leaves and hence the lopping is more cost effective, if done before the second week of February in western Pokhara Nepal, which stops further lignification and leaf drop.



Plate 4.4 Rice growing under canopy of *F. glaberrima*, Kalika-6, Sunpadali, Kaski, Pokhara Nepal.

4.5 Conclusions

The result of this study clearly demonstrated that *F. glaberrima* has significantly higher DBH, CR and DM production than *A. lakoocha*. However, *Artocarpus* produced significantly taller trees than *Ficus*. In contrast to previous assumptions of farmers and researchers in Nepal, *A. lakoocha* was inferior to *F. glaberrima* in terms of total amount of edible DM and CP production per tree per year. These results will serve as a standard decision tool for examining whether a tree species is better than *A. lakoocha* and *F. glaberrima*. To produce significantly higher amount of DM and equivalent amount of CP as that of *A. lakoocha* per tree per year, it is recommended that more *F. glaberrima* trees are planted at altitudes in the region of 1000 masl.

Considering the current importance of *F. glaberrima*, it is imperative to carry out research exploring its potential in evolving production systems and to quantify the opportunities for improving its nutritional quality and productivity through selection and research.

CHAPTER 5

Sheep preferences for *Ficus benjamina*, Poplar and Willow

5.1 Introduction

Lack of green fodder for livestock particularly during dry periods is a global problem (Roder *et al.*, 2003). Fodder trees are an integral part of the farming system that forms the low cost protein and energy sources of ruminants in the hills of Nepal (Subba, 2001). Many species of trees are used as fodder in the tropics, especially in the dry season, when there is always a scarcity of grass and herbaceous legume forage (Bamikole, *et al.*, 2004). In Nepal 20 to 40 % of the feed requirement is met by tree fodder (Amatya, 1990; Kshatri, 2003; Pariyar, 2006). In Bhutan the contribution of tree fodder to the total ruminant feed requirement is 20% (Roder *et al.*, 1998). In the middle Himalayan hills of India, fodder trees and shrubs contribute green forage to the extent of 10 – 15% during monsoon; 80% during winter and 60% in summer (Misri, 1998). Fodder trees have potential to remain green and so form a good source of dry-season feed for animals. (Bamikole, *et al.*, (2004) noted that the inherent value of browse trees lies in the provision of protein, vitamins, and frequently also the mineral elements that are lacking in grassland pasture during dry season. Willow and poplar were superior to drought pasture diet, with a higher N content, OMD and ME (McWilliam *et al.*, 2005). However, such basic information is lacking for the 250 different tree species being fed to ruminants in Nepal (Subba *et al.*, 2002).

F. glaberrima is not available in New Zealand, but *F. benjamina* is readily available as it is used as a household plant. Willow and poplar were compared to *F. benjamina* as they have been well researched in NZ and are known to be trees with high feed quality.

F. benjamina is used by locals in some areas of Nepal and grows better on eroded areas. It has potential as a multipurpose fodder tree (MFT) in the tropics and is easy to propagate and use in cut and carry systems in Nepal where

Leucaena, *Gliricidia*, *Mucuna* and *Desmodium* are performing poorly (Personal experience; also see Chapter 4).

To establish the suitability of *F. benjamina* as fodder and create basic information on the fodder value of *F. benjamina*, an experiment was conducted to examine the relative preference (palatability and acceptability) of *F. benjamina*, poplar, and willow as fodder. This was based on dry matter (DM) intake over four days and rate of intake over time within a day by sheep, the force applied by sheep to tear the browse species, and crude protein and neutral detergent fibre (NDF) content.

5.2 Material and methods

Three different species of trees growing within the farm and Plant Growth Unit (PGU) glasshouses of Massey University, Palmerston North were used for this study. The three tree species studied were *F. benjamina*, (variety benjamina) poplar (*Populus deltoides* x *nigra*, Veronese) and willow (*Salix matsudana* Koidz. X *alba* L, Tangoio). *F. benjamina* was grown inside a glasshouse at PGU in containers as outside temperatures were not favourable for year round growth. Willow and poplar browse were harvested from trees growing on the Pasture and Crop Research Unit (PCRU), Massey University, New Zealand.

5.2.1 Forage preference

Study on the relative preference of browse was carried out in the Intensive Animal Research Unit of Massey University Palmerston North. Table 5.1 represents the daily timetable for the sheep preference trial conducted for 18 days at Massey University New Zealand during 22 November to 9 December 2005.

Table 5.1 *Ficus*, Poplar and Willow trees required for trial.

Days	Activities	Days	Date	No of Sheep	Number of branches			Total
					<i>Ficus</i>	Poplar	Willow	
1	Adaptation period	Tuesday	22-Nov-05	24	Chaff	Chaff	Chaff	Chaff
2		Wednesday	23-Nov-05	24	Chaff	Chaff	Chaff	Chaff
3		Thursday	24-Nov-05	24	Chaff	Chaff	Chaff	Chaff
4	Pre-experimental training for sheep	Friday	25-Nov-05	16	16	16	16	64
5		Saturday	26-Nov-05	16	16	16	16	64
6		Sunday	27-Nov-05	16	16	16	16	64
7		Monday	28-Nov-05	16	16	16	16	64
8		Tuesday	29-Nov-05	16	16	16	16	64
9		Wednesday	30-Nov-05	16	16	16	16	64
10		Thursday	1-Dec-05	16	16	16	16	64
11		Friday	2-Dec-05	16	16	16	16	64
12		Saturday	3-Dec-05	16	16	16	16	64
13		Sunday	4-Dec-05	16	16	16	16	64
14	Period of true experiment	Monday	5-Dec-05	16	16	16	16	64
15		Tuesday	6-Dec-05	16	16	16	16	64
16		Wednesday	7-Dec-05	16	16	16	16	64
17		Thursday	8-Dec-05	16	16	16	16	64
18	Ficus only	Friday	9-Dec-05	4	12	16	16	48
Total				228	236	240	240	944

Note: Chaff: *Ad libitum* lucerne chaff and clean water provided at all times except two hours before the start of experimental feeding.

The first three days were used for the adaptation of sheep to the experimental environment such as mutual understanding between researcher and sheep. It is also important to habituate the sheep which were coming directly from open pasture conditions to a totally confined housing environment. Similarly, a second period of 10 days was used for training the sheep to eat the new food of *F. benjamina* as a choice among willow and poplar. Likewise, a third period of 4 days was used for collecting data for analysis. During the final period of one day, sheep were given only *F. benjamina* browse without choice (Table 5.1).

Sixteen female adult Romney sheep were used. Average age and body weight of sheep used was 45 months and 55 - 60 kg, respectively. Ewes were housed

inside a 10.6 m x 10.4 m x 3 m shed, in a building specially designed for small ruminant experiments with good ventilation and appropriate supply of water. There were eight pens measuring 2.5 m x 2.1 m x 1 m. To ease the measurement of intake only four pens were used at one time while the other four pens were used for sheep to be put in before the next hour's trial. The floor of the house was made of concrete to allow easy cleaning using a water jet that prevented build-up of ammonia.

Throughout the experiment, dust free lucerne chaff supplied by Lucerne Product Ltd., Harris Road, Putaruru, was provided in a feeder measuring 48 cm x 48 cm x 48 cm [(for ease of eating the height of the feeder was 16 cm shorter (48-32 = 16 cm) near the animal). Ad lib clean water was provided at all times. However, lucerne chaff was temporarily removed for two hours before experimental feeding each day. The browsing experiment lasted for an hour per sheep/day, which included three successive instances of 15 minutes browsing and three intervals of five minutes for successive measurement of intake by difference.

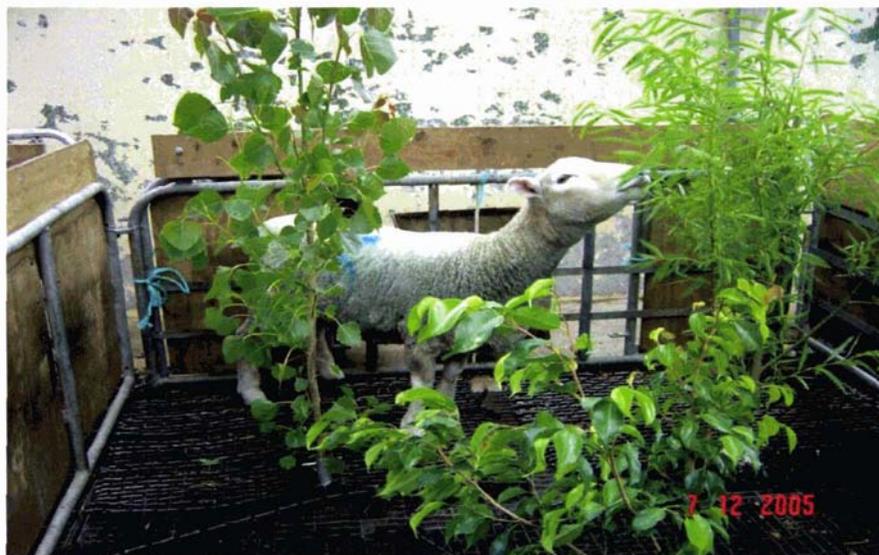


Plate 5.1 Sheep No 15 is browsing Willow with *Ficus* and Poplar within 70 cm and the sheep has easy access to all three species of browse in trial.

During each period of 15 minutes single sheep were allowed to browse on the same three fresh branches of *Ficus*, Poplar and Willow containing moisture of 61.8% 67.7% and 66.6%, respectively. To mimic the poplar and willow pasture browse blocks currently being developed in New Zealand (Sulaiman, 2006)

branches were erected vertically on three clamps and positioned triangularly in the centre of the pens 70 cm equidistance from the wall of the pen (Plate 5.1).

Equal distance between the branches and the wall of the pens permitted equal opportunity to browse any species of browse that sheep preferred. All 16 sheep were exposed randomly to treatment browse species for a total of 45 minutes per day and intake was recorded as DM g/sheep/day.

The positioning of the browse species in the pen was rotated every 15 minutes to prevent bias by the animals preferring a particular part of a pen (Bamikole *et al.*, 2004). Relative preference (palatability or acceptability) was determined by comparing total amount of DM intake (DM g/sheep/day) over four days.

On the fifth day of the trial, four sheep selected randomly were offered *F. benjamina* only for two consecutive periods of 45 minutes to measure intake where there was no choice.

To identify the fodder species with highest intake, individual observations for the first, second and third 15 minutes intake-data were pooled to make 64 cumulative data per species (64 cumulative data x 3 species = 192 data) and were analysed for reporting.

5.2.2 Rate of intake

The DM intake over time is a means to quantify the preference of a particular browse species. In this experiment both the amount of browse offered and the time allowed to browse on it was limited to maximise the available resources.

The average starting weight (Appendix 1, $n = 576 = 64$ branches x 3 time offered x 3 species) of the branches of *F. benjamina*, Poplar and Willow offered to sheep varied from 479-430 g, 922-593 g, to 839-553 g respectively. During the first 15 minutes of the trial the initial weight of the poplar branch offered to sheep no 13 on 8th December 2005 was 834 g and when weighing the same branch after subsequent browsing for second, third and fourth times the weight of branch was reduced to 597 g, 454 g, and 347 g, respectively. An electronic

balance “Mettler PE22” (max = 24 kg, precision = 0.1 g) was used to record the initial fresh weight and subsequent weights (Plate 5.2).

To determine the rate of intake of a preferred browse species, 15 minute browsing events were repeated 576 times over 4 days using three browse species (64 branches/species x 3 species x 3 times = 576) and 16 sheep. To verify the palatable species identified by cumulative data analysis, the rate of intake per species was calculated using those 576 original observations. The higher the rate of DM intake, the higher is the total intake therefore the presumed palatability of the species.



Plate 5.2 Weighing *F. benjamina* branch using electronic balance (“Mettler PE22” (max = 24 kg, precision = 0.1 g).

5.2.3 Tensile strength of leaves

Plant species and the environment in which they were grown have a direct influence on browsing behaviour and amount intake of an animal. The value of an intake study can be greatly enhanced by associated measurements on vegetation characteristics and management factors which themselves influence foraging behaviours and nutrient intake (Greenhalgh, 1982; Hodgson, 2004).

Ultimate browsing force used by sheep to detach the fresh leaves of *F. benjamina*, poplar and willow from the trees were determined using TA.XT Plus, Texture analyser stable micro system (Plate 5.3) following the Standard Test Method prescribed in its manual. The tests were carried out at room temperature (20 ± 2 °C) where relative humidity was 50 ± 5 % using facilities available at the Institute of Food, Nutrition and Human Health, Massey University, New Zealand. A Pulling rate of 600 mm/min was employed. The full scale load is 500 Newton (N) (50 Kg). Leaf clamp distance was set 30 mm apart to fit the size of the leaves. Leaves were cut into 10 mm x 40 mm size with mid-rib intact to fit the clamp distance. The tensile testing was continued until five similar leaves gave a reproducible reading.

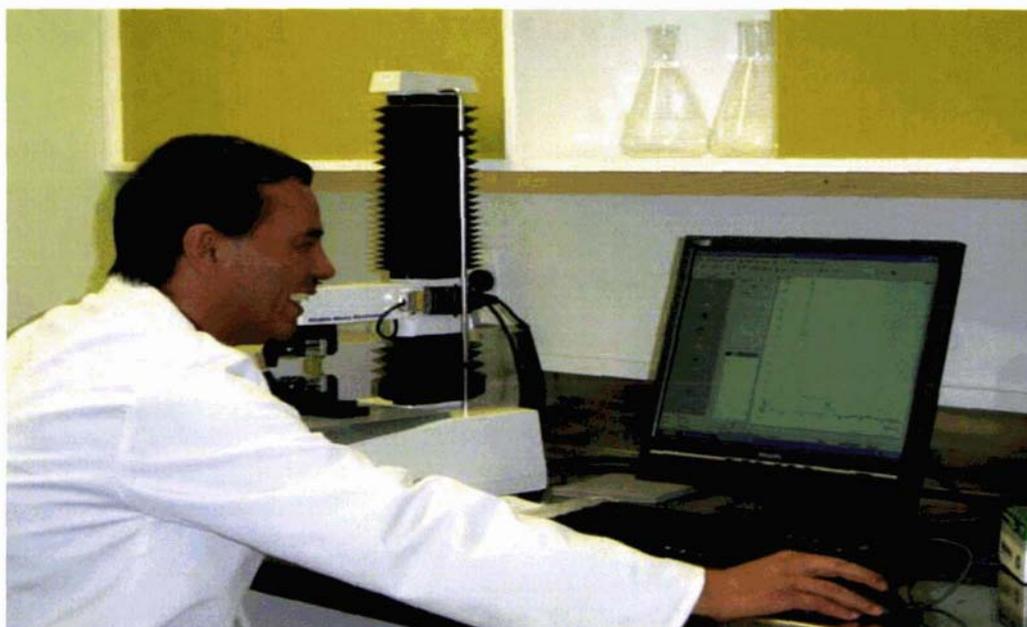


Plate 5.3 *F. benjamina* leaves being tested using TA.XT Plus, Texture analyser stable micro system at Institute of Food, Nutrition and Human Health, Massey University, New Zealand.

5.2.4 Chemical analysis

Chemical analysis of fodder plant samples were carried out using facilities available at the Institute of Food, Nutrition and Human Health, Massey University, New Zealand based on the Association of Official Analytical Chemist (AOAC) methods. Daily sub-samples of 200 g fresh leaves from each browse species were taken and stored in fridge. On completion of the four days trial, the sub-samples were bulked together, mixed well, and a final sample of 200 g each of *F. benjamina*, Poplar and Willow was separated for freeze drying and chemical analysis. The samples were ground to pass through 1 mm sieve and

were analysed for neutral detergent fibre (NDF), (van Goest *et al*, 1991) organic matter digestibility (OMD) (Roughan and Holland, 1997) and crude protein (CP) and ash. For CP, (C P =N 6.25) total nitrogen (N) was determined by combustion ("Dumas") procedure (AOAC 2000b) using a LECO nitrogen analyzer (LECO Corporation, St. Joseph, MI, USA). For DM, convection oven was used (AOAC 2000a), In vitro DMD, in vitro DOMD and in vitro OMD were calculated on DM basis using forage tree in vivo standards. In vitro gas production technique used was calibrated with standards obtained in vivo (McWilliam, 2005).

5.2.5 Statistical analysis

The data were analysed in a factorial experiment (split plot) using General Linear Model (GLM) procedure (SAS, 2001). The analysis of variance (ANOVA) was conducted and mean intake of different fodder species were compared using least significant difference (LSD). The following statistical models were used to analyse the data:

(1) Tensile strength of leaves (Table 5.5);

Proc glm;

Class treatment replicates;

Model Force_N = treatment replication/ss1;

Means treatment replicates/lsd;

Lsmeans treatment / stderr tdiff;

Run;

(2) Preferential browse intake (g DM/sheep/day = Table 5.2)

Proc glm;

Class species sheep days;

Model Intake = species sheep days species*sheep species*days
sheep*days/ss1;

Means species sheep days species*sheep species*days sheep*days/lsd;

Lsmeans species sheep days / stderr tdiff;

Run;

(3) Intake of *Ficus* alone (Table 5.3)

Proc glm;

Class treatment rep;

```
Model Intake = treatment /ss1;
```

```
Means treatment rep /lsd;
```

```
Run;
```

(Note: rep= sheep in case of no 3)

(4) Rate of browse intake (Table 5.4)

```
Proc glm;
```

```
Class species time days;
```

```
Model Intake = species time days species*time /ss1;
```

```
Means species time days species*time /lsd;
```

```
Lsmeans species time species*time/stderr tdiff;
```

```
Run;
```

5.2.6 Tensile strength (Newton/leaf)

Fifteen raw data for tensile strength (Plate 5.3) were plotted against 15 means pooled from 192 observations of sheep intake raw data. To match the equal number of data for regression analysis, intake of *Ficus* (n=64) poplar (n=64) and willow (n=64) recorded over 4 days using 16 sheep were pooled to 15 sets of data which is equal number of data recorded for tensile strength of five leaves from the same species (3 species x 5 leaves as replicates each species). While pooling 192 observation into 15 sets; there were 13 data in each mean and the last mean had only 10 data (182 observations were pooled into 14 means = 13 x 14 and the 15th or the last mean was made up of only 10 observations).

5.3 Results

5.3.1 Intake

Table 5.2 represents the total daily intake of three-fodder species *F. benjamina*, Poplar and Willow. There was a significant interaction on intake of browse between days and species ($P=0.0206$). Similarly, there was a significant interaction between sheep and days ($P = 0.0093$). Intake of Poplar and Willow was significantly higher than *Ficus* ($P=0.0001$).

Table 5.2 Preferential intake of fodder (gDM/sheep/45 mins).

Days	Ficus	Poplar	Willow	Total
1	27	107	91	226
2	15	102	79	197
3	16	92	92	200
4	15	122	117	255
Mean	18	106	95	220
SEM			± 3.19	
Significance			Probability	
Days			0.0010	
Species			<0.0001	
Species*days			0.0206	
Sheep*days			0.0093	

Table 5.3 presents the intake of *Ficus* only and clearly demonstrates that given no choice sheep will eat *F. benjamina* in reasonable amounts. There was no significant effect between the two 45 minute treatments. When given no choice, intake of *F. benjamina* was 89 g/sheep compared to an average of 18.56 g/sheep (range 15.13 g to 27.17 g/sheep) when offered with Poplar and Willow (Table 5.3).

Table 5.3 Intake of *Ficus* alone (gDM/sheep± SEM)

g DM/sheep (± SEM)	
First 45 minute	89± 22.98
Second 45 minutes	64 ± 7.2
LSD	77.9
Significance	Probability
Treatment	0.3875
Replicates	0.5227

5.3.2 Rate of intake

Intake rate had a significant interaction (Table 5.4) between time and species ($P = <0.0001$). Rate of intake of Poplar and Willow species was significantly higher ($P = <0.0001$) than *Ficus*. The rate of intake was higher for the first 15 minutes and decreased significantly ($P = <0.0001$) over the second and third 15 minute periods for Poplar and Willow indicating that successive units of fodder provide less and less satisfaction to an animal, given that the previous units already have been consumed.

Table 5.4 Rate of browse intake in 15 x 3 minutes.

Time in minutes	Ficus	Poplar	Willow
First-15	5.5	72.1	60.9
Second-15	7.3	20.2	23.2
Third-15	5.7	13.9	10.9
SEM			2.2
Significance			Probability
Time			<0.0001
Species			<0.0001
Species* time			<0.0001

Table 5.5 represents the tensile force (Newton/leaf) that is used by sheep to tear the leaves from *F. benjamina*, poplar and willow. Results clearly demonstrated that the fodder tree species requiring minimum force to browse (Willow) showed higher rate of intake as compared to species (*Ficus*) that require a higher force to tear.

Table 5.5 Tensile strength (Newton/leaf) required for breaking leaves.

Tensile strength	Ficus	Poplar	Willow
Newton/leaf	21	14.7	14.6
SEM			0.84
Significance			Probability
Treatment			<0.0001

Note: *Ficus*: randomly selected leaves from a 25 month old glasshouse tree tested on 29 March 2006

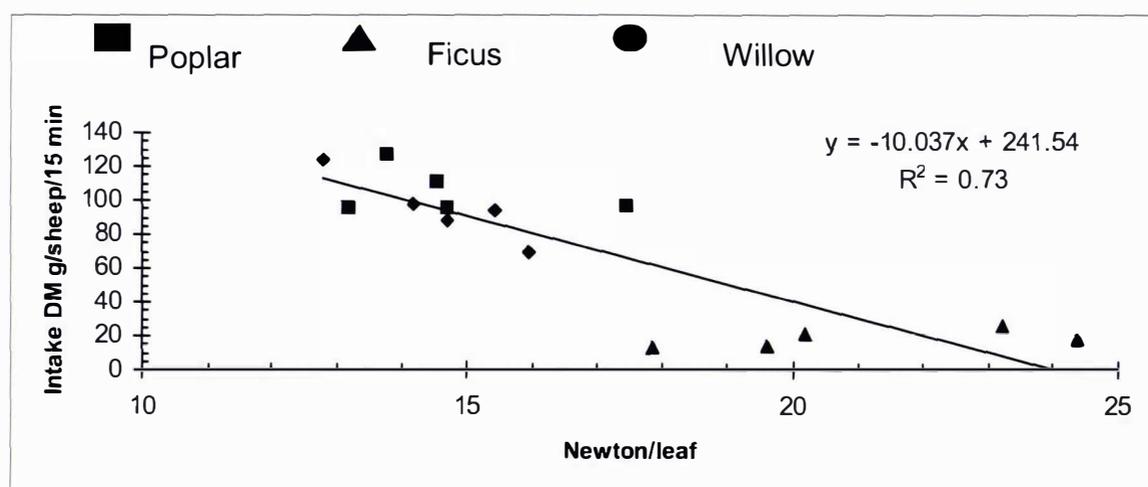


Figure 5.1 Relationship between tensile strength (Newton/leaf) and dry matter intake (DM g/sheep/45 min).

There was a strong negative correlation ($r = 0.73$) between the leaf strength (measured in Newton) with DM intake by sheep. The stronger the leaves (higher tensile strength required) the less will be the DM intake. The relationship between leaf strength and DM intake was linear (Figure 5.1). The leaves of *Ficus* species required the greatest force (21.0 ± 1.20 Newton) to tear compared to poplar and willow, 14.6 ± 0.54 and 14.7 ± 0.73 respectively.

5.3.3 Nutritive values

Table 5.6 Approximate values of browse used in the experiment.

Fresh basis				
	% Dry matter	Ash g/kg	Protein g/kg	NDF g/kg
Ficus	38.13	42.9	41.1	155.2
Poplar	32.28	24.8	40.4	104.3
Willow	33.31	22.6	50.0	97.1
DM basis				
	Protein g/kg		NDF g/kg	
Ficus	107.8		407	
Poplar	125.1		323.1	
Willow	150.2		291.5	
DM basis				
	In vitro DOMD %		In vitro OMD %	
Ficus	59.07		66.64	
Poplar	65.86		71.65	
Willow	71.04		76.2	

Note: In vitro digestibility was calculated using forage tree in vivo standards.

DM = Dry matter; DOMD = Digestible organic matter in the DM; OMD = Organic matter digestibility; NDF = Neutral detergent fibre

Table 5.6 presents the nutritive value of fodder leaves on fresh and dry matter basis. The DM results clearly indicate that *Ficus* has the highest NDF and ash and lowest CP compared to poplar and willow. Willow was found to have the highest CP, and the lowest NDF and ash. Likewise, NDF, CP and ash of Poplar was between *Ficus* and Willow (Table 5.6). Willow was the most highly digestible followed by Poplar and *Ficus*. These results clearly indicated that *Ficus* was the least digestible fodder in the treatment.

5.4 Discussion

In this experiment, poplar was the most preferred fodder tree of the three species, followed by willow (second) and *F. benjamina* (third), respectively. Preference ranking was determined by relative intake in a free-choice trials using methods described by Hodgson (1979), where preference is a general term used for the discrimination exerted by animals between species offered (Table 5.2). A similar method of direct feeding observation was also used by Salem *et al.*, (1994). Selection happens when a food item is examined by the herbivore and is ingested or rejected (Wright & Cannon, 2001; Wright & Westoby, 2003). Preferences are influenced by physical and chemical properties of the fodder species and the age of both plant and animal (Tribe, 1950). There is a deliberate preference for feeds which can be eaten faster (Kenney & Black, 1984).

Regarding the stepwise procedure to examine animal preferences on browse species, there is no fixed agreement among applied research scientists on the time allocated for sheep intake recording. Different durations have been reported; some trials have been limited to 1-min periods (Kenney & Black, 1984), 15 minutes (Karda, *et al.*, 1998) similar to this experiment, 30 minutes (Smith, *et al.*, 1997), 2 hours (Pande, *et al.*, 2002), and one day after the start of the intake trial (Mill, *et al.*, 1988). An experiment lasting months and seasons was also reported from Northern Kenya (Lusigi, *et al.*, 1986). Similarly, the number of sheep used to examine the rate of intake varies from four (Colebrook, *et al.*, 1985; Salem *et al.*, 1994), six (Kenney & Black, 1984), eight (Bamikole *et al.*, 2004), 12 (Morand-Fehr, *et al.*, 2006) and 20 (Adjorlolo, *et al.*, 2004), whereas 16 mature Romney sheep were used in this trial.

The amount and the rate of DM intake of *F. benjamina* (g/sheep/day) was found to be significantly lower than those of Willow and Poplar species (Table 5.2 and 5.3). Bamikole, *et al.*, (2004) examined the five species of *Ficus* in Nigeria and found that *F. benjamina* was the most preferred tree fodder species and the order of preference was *F. benjamina*, *F. thonningii*, *F. mucoso*, *F. religiosa*, *F. polita*. This contrasts with other authors' assumptions of similarity in the amount of intake between the species in this experiment. Average daily DM intake was

220 g/sheep (daily refers to 45 minutes only), which included 48% Poplar, 43% Willow, and only 8% *F. benjamina*, indicating *F. benjamina* was not a good choice for Romney sheep of New Zealand, which were lacking previous experience on browsing hardy fodder tree species of Africa and Asia. However, DM intake of *F. benjamina* alone was 89 g and 64 g/sheep for the same period of time (first and second instances of 45 minutes) as against only 18 g/sheep when offered in cafeteria style. Given no choice, the amount of DM intake of *F. benjamina* alone was 4.9 times (89 g) and 3.5 times (64 g) higher than in combination with other tree fodder indicating *F. benjamina* can be a good feed resource for dry and lean periods, but is unlikely to be the best choice for the glut period.

The rate of DM intake between species was analysed and least squared means were compared to find the relative rate of intake by sheep to verify the palatable species identified by the gross intake above. The faster the rate of intake the higher will be the intake per unit time indicating difference between palatable and non-palatable fodder tree species. Palatability of diets can influence the rate of intake very strongly (Morand-Fehr *et al.*, 2006).

Among the factors contributing to low intake of *Ficus*, the strong force required to detach the leaves from the tree was the most important. The peak force required to break and detach the mid-rib of the leaves was recorded, analysed and compared. The harder and drier the browse the greater the force required to tear and hence the lower the intake. Fodder species requiring comparatively less energy for the detachment of leaves by browsing animals are likely to be preferred over tree species with leaves that require greater force to detach.

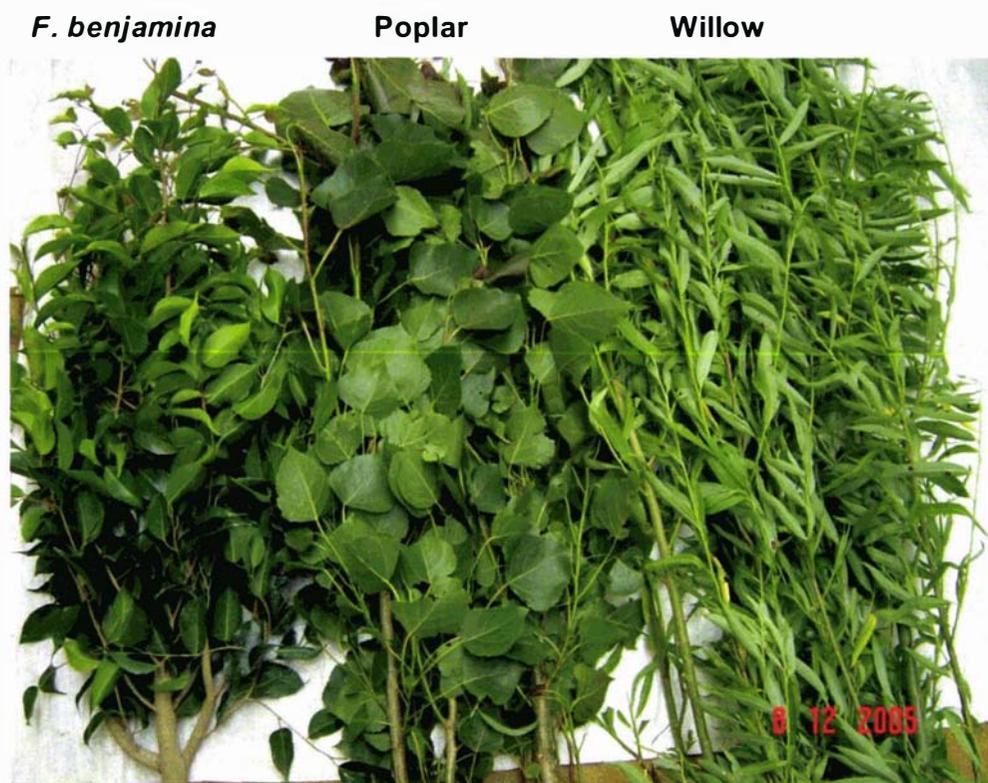


Plate 5.4 Easily distinguishable size of fodder tree leaves of *F. benjamina*, Poplar and Willow fresh branches ready for intake trial.

Ficus was the toughest browse species. There was a negative linear relationship ($R^2 = 0.73$) between DMI and the force applied to tear a leaf ($y = -10.043x + 241.62$). Each unit change in tensile strength of leaf (Newton) causes 10.043 gram change in intake. Leaves of *Ficus* have nearly double the time for lignification compared to Poplar and Willow leaves, both of which are deciduous and do not have leaves older than nine months. The common practice of lopping fodder tree once a year leads to a predominant use of one year old leaves of evergreen *Ficus*.

Mean DM intake per 45 min feeding period was greatest for Poplar and Willow, followed by *Ficus* (Table 5.2). In contrast, intake of Poplar was significantly higher than Willow, which could be related to its larger leaves (Plate 5.4) and possibly lower tannin content (Kemp *et al.*, 2003). Estimates of tannin content are not available from this study, but the results indicate that the low preference rating of *Ficus* reflected the relatively high structural strength of this species irrespective of any biochemical limitations. The differences were consistent over

four days. Based on comparative intakes, Poplar and Willow were the most palatable species, and *Ficus* was of substantially lower palatability (table 5.2)

The most important finding of this work is the linearity between browsing intake (DM g/sheep/day) and equivalent breaking force applied by sheep to detach the leaves from a particular browse tree species. This finding is supported by the fact that, the higher the NDF value of a browse species the lower will be the protein content and conversely, the lower the NDF value the higher the DM protein content (Table 5.6). As NDF percentage increases, dry matter intake generally decreases (Schroeder, 2006). The NDF value comprises the total cell wall, which is composed of the acid detergent fibre (ADF) fraction plus hemicelluloses (Schroeder, 2006), cellulose, lignin and neutral detergent-insoluble nitrogen (bound protein). That reflects the amount of forage the animal can consume (Hall, 2006). *F. benjamina* had a higher NDF than for Poplar and Willow. Scientists from Nepal Agricultural Research Council (NARC) found no specific trend of distribution of lignin in tree fodder leaves available in the eastern hills of Nepal (Khanal & Subba, 2001). Results of this experiment suggest that sheep preferred to browse young and succulent leaves of Poplar and Willow compared to hardy leaves with low moisture content of *Ficus* for which sheep need to struggle for browsing. The lower the force required to break the leaves of a fodder species, the easier it would be for the animal and better the plant species as fodder (Table 5.5) However, there was no previous work to compare with the breaking force.

5.4.1 Digestibility comparisons

Laboratory analysis clearly indicated that Willow leaves were the most digestible followed by leaves from Poplar and *F. benjamina* (Table 5.6). Willow was highest with in vitro OMD followed by Poplar and *Ficus* respectively. In contrast, intake of Poplar was significantly higher than willow which could be related to the relatively higher percentage of moisture, low content of condensed tannin and bigger leaf size of Poplar (Plate 5.4). Willow (5.2%) has a higher condensed tannin concentration (0.7 %: Kemp, *et al.*, 2003) than Poplar (Bamikole *et al.*, 2004). Tannins are known anorexic compounds in fodder plants. Estimation of tannin concentration are not available from this study, but the results indicate that the low preference rating of *Ficus* reflected the relatively

high structural strength of leaves of this species irrespective of any biological limitations.

The digestibility values were within preliminary criteria required for a tree or shrub species to be recommended for further research and development (Kemp *et al.*, 2003). Lefroy (2002) suggested that species only be considered where preliminary evidence is presented to demonstrate that they are capable of meeting the basic requirements of cultivated forage species (accessible, acceptable, sufficiently high in energy, protein, minerals and non-toxic in nature), and, more specifically, edible dry matter production is in excess of 1t/ha/yr under cultivation with *in vivo* DMD greater than 55%.

Species are commonly advocated on the basis that they are observed to be browsed by stock, or are regarded as valuable sources of feed during drought (Lefroy, 2002). The results presented here support the call by Lefroy (2002) for detection of browse species using specific criteria rather than anecdotal observations.

5.5 Conclusions

The results based on the total intake, rate of intake, leaf strength and the DMD of leaves clearly demonstrated that poplar was the most preferred supplementary fodder tree species for Romney ewes followed by willow and *F. benjamina*. One unit increase in Newton decreased voluntary feed intake by 10 g DM/sheep. *F. benjamina* is an evergreen tropical tree and is not suitable to grow outside in temperate New Zealand. However, the *in vivo* DMD of *F. benjamina* was 65%, which was above the 55% DMD requirement for a species to be recommended for further investigation. Results obtained and methods used in this study suggest that *F. benjamina* is sufficiently palatable and digestible for use as supplementary fodder but that it is likely to offer lower feed quality than the deciduous tree species evaluated.

CHAPTER 6

Evaluation of multipurpose tree fodder; milk production of water buffaloes (*Bubalus bubalis*) eating mixed diets of *F. glaberrima*, *A. lakoocha* and rice straw (*Oryza savita*) in the mountain ecosystem of Nepal

6.1 Introduction

In South Asia including Nepal, Pakistan and India, landless farmers often keep one or a few buffaloes, cows or goats (APN, 2005). The future of hill farming lies in the on-farm plantation (Dhakal & Lilleso, 2000) and its scientific management. Planting *Ficus* trees could provide a sustainable supplement to chronic lack of feed, producing up to 154.4 kg DM/tree/year (Chapter 4) which is the highest edible biomass produced by a single fodder tree species in Nepal particularly during the most critical fodder scarcity months of March to April (Rana & Amatya, 2000) when deciduous *Artocarpus* have no leaves on them *Ficus* are a preferred species for their quality, yield and availability of fresh and green feed during the dry season (Dorji & Gyaltzen, 1998), but the potential feeding value of *F. glaberrima* is unknown. Therefore, the objective in this study was to compare feeding value of *Ficus* with *Artocarpus* before the latter completes its senescence, and to create a standard database as a decision tool for the selection of multipurpose trees (MFT) for mass scale planting and renovation of degraded hills (Kshatri, 2001).

6.2 Methods

The experiment was run for three periods of 20 days when 3-diets using a mixture of straw and browse were fed to 6 animals in a replicated 3 x 3 Latin square design. To avoid the carry-over effect of the previous diet, while estimating DMI and MEI, faecal output and milk production, data were only collected for the last four consecutive days of each period and treatment. Management procedures are detailed below:

A 60 day trial started on 25 December 2004 examined the digestive and lactation response and dry matter intake (DMI) of three mixed diets by “Lime” dominant intermediate type hill buffalo breed originated from wild Arna, (*B. arnii*). Three diets studied were (1) *A. lakoocha*, the best MFT of the area but not available after February due to its deciduous nature (2) rice straw, which is a common basal diet on which most ruminants survive particularly during the dry season, supplemented with *F. glaberrima* and (3) *F. glaberrima*, a potential supplement available throughout the year, described hereafter as “*Artocarpus*”, “straw” and “*Ficus*” respectively. Energy balances in buffalo were compared by difference in metabolisable energy (ME) intake and ME output as total solids (TS = % fat + % SNF) in milk produced daily by six lactating buffaloes.

6.2.1 Location

The research was conducted on-farm at Sunpadali village of Kalika-6, Kaski, Pokhara Nepal, located at Latitude: 28 10' N to 28 16' N, and altitude 900 m that represents typical habitat for smallholders in Nepal. The site was nearly at the mid-altitude of the 1000 ± 500-metre range where *Artocarpus* and *Ficus* thrive well. Sunpadali village elevation is from 700 m at Bijayapur stream to 1500 m on “Kalikakot” hilltop of the village. Different species of fodder trees are available within this range.

6.2.2 Collection of fodder tree foliage

The feeding trial started on 25 December 2004. Late in December, the dry period begins and hill farms become brown. Farmers start lopping their deciduous fodder trees first, saving the evergreen trees for the following driest months of March to June. To avoid the scarcity of *Artocarpus* due to senescence, the trial was ended on 22 February 2005 when nearly 30% leaves were dropped and another 50% were turning yellow and ready to drop during lopping. Dropped leaves were collected in a jute bag. About 90% of *Artocarpus* lopping occurs from November to January (Chapter 3).



A. *Ficus* twigs separating after lopping.



B. *Artocarpus* leaves collected in a bag.



C. *Artocarpus* carrying to buffalo shed.



D. Spring balance in use (capacity 100 kg).

Table 6.1 Daily timetable during experiment with lactating buffaloes in on-farm conditions (Clean water was available to all buffaloes at all times).

Time	Activities	Descriptions (Milk and dung data recorded simultaneously)
0500	Dung collection	Dung excreted in past 24 hours collected in a gunny-bag and put in a safe place for weighing after cleaning, milking and feeding is over.
0530	Refusal collection	Residual browse twigs and straw collected separately for weighing after dung.
0600	Straw feeding	(a) straw offer 0.98 kg - 1.25 kg per day depending on BW, to four buffaloes. (b) Offer 2 kg straw to 2 buffalo on straw diet
0630	Feeding Concentrate	Offer 1/2 of 0.382 % body weight (BW) concentrate feed (0.55 kg) give as slurry in 5 litre of water.
0700	Washing udder and hand milking	Milk letdown takes 5 - 30 minutes depending upon individual buffalo. Milking is convenient during eating concentrates.
0800	Feeding treatment diet offer 1 of 3	2 buffaloes = Diet 1 = 10 kg Artocarpus 2 buffaloes = Diet 2 = 10kg Ficus 2 buffaloes = Diet 3 = 5 kg Ficus + 2 kg straw offered separately to each buffalo in individual feeding box made of bamboo (Table 6.4). Diets were continuously available.
1000	Weighing	Left over twigs and straw weighed
1100	Planning for tomorrow	Store and record checking to make sure that required amount of Artocarpus, Ficus, Straw and concentrate is in store and labour, fodder trees and equipment are in place for use as and when needed
1400	Feeding treatment diet offer 2 of 3.	Repeat process mentioned at 0800 hours
1600	Milking	Second milking of the day, while feeding 0.55 kg concentrate.
2200	Feeding treatment diet offer 3 of 3.	Repeat process mentioned at 0800 hours

Branches were harvested on a weekly basis from trees located across about 25 square km area around the Sunpadali trial site. A total of 30 trees were bought from 15 farmers. Lopped branches were approximately 1 – 2.5 m long with basal diameter of less than 30 mm.

To avoid daily the chore of carrying un-necessary woody materials, at the site of harvest the branches were further cut into edible size of less than 20 mm diameter and about 100 cm long twigs with leaves and figs on them, and carried to the trial site on the backs of people. Some trees were available as far as 10 km from the trial buffalo shed. Weekly lopping eases the preparatory work involving finding daily labour for lopping, carrying, weighing and the rest of the trial management with six lactating buffaloes. The twigs were weighed and collected into 5 kg bundles for *Ficus* to supplement with rice straw, one bundle each for morning and evening feeding. *Artocarpus* was prepared into 10 kg bundles and both species were stored in a relatively cool and shady place to be fed within 7 – 10 days.

Current farmers' practices for managing local buffalo were used in this trial. Details of the diets used in the trial are reported in table 6.1. There are three types of feeds available during dry seasons in the Nepalese hill farms. Rice straw is the most abundant followed by tree browse, and concentrate is the most limited feed for animals. Concentrate is expensive and competes with human food. Forage was offered at 0600, 0800, 1400 and 2200 hours daily whereas concentrate was offered twice daily about 10 minutes before milking. While sets of two buffaloes were eating *Artocarpus* only, *Ficus* only and straw only, it comes to a mixture over a period of 24 hours, when treatment diets were supplemented with 0.382 % of live weight of concentrate and 0.382 % of live weight of straw. Thus individual feeds in the mixed diets were offered separately, and not as any type of a mixture (Table 6.1). This procedure served to limit the influence of selective behaviour on diet composition, and was based on experience during pre-treatment observation of buffalo's behaviour. The daily work schedule followed for the management of the experiment is presented in Table 6.1.

6.2.3 Experimental animals and management

All six buffaloes were calved for their first lactation aged 45 – 55 months within 45 days of each other with first and last calving on 16 September 2004 and 2 November 2004, respectively (Table 6.2). When 60 days experiment ended on 22 February 2005, they were within 145 days of their standard 305 days lactation period. The standard 305 day lactation yield of Lime breed of buffalo is 962 litre, varying from 300 to 2300 litre (Shrestha, 2003). The age at first calving, calving interval and calving to mating interval in Lime buffalo was 4.56 yrs, 600 days and 198 days, respectively, based on extensive survey of 11836 households with buffaloes in the Pokhara area (Shrestha 2003). This survey also found an actual lactation length of 276 days as opposed to original 305 days standard lactation length.

Table 6.2 Date of calving and purchasing the milking buffaloes and milk yield (L/buffalo) on the day of arrival at the site of experiment.

Name of farmers from whom buffalo were bought	Buffaloes' identification (ID)	Date of calving	Date of purchase and arrival at research site	Milk yield on the first day of arrival (L)	Walking distance from buffalo owner's home to research site
Dan Bahadur	Db	16-Sep-04	8-Oct-04	1.50	1 km up hill
Vishnu	Va	17-Sep-04	5-Nov-04	0.30	3 km down hill
Khum Bahadur	Kb	19-Oct-04	19-Oct-04	1.00	0.5 km
Rishi Ram	Rr	25-Oct-04	12-Nov-04	1.00	4 km down hill
Kamala	Ka	26-Oct-04	9-Nov-04	1.50	0.5 km up hills
DataRam	Dr	2-Nov-04	12-Nov-04	Nil	5 km down and up hills, calf suckle until 2pm

Milk and faecal samples were tested for the most common ailments of the area, liver fluke and mastitis, on 18 November 2004. Three out of six buffaloes were diagnosed as infected with liver fluke and all tested negative for mastitis, (Veterinary hospital in Pokhara Nepal). They were drenched against liver fluke and buffalo stomach worms and vaccinated against haemorrhagic septicaemia (HS), which is a common ailment during the dry seasons when animals are

malnourished. Buffalo were housed in an ordinary 2.5 x 2.5 m ground floor shed tethered by the neck with individual access to feeding and watering troughs. Arrangements were made to protect animals from hailstorms and extremes of cold weather.

6.2.4 Components of concentrate ration

The concentrate used in this trial was a mixture and was made up of particles of 60 % crushed maize, 20% ground soybeans, 15% wheat bran and 5% mineral and was bought from the government's Livestock Development Farm, Lampatan Pokhara, Nepal. Crude protein in the concentrate was 15.26%. The contribution of concentrate to total DMI (kg DM / buffalo/day) was 13 %, 15 % and 17 % respectively for *Artocarpus*, straw and *Ficus* diets

6.2.5 Khole (Buffalo porridge)

"Khole" or Kundo (Subba *et al.*, 1994) is the local name given to a slurry type of watery mixture constituting about 90 % water and only 10% concentrate and table salt. Concentrate in the local farmers' situations could be only rice bran, wheat bran or maize flour or cake of any oil seeds which contains relatively higher energy per unit weight compared to roughage.

6.2.6 Feeding of *Artocarpus* and *Ficus*

In this trial, similar to that of local farmers practice, whole branches of about 100 cm long and 20 mm diameter were provided to trial buffaloes, and amounts offered and refused were recorded for analysis. Actual twig diameters of 20 samples per species were 6.4 ± 0.35 and 8.8 ± 0.46 mm for *Ficus* and *Artocarpus* respectively. Length of untreated straw offered was about 100 cm and diameter about 3 mm.

There were no references available to justify the choice of level of feedings; however, the choice of treatment diet was based on the 30 days preliminary feeding trial with the same buffalo before the actual trial. The diets were typical of the procedures on local farms. Additionally choice of diet is also based on local conditions and dry periods (personal experience). The amount of straw offered (0.98 kg - 1.25 kg per day depending on BW) was based on the assumption that, if buffaloes did not have a continuous habit of eating straw, it would be hard for buffalo to adapt to an ad lib diet of straw after 20 days

continuously eating a fresh and green diet of *Artocarpus* or *Ficus*. Thus, straw was offered to remind buffalo continuously that straw is an inescapable part of their diets. Similarly, concentrate feed was offered at the rate of 0.382 % live weight was based on the traditional system to supplement the poor quality straw typically fed to lactating animals.

Table 6.3 Experimental diet eaten by lactating buffaloes.

Number	Treatment diet	Form	Proportion
1	<i>A. lakoocha</i>	Mixture (90:10)	Ad lib <i>Artocarpus</i> + straw 0.98 kg - 1.25 kg per day depending on BW and 0.382 % live weight concentrate
2	Rice Straw	Mixture (53:47)	Ad lib Rice straw + 0.382 % live weight of concentrate and fixed 3.38 kg DM, (47% of diet) of <i>F. glaberrima</i> / buffalo/day divided for morning and evening
3	<i>F. glaberrima</i>	Mixture (90:10)	Ad lib <i>F. glaberrima</i> straw 0.98 kg - 1.25 kg per day depending on BW and 0.382 % live weight concentrate

6.2.7 Dung collection

Gunny-bags were spread on the floor to prevent dung contamination with soils, urine, mud and rainwater and other unwanted materials. It also prevented the buffalo itself resting on dung, stepping on it, and kicking into pieces.

Dung was collected manually within five minutes of excretion and kept in a polythene bag to protect against moisture loss until 0600 hrs next morning when dung passed during last 24 hours was weighed and recorded (Lapitan *et al.*, 2004).

As there was no effect of heat during the night and animals were resting, dung excreted during dark hours of 2200 to 0600 was collected at once in the morning. This process was repeated for four days during 17th to 20th day of

treatment. Dung collected over this period was mixed for each animal and 0.5 kg dung was separated for dry matter estimation to determine *in vivo* DMD.



Plate 6.1 Gunny-bags are hardly visible at the hind-quarters of resting buffaloes after feeding and morning milking.



Plate 6.2 Buffaloes arranged to face away from the gutter for easy observation and collection of dung.

Table 6.4 Order and combination of three diets and periods to for lactating buffaloes.

Three sets of two buffaloes	Period		
	I 25 December 2004 to 13 January 2005	II 14 January 2005 to 2 February 2005	III 3 February 2005 to 22 February 2005
Kb + Rr	<i>A. lakoocha</i>	Rice straw	<i>F. glaberrima</i>
	Kb + Rr	Kb + Rr	Kb + Rr
	1	2	3
Va + Ka	<i>F. glaberrima</i>	<i>A. lakoocha</i>	Rice straw
	Va + Ka	Va + Ka	Va + Ka
	3	1	2
Db + Dr	Rice straw	<i>F. glaberrima</i>	<i>A. lakoocha</i>
	Db + Dr	Db + Dr	Db + Dr
	2	3	1

6.2.8 Body weight of lactating buffaloes

The weigh-band made by Henley-on-Thames, Oxon, World Concessionaires Dalton Supplies Ltd, Telephone (0491) 419000, England, was used to estimate the live body weight of buffaloes at the beginning and end of the experiment using the following formula (Shrestha, 2003).

$$\text{Bodyweight}(kg) = \frac{\text{Bodyweight}(cm) \times \text{Chestgirth}(cm) \times \text{Chestgirth}(cm)}{10500}$$

Resulted change in body weight is for over all diet and periods.

6.2.9 Chemical analysis

Leaves, edible twigs and figs were collected covering the whole area and altitudes during January and February 2005, when they were important fodder for ruminants. One kg samples collected from individual trees (top, bottom, inside and outside) in the canopy were bulked and representative samples of 0.5 kg were put in a polythene bag and within the same day samples were transported to the laboratory. Dry matter was determined by drying the sample at 60±3 °C to constant weight (AOAC, 2000b).

Dried sample was ground to pass a 1 mm diameter sieve and total nitrogen (N) concentration was determined by using Dumas method (Leco Corporation, USA 1994) and organic matter (OM) by ashing samples for 16 h at 550 °C. Neutral detergent fibre (NDF) was determined by the detergent procedure of van Soest *et al.*, (1991). In vitro OM digestibility (OMD) was determined by the enzymatic method (Roughan & Holland, 1977), using separate standard curve prepared from in vitro values for forage and willow fed to sheep. Metabolisable energy (ME) in the diet was calculated as $16.3 \times \text{digestible organic matter}/100 \text{ g DM}$ (DOMD) (Drew & Fennessy, 1980)

Details of proximate components analysed are reported in sections (A), (B) and (C) of Table 6.5. The seven components of treatment diets and corresponding numbers of samples analysed were; *Artocarpus* leaves 23, *Ficus* leaves 17, *Artocarpus* twigs 4, *Ficus* twigs 2, *Ficus* buds 1, *Ficus* figs 1, and rice straw 3 samples. Despite limited samples, twigs of *Artocarpus* and the twigs, buds and the figs of *Ficus* (Table 6.5) represent pioneer data of this kind; however their contribution to overall diet was not the objective of the present study.

Dry matter (DM) varied from a maximum of $905 \pm 8.6 \text{ g/kg}$ to a minimum of 285 g/kg DM ($n=1$) for straw and *Ficus* buds respectively. Only one sample each of the buds and figs of *Ficus* was analysed, so the results are indicative only. However, these values were comparable to the fodder tree DM presented by previous researchers in Nepal (Khanal & Subba, 2001).

6.2.10 Milk sampling and analysis

To estimate total solids (TS) in milk, a 100 ml milk sample was taken from each buffalo daily during the last four days of each 20 day period and fat % and solids not fat (TS % = SNF + fat) was determined. Fat % was determined using Gerber butyrometers (ISO-488, 1983) and SNF % was determined using a corrected lactometer (Lc) reading as follows .

$$\text{TS} = \text{Lc } 4 + (1.22 \times \text{fat } \%) + 0.72$$

$$\text{SNF} = \text{TS} - \text{fat } \%$$

$$\text{or} = \text{Lc } 4 + (0.22 \times \text{fat } \%) + 0.72$$

It should be noted that the relationship between Lc and TS varies from country to country depending on milk composition. The above formulae are called the Richmond formulae and were calculated for Great Britain (O'Connor, 1995) and are commonly used in Nepal as well.

The total solids content of milk is the total amount of material dispersed in the aqueous phase, i.e. SNF = TS – % fat. The only accurate way to determine TS is by evaporating the water from an accurately weighed sample. However, TS can be estimated from the corrected lactometer reading. The results are not likely to be very accurate because specific gravity is due to water, material less dense than water (fat) and material denser than water (SNF). Therefore, milk with high fat and SNF contents could have the same specific gravity as milk with low fat and low SNF contents (Hemme, *et al.*, 2003).

6.2.11 Nutritional value of diets

Estimate of ME and CP requirement and intake required some extrapolation beyond normal ranges of diet and milk composition, and some assumption about body weight changes (see section 6.2.11). However, the consistency of estimates across diets and periods provides a reasonable basis for confidence the outcomes of an experiment carried out in difficult conditions.

Using the direct method, the apparent digestibility of each diet was estimated. The difference between the amounts of DM ingested and excreted, expressed as a proportion of DM ingested, was estimated and the ME content of each diets was calculated as follows;

$$\% \text{ Dry matter digestibility (DMD)} = \frac{\text{FoodDM} - \text{FaecesDM}}{\text{FoodDM}} \times 100 \quad (1)$$

$$\begin{aligned} \% \text{ Digestibility of the organic matter (OMD)} \\ = \frac{(\text{Food OM} - \text{Faeces OM})}{\text{Food OM}} \times 100 \end{aligned} \quad (2)$$

$$\begin{aligned} \% \text{ Digestible organic matter in dry matter (DOMD)} \\ = \frac{\text{OMD}\%(100 - \text{Ash})}{100} \end{aligned} \quad (3)$$

$$\text{DOMD \%} = 0.98 \text{ DMD \%} - 4.8$$

$$\text{Metabolisable energy in Food (MEF)} = 0.16 \text{ DOMD \%}$$

OM = Organic matter (MAFF, 1975).

In vivo digestibility of DM, OM, digestible organic matter in the dry matter and ME concentration were calculated. ME kg⁻¹ was estimated as DOMD (kg DOM kg DM⁻¹) multiplied by x16.3 (Drew & Fennessy, 1980)

Estimates of the ME requirements of the buffalo for maintenance and lactation were derived from Holmes *et al.*, (2002) assuming zero body weight changes, (See section 6.3.6) These values were used to calculate the balance between metabolisable energy intake and requirement (Baumgard *et al.*, 2006; MAFF, 1975) for individual animals and periods.

Crude protein (CP) requirements for maintenance were calculated as follows;

Body maintenance, CP = 5.43g/kgW^{0.75}

CP requirement for 1 kg fat corrected milk (FCM) milk production=90.3 g/kgW^{0.75} (Paul, *et al.*, 2002)

FCM = (milk produced x 0.15) + (milk produced x 0.6)(Rice, *et al.*, 1970)

6.2.12 Statistical analysis

A mixed "repeated measure" model was used to test the effect of treatment on experimental results (milk solids production by lactating buffaloes as response to diet in this case) measured repeatedly over time (Kaps & Lamberson, 2004). Analysis was via maximizing likelihood of observed values rather than ANOVA's approach of minimizing error variance. Mixed = fixed + random variation (Hopkins, 2003). Originally data were collected using 3 treatments x 3 periods of 20 days, with sampling and measurement taken over the last 4 days of each period in a latin square design (Table 6.4) with two replicates of animals per square. However, results were analyzed using a mixed procedure.

The statistical analytical system (SAS) model used for analysis was:

```
Proc mixed data=reprs;
```

```
Class period buff treatment;
```

```
Model TS = period treatment;
```

```
Repeated /type=cs sub=buff (treatment);
```

```
LSMEANS period treatment/diff;
```

```
Run;
```

The “class” statement defines categorical variables. The “model” statement defines the dependent variable (e. g. TS; total solids in milk), and independent variables period and treatment. The “repeated” statement defines the variable structure or repeated measurements. The subject (sub=buff) defines the variable on which repeated measurements were taken. The type of variance-covariance structure is called compound symmetry (type=cs), because it is diagonally symmetric and it is a compound of two variances. The LSMEANS statement calculates the treatment means (Kaps & Lamberson, 2004).

None of the period and diet interactions in these analyses were significant, so results are reported as main effects of period and diet.

6.2.13 Offered and refused diet

Figure 6.1 represents the actual amount of fresh straw + *Ficus* eaten by a buffalo (Va) during period III. *Ficus* and straw refusal was $23 \pm 3\%$ and $31 \pm 2\%$ (SE), respectively, on a fresh matter basis indicating greater than 69% of the offered feed diet was consumed. (Note = Mean DMI as percent of LW was 1.94 kg DM (n=20) (range = 1.5 – 2.27 % of the LW) per day, DMI value greater than 2% of LW was recorded during 8 out of 20 days period for this particular buffalo with straw diet).

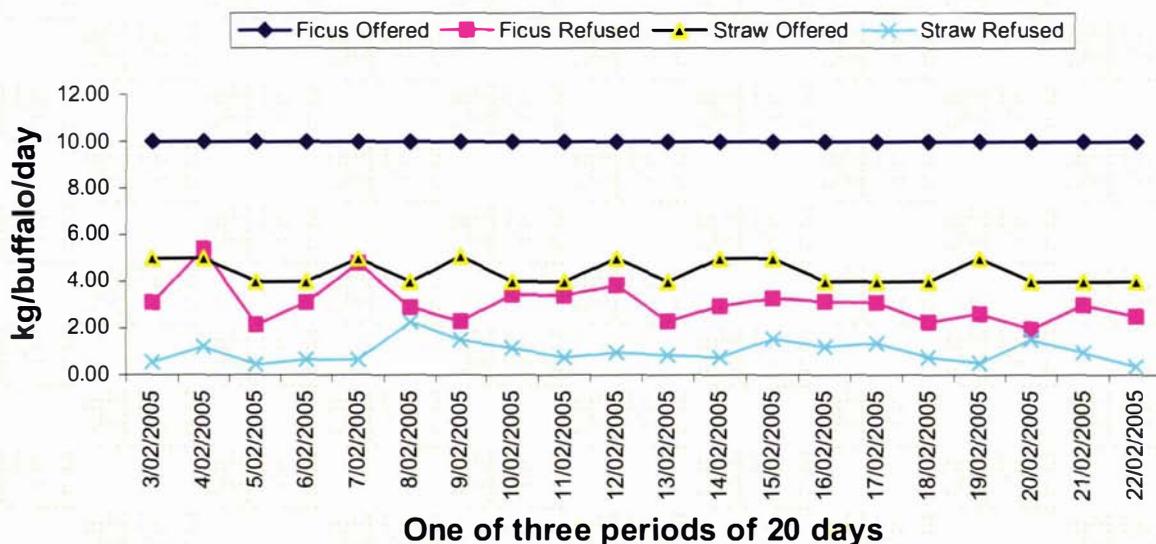


Figure 6.1 An example of offered and refused diet by one of two buffaloes under straw diet receiving (constant fresh twigs of *Ficus* = 10 kg daily) 47% DM of diet + 53 % straw.

6.3 Results

6.3.1 Nutritive values

The nutritional components of all diets (g/kg DM) (Table 6.5) were analysed at Lumle Agricultural Centre Pokhara Nepal and were used to calculate nutrient digestibility, metabolic energy of feed and energy balance in lactating buffaloes in the experiment.

Table 6.5 Chemical composition of diet components (g/km DM).

Chemical composition (g/kg DM)								
	g/kg fresh wt.	Ash	CF	g/kg DM	NDF	ADF	ADL	NCD
(A) Descriptions	DM			CP				#
(1) <i>Artocarpus</i> leaves								
Mean (n= 23)	367	152	212	125	439	380	210	525
Standard Error (±)	7	7	8	3	8	11	8	12
(3) <i>Ficus</i> leaves								
Mean (n = 17)	341	134	226	97	432	372	224	505
Standard Error (±)	8	7	9	2	5	6	5	13
(4) <i>Artocarpus</i> twigs								
Mean (n = 4)	333	132	249	68	486	440	266	472
Standard Error (±)	32	24	20	2	6	4	10	28
(5) <i>Ficus</i> twigs								
Mean (n = 2)	387	112	314	56	532	435	262	379
Standard Error (±)	12	17	8	1	13	21	9	11
<i>Ficus</i> (n = 1)								
Edible buds	285	74	151	66	339	286	209	612
Edible figs	350	89	356	69	539	445	271	320
(B) Rice straw								
Mean (n= 3)	905	128	397	37	623	480	59	262
Standard Error (±)	8	16	7	2	17	21	9	10
(C) Concentrate	895	102	82	152	NA	NA	NA	NA

= Neutral Cellulose Digestibility (NCD) values presented in Table 6.5 were taken from Subba 1998.

Dry matter (DM), crude protein (CP) and ash content of experimental diets including (Table 6.5) fodder tree leaves ranged from 385 and 905, 37 to 152, 74

to 152 g/kg DM, respectively. Acid detergent fibre was 286 to 480 g/kg DM and lignin 69 to 266 g/kg DM. Neutral cellulase digestibility (NCD) of the leaves varied greatly among the diets and ranges between 262 to 612 g/kg DM. Ash contents ranged from a high of 152.7 ± 7.8 g/kg DM to a low of 74 g/kg DM (Table 6.5) respectively for leaves of *Artocarpus* and *Ficus* buds.

6.3.2 Live weight changes

The body condition of the six trial buffaloes was normal when measured finally on 14 March 2005. Body weight measurement was taken twice during the 80 days period that includes the 20 day pre-experimental period. Initial measurement was taken on 22 December 2004 with resulting body weight ranges from 279 to 375 kg, whereas the final body weight range was 268 to 372 kg with a mean of 319 ± 16 and 314 ± 16 kg respectively, indicating only a minor decline in LW during the trial.

6.3.3 Voluntary Intake of dry matter

The DMI and faecal DM output (kg DM/buffalo/day), and DMD percent are presented in Table 6.6. DMI differed significantly between diets ($P=0.0001$), being highest for the *Artocarpus* and lowest for the *Ficus* diet, both in absolute terms and as a percentage of body weight. DMD was not significantly different between diets ($P= 0.32$) and periods ($P= 0.49$).

Table 6.6 Dry matter intake (DMI), faecal dry matter (FDM) and dry matter digestibility percentage.

Treatments	DMI (kg)	DMI (% of BW)	FDM (kg)	DMD %	ME MJ/kg DM
Period 1	7.47	2.35	2.83	60.52	8.72
Period 2	7.4	2.30	2.61	64.56	9.35
Period 3	7.09	2.24	2.59	62.46	9.02
Treatment					
<i>Artocarpus</i>	8.42	2.66	3.07	62.92	9.09
Straw	7.17	2.27	2.49	64.92	9.41
<i>Ficus</i>	6.39	2.02	2.48	59.71	8.59
SE	0.23	0.1064	0.16	2.35	0.36
Significance					
Period	0.4833	0.6631	0.5537	0.4968	0.4978
Treatment	0.0001	0.0032	0.044	0.3181	0.3168

BW= body weight for each animals at the start of the experiment.

6.3.4 Milk yield and composition

Fat % increased progressively from period 1 to period 3 ($P=0.0097$). Milk yield and composition did not differ between diets (Table 6.7).

Table 6.7 Milk yield, percentage of fat, solids not fat (SNF), total solids (TS), milk gravity and production of total milk solids (kg/buffalo/day)

Milk composition						
Treatments	Milk yield Ltr/buff/day	Fat %	SNF%	TS%	Milk gravity	TS (kg/buffalo/day)
Period 1	2.3	7.48	9.18	16.67	1.027	0.383
Period 2	2.2	8.23	9.36	17.6	1.027	0.378
Period 3	1.9	8.64	9.44	18.09	1.027	0.341
Treatment						
<i>Artocarpus</i>	2.54	7.84	9.4	17.25	1.027	0.437
Rice straw	1.92	8.07	9.39	17.46	1.026	0.332
<i>Ficus</i>	1.88	8.45	9.2	17.65	1.027	0.332
SE	0.25	0.22	0.111	0.284	0.0004	47.890
Significance						
Period	0.51	0.0097	0.284	0.0114	0.9968	0.7988
Treatment	0.14	0.2022	0.3888	0.6145	0.0963	0.2558

6.3.5 Metabolisable energy balance

Metabolisable energy intake (MEI) and balances in trial buffalo are presented in Table 6.8. Requirements of ME ranged from 67.82 – 74.93 MJ / buffalo /day and were not significantly different between period and diets. MEI was not different between periods, but was different between diets ($P= <0.0001$). MEI of the *Ficus* diet was only 72% and 81 % that of *Artocarpus* and straw diet respectively.

Table 6.8 Metabolisable Energy (MJ ME/buffalo/day) balance in lactating buffaloes.

Treatments	Energy requirement and milk solids production in lactating buffaloes based on body weight (MJ ME/buff/day).				
	Maintenance	Production	Total requirement	Total intake (MEI)	Energy Balance
Period 1	45.22	26.05	71.28	67.74	-3.54
Period 2	45.20	25.7	70.90	67.01	-3.89
Period 3	45.22	23.19	68.41	67.17	-4.24
Treatment					
<i>Artocarpus</i>	45.20	29.73	74.93	76.53	1.60
Straw	45.22	22.62	67.82	67.48	-0.34
<i>Ficus</i>	45.22	22.6	67.85	54.90	-12.94
SE	1.79	2.78	4.38	2.10	3.70
Significance					
Period	0.9999	0.7359	0.8822	0.4991	0.9912
Treatment	0.9999	0.1534	0.4402	<0.0001	0.0318

The ME balance was greater for the *Artocarpus* than the *Ficus* diet (+ 1.6 vs - 12.9 ± 3.77 MJ ME/buffalo/day, P=0.0318) but did not differ between *Artocarpus* and the combined straw/*Ficus* diets (+1.6 vs -0.34±3.7 MJ ME). ME balance did not differ between periods.

6.3.6 Crude protein balance

Table 6.9 shows CP requirement, intake and balance. The CP balance was positive for the *Artocarpus* diet, but negative for the other two diets and in all the periods.

Table 6.9 Crude protein (CP) requirement, (g/kg) intake and balance (g/buffalo/day).

CP balance in lactating buffaloes						
Treatment	Maintainance	6% FCM kg	Required for milk production	Total CP requirement	CP Intake	CP balance
Period 1	407.00	3.95	356.69	763.69	651.15	-112.54
Period 2	406.00	3.92	353.98	759.98	651.15	-108.83
Period 3	407.00	3.57	322.37	729.37	651.15	-78.22
<i>Artocarpus</i>	406.00	4.51	407.25	813.25	1059.49	246.24
Straw	407.00	3.42	308.83	715.83	269.88	-445.95
<i>Ficus</i>	407.00	3.52	317.86	724.86	624.09	-100.77
SE						
Period	16.19	0.42	-	-	-	
Treatment	16.19	0.42			-	
Significance						
Period	0.99	0.7862	-	-	-	
Treatment	0.99	0.1773	-	-	-	

NA = Not analysed due to infinite likelihoods

6.4 Discussion

The diets used in this experiment were designed to take account of the limited forage resources available to farmers in Nepal. The first section of this discussion (section 6.4.1) deals with some of the potential issues unsolved, in order to provide a context for evaluation of the experimental results which are dealt with in the following sections.

6.4.1 Feeding Practices in Nepal

The fodder tree evaluation trial using six lactating buffalo started on 25 December 2004 and ended on 22 February 2005 in an on-farm stall-feeding management system. The objective of selecting these dates was to use the latest period of availability of deciduous *Artocarpus* before its senescence, and to compare its feeding value with evergreen *Ficus* and rice straw. The diets used were representative of the diets used by local farmers. Hand milking was done in this trial, as it is sole milking practice all over Nepal.

Whole branches of *Artocarpus* and *Ficus* that were less than 20 mm in diameter and about 100 cm in length were offered to lactating buffaloes as is the usual practice of the area and these branches were composed of leaves, buds/figs, bark, hardwood and soft wood of unknown proportions. About 100 cm long rice straws were offered whole without cutting into pieces. Evaluation of all these components was beyond the scope of this study, however, efforts were made to generate maximum possible information about the lactating buffalo's energy and protein balance utilising limited resources in the complex subsistence hill farms.

On 25 December 2004 when the feeding trial started, the *Artocarpus* was already in the process of senescence. Farmers who have *Artocarpus* tree and lactating buffaloes try to prolong the period of availability of leaves to sustain milk production but, when they sell the trees to other farmers, they want their trees to be lopped first, so that they will get a good crop of leaves next year.

The original objective was to compare the DMI (kg/buffalo/day) of diets with corresponding milk yield (Litre/buffalo/day) to select the best MFT. Later on the proposal was upgraded to collect data for analysing energy balance in lactating buffaloes to select the best MFT for renovation of degraded hills. DMI and DMD did not change over periods, suggesting that browse changes over the time of the trial were not large. *Artocarpus* leaves seen on the trees on 25 December 2004 were denser and greener compared to only about 50% leaves intact on trees that also turned yellowish in colour and were ready to drop within a week on 22 February 2005. Similarly, leaves of *Ficus* might have developed into more fibrous and less digestible form with age but this was not investigated due to the limited resources of this study. The author has noted a number of buffaloes browsing and waiting under *Ficus* trees to eat any dropped leaves. No matter how hard the leaves may be, they will be eaten up immediately after dropping by waiting ruminants and will not be wasted. During the dry season, grazed pasture becomes a loitering place (Rajbhandary & Shah, 1981) and the only thing ruminants may find to eat is a few dropped leaves under the canopy of the MFT.

The buffaloes remained healthy with normal levels of production throughout the 60-days of the trial, and all six buffaloes were served naturally using buffalo bull as a preparation for their second lactation. Only one buffalo did not conceive even after third consecutive mating following 21 days cycle. As of 9 January 2007, four out of six buffaloes were still producing milk for their third lactation; however, two buffaloes were sold for meat purpose, indicating 66% trial buffaloes are still producing economic benefit to local farmers (Personal communication). Of the various reasons for infertility of buffaloes in the area 2.53 to 3.90 %, was contributed by chromosomal abnormality (Shrestha, 2003).

6.4.2 Feeding period effects

Milk fat content increased significantly over the course of the experiment (Table 6.7), presumably reflecting the normal increase in milk fat content during the course of lactation (Holmes *et al.*, 2002), but no other parameters of diet, nutrient intake or milk production differed across periods. This is surprising given the expectation that forage quality would decline with time, particularly in the *Artocarpus* diet (see chapter 2 and section 6.2.11).

6.4.3 Diet contrasts

Farmers are realising that feeds available are not adequate in nutrients and hence the practice of supplementing concentrate is followed. A daily allowance of about 1 ± 0.5 kg mixture of maize, soybean or rice-bran or only one of them is being used as concentrate. Compared to fodder leaves, concentrate feed is rich in mineral nutrients as it is incorporated with 5% mineral supplement. However, most of the fodder tree leaves had higher calcium contents, more than 1% on DM basis with values as high as 5.72% in *Brassaiopsis hainla*. *Artocarpus* and *Ficus* have a calcium content of 1.38 ± 0.21 and 0.39 ± 0.06 % of DM respectively which is higher than the normal requirement (Khanal & Subba, 2001). The concentrate diet is used mainly after boiling and cooling to 20 to 30° centigrade, because local farmers believe that boiling will increase its nutritive value. However, in this trial boiling was not practiced to save the firewood, labour, time and also to demonstrate to local farmers that buffalo keep producing milk even if the concentrate is not boiled. The practice of boiling concentrate feed in hill farms needs to be abolished.

The nutrient content of the experimental diets offered to the trial buffaloes (Table 6.5) were typical of hill farms and typical of the dry months of January and February. All were low in nutrients and digestibility. CP for example was the most limiting nutrient for lactating animals during the dry season. Therefore lactating animals' on the sole diet of straw require supplementary feeding to maintain normal body functions. CP content of *Artocarpus* and *Ficus* was only 83% and 59% that of the same species reported by Khanal and Subba (2001) without specifying the date of leaf sample collection. However all of the proximate values were within the range reported by Subba (1998) in Nepal.

Twigs were part of the diet. Diameter of *Ficus* twigs ranged from 3.78 mm – 15.5 and those of *Artocarpus* from 1.2 mm – 19.4 mm with means of 6.38 mm and 8.81 mm respectively. Dairy cows in New Zealand offered browse material from 20 mm ate similar sized branches (Kemp *et al.*, 2001).

Among the diets, the lowest ME concentration (8.59 MJ ME /kg DM *Ficus*) (Table 6.6) was higher than the 8.2 MJ/kg DM of short drought pasture in New Zealand (Pitta *et al.*, 2006). Similar energy concentrations of 7.7 and 10.5 MJ ME /kg DM for *Ficus semicordata* and *Ficus nemoralis* respectively were reported by Khanal & Subba (2001) without specifying the season of sampling. Only one out of six buffaloes in this trial gained body weight (5) kg, which is negligible in terms of body size of large ruminants. Both energy and CP values were marginal for lactating animals, but straw and *Ficus* are the only practical feeds available to farmers. Because *Artocarpus* is a deciduous MFT, its twigs will become rare after February until next lopping.

There was no significant difference in DMI of *Artocarpus* between periods despite a decline in the properties of leaf and increased maturity of leaves. Table 6.6 shows that DMI ranged from 2.1 to 2.6 % of LW of the lactating buffaloes. This result is similar to that found by Indian scientists (Sharma, *et al.*, 2004). Comparatively low daily intakes of 1.3% to 1.7% of LW for maintenance were observed in a metabolism trial with Brahman cattle, swamp buffalo and native cattle in Thailand (Kawashima, 2006). Thorne, *et al.*, (2000) found that farmers in the eastern hills of Nepal are offering 4.0 to 5.5 % of live weight of buffalo cows and oxen.

DMI recorded as a percent of BW ranges from 2.0 - 4.5 % for bovine species (Hendy *et al.*, 2000). Thus, the DMI results of this experiment appear to be reasonably realistic estimates.

A. lakoocha was superior to *F. glaberrima* in terms of DM and ME intake (Table 6.6 and 6.8), though estimates of digestibility and ME contents for the two diets did not differ (Table 6.6). The intake differences observed may be attributable in part to greater CP content in leaves and twigs of *A. lakoocha* than *F. glaberrima* (Table 6.5 and 6.8).

The DMI of browse material is influenced by biophysical and chemical properties of feed to the extent to which they can be relied upon as feed resources (Dzowela, *et al.*, 1997). Secondary compounds like condensed tannin affect the intake and digestibility of protein (Barry & McNabb, 1999). The leaf area, shape, size, and texture influence the rate of eating. The actual mean leaf area of 556 cm²/leaf for *A. lakoocha* is 10.8 times higher than 51.37 cm²/leaf of *F. glaberrima* (Singh, 2001). This implies that the bigger the size of leaves the higher will be the intake and consumption efficiency. Intake of *Ficus* was 24 % (*Artocarpus* 8.42 - 6.39 kg *Ficus* = 2.03 kg DM) less compared to intake of 90% *Artocarpus*. Presumably, evergreen leaves of *Ficus* would have been progressively lignified and harder to chew with age compared to *Artocarpus*, and this could have contributed to low intake of *Ficus*, reinforcing the effects of lower energy and protein content in the 90% *Ficus* (Table 6.6). However, *Ficus* is the only reliable sources of green feed supplement available in the absence of *Artocarpus* and all other deciduous MFT during dry seasons.

Moringa oleifera supplemented at 2 to 3 kg DM /day on *Brachiaria brizantha* hay *ad libitum*, was also found to improve DMI, nutrient digestibility and milk yield of dairy cattle (Nadir, *et al.*, 2006). But milk yield and composition differ within and between breeds in cows (Rice *et al.*, 1970), and such differences were observed in Nepali hill buffaloes (Shrestha, 2003).

The mixed diet composed of 53% unchopped straw and 47% *F. glaberrima* had significantly greater dry matter and ME intake than *F. glaberrima* alone (Table 6.6

and 6.8) and was also superior in digestibility and ME content, though those differences were not significant (Table 6.6) the comparatively high energy value of the straw/*Ficus* diet relative to *F. glaberrima* alone (Table 6.6), and in contrast to estimated value of 5.15 Mj ME/kg DM for straw alone (Baumgard *et al.*, 2006) suggest a significant interaction between the diet constituents. There was probably a direct contribution of *F. glaberrima* to the CP content of the mixed diet (Table 6.5), and a part contribution from condensed tannins in *Ficus* to the efficiency of use of the limited content of CP in the diet (see section 6.4.4) the buffalo on all these diets received 1.1 kg DM of concentrate per day.

Results of this study suggest that there is little difference in nutritive value between diets of *Artocarpus* and of straw supplemented with 47% *Ficus*. Thus, in the absence of *Artocarpus*, a *Ficus* supplement to the basal diet of straw would serve as an alternative diet during deciduous seasons. The enhanced feeding value of the straw offered in conjunction with *Ficus* indicates the potential value of the mixed diet for farmers.

Notable differences were found in fibre content, *in vitro* dry matter digestibility, acceptability and intake by livestock and therefore, their potential in affecting animal productivity (Dzowela *et al.*, 1997). Most rations are found to be unbalanced in at least one factor, either ME or CP, because farmers feed similar rations to all cows regardless of milk yield and other such indices in Vietnam (Duc Vu, *et al.*, 1999). Researchers from Kenya reported that dairy heifers were able to select the part of the tree fodder with higher content of CP, higher *in vitro* digestibility and higher rumen degradability than the average of the offered supplement (Roothaert, 1999).

In this study milk yield was not affected by diet (Table 6.7), in contrast to the significantly higher milk yield reported in buffaloes eating *Artocarpus* leaves at 4% of LW compared with untreated rice straw (Rana & Amatya, 2000). Various factors related to browse quality used, season of trial, proportion of straw and chemical composition of feed could have contributed to reduce the effect of diet in this study. Rana & Amatya (2000) did not mention whether the trial was conducted at lean period of *Artocarpus* or not. Also CP concentration (131 g/kg DM) and DMI (9.72 kg DM/buffalo/day) was higher in his study. CP content of

Artocarpus in November was 14 % whereas it was only 10.38% in February (Kaphle & Devkota, 2000). Presumably, dry seasons and lignified *Artocarpus* and single season trial could have contributed to limit the effect of diet. Fat % and TS % were similar to those found by Chinese and Nepali researchers (Han *et al.*, 2006; Rana *et al.*, 2000).

Energy balance was not significantly different between periods, but was significant between diets (Table 6.8). LW changes were small, confirming the relatively small differences calculated between intake and requirements. The potential energy balance of 1.60 MJ ME/buffalo/day while on diets of *Artocarpus* and negative balance of -0.3425 MJ ME/buffalo/day while on diet of straw and *Ficus* were not significantly different ($P=0.7160$). A negative balance of -12.94 MJ ME /buffalo/day on the diet of 90% *Ficus* indicates that the buffaloes were not able to eat enough *Ficus* as they eat *Artocarpus* to meet their energy requirements (Table 6.8) and hence buffaloes were mobilising an equivalent body reserve and losing body weight to produce milk. Average BW of buffalo dropped to 314 ± 15 kg from its original 318 ± 15 kg in 80 days interval indicating that there was a general trend for live weight loss in trial buffaloes during dry seasons. Similar results were found by Japanese researchers in Nepal (Hayashi, *et al.*, 2005). The body tissue loss was assumed to be converted to milk with an efficiency of 84% and milk equivalent energy balance was estimated to be energy in milk plus positive tissue energy balance or plus 0.84 times negative tissue energy balance (Tyrrell, 2005). A negative balance of -64 MJ/day starting at day 7 continued until 60 days post partum in low and high genetic potential cows (Collier, *et al.*, 2005; Crooker, *et al.*, 2001).

Loss in the BW of buffaloes on the hill farms particularly during dry and cold seasons is a normal physiological phenomenon of animals generally observed by farmers and researchers (Hayashi *et al.*, 2005). To achieve comparable data, buffaloes were measured before 0900 hours on both occasions. Similar timing was used by other researchers for weight measurement (Williams & Dudziński, 1982).

Cows in early lactation typically cannot consume enough calories to meet the energetic requirements of maintenance and copious milk secretion, and

consequently enter into a state of negative energy balance (Baumgard *et al.*, 2006). During this study, apart from animals' physical limitations, advancing days were colder and drier, and available feeds were poor in nutrition and digestibility. The energy value of body tissue mobilised is about 20 MJ/kg LW (MAFF, 1975) and hence 0.647 kg of buffalo tissue is estimated to have been mobilised each day in buffaloes eating a diet of *Ficus*.

6.4.4 Dietary crude protein and secondary metabolites

Crude protein (CP) concentration of *Artocarpus*, *Ficus* and straw, respectively, was 125, 97 and 37 g/kg DM (Table 6.5). The CP content of *Artocarpus* was within the range of 122 -131 g/kg DM reported from eastern Nepal (Panday & Nösberger, 1985), but that of *F. glaberrima* was lower than the 101 -114 g/kg DM reported by Wood *et al.*, (1994) for the months of January and February 1991. Similarly, CP concentration of straw was lower than the 41 g/kg DM reported by Bhuiyan *et al.*, (2003). Below about 60 g/kg dietary CP which is a threshold, urinary nitrogen is vanishingly low, most of it recycling and ending up in faecal nitrogen (van Soest, 2006).

The minimum CP diet concentrations required for effective rumen function were estimated using Indian feeding standards for buffalo (Paul *et al.*, 2002). Generally, CP concentration in the diet fed to lactating buffaloes was not sufficient to meet requirements. *Artocarpus* with 125 g CP/kg DM was good enough to over-supply the CP requirement, however, that will not be available during the true dry season. Generally, buffaloes were in CP deficit 15 % throughout the periods except for 20 days when buffaloes were eating 8.42 kg DM of *Artocarpus* that was supplying 1059 g of CP. This was a 246 g excess of CP over the 813 g CP requirement (8.42 kg x 125.53 g CP /kg DM of *Artocarpus*). Untreated straw having crude protein level 30 to 40 g/Kg DM initially could be improved to have potential crude protein levels of 70 to 90 g/Kg DM after treatment, which is normally considered the minimum necessary in the diet for adequate intake, digestive activity of micro-organisms and maintenance of live weight (Chriyaa, *et al.*, 1997). Below 70 g kg CP in the diet, forage intake declines because protein needs of the rumen microbes are not satisfied (Chriyaa, *et al.*, 1997). Table 6.5 shows that only leaves of *Artocarpus* and *Ficus* had CP above the limit of 70 g kg DM; buds, figs and straw have less than

7% CP. In this study the straw diet was supplemented with 47% of *Ficus*, which has a CP concentration 2.6 times higher than that of straw. This was found to improve digestibility of the straw diet hence there was no significant difference ($P=0.31$) between MJ ME/kg DM values of *Artocarpus*, straw and *Ficus* (Table 6.5).

MFT are a cheap source of protein and energy for ruminants. However, though the utilization of dietary protein may be enhanced by the presence of low concentration of polyphenolics (tannins) high tannin concentration may inhibit forage intake (Barry & McNabb, 1999; D. Subba, 2001).

Artocarpus and *Ficus* are reported to have less than 5% tannin but its nature in these species is not known. Phenolic compounds which include lignin and tannin are quantitatively the most important anti-nutrients present in tree fodder leaves and are considered to limit voluntary feed intake, digestibility and nutrient utilisation (Khanal & Subba, 2001). Animals feeding on MFT twigs may have adverse effects in terms of DMI and metabolic functions due to effects arising from commonly occurring secondary plant metabolites (Jackson & Barry, 1996; Melaku, *et al.*, 2004). Increasing concentration of condensed tannins (CT) in *Lotus corniculatus* and *Lotus pedunculatus* reduces the rates of solubilisation and degradation of fraction 1 leaf protein in the rumen (Barry & McNabb, 1999). Subba (1998) reported CT content of *Artocarpus* and *Ficus* as being 6 and 4 g CT/Kg DM respectively, but their quality in terms of extractible, protein bound or fibre bound/components (Barry & McNabb, 1999), and its effects on diet digestibility is not known. Willow browse in New Zealand was found to have 30 g of condensed tannin /kg DM and that improved reproduction of sheep (Pitta, *et al.*, 2005). Study of these effects on *Ficus* and *Artocarpus* intake on buffaloes will be useful.

6.5 Conclusions

It is concluded from this study that *ad libitum* feeding of *Artocarpus*, *Ficus* and 53% straw plus 47% *Ficus* diets provided satisfactory level of nutrition for Lime breeds of lactating buffaloes in the hills of Pokhara, Nepal. But buffalo on the *Ficus* diet were in substantial energy deficient. DMI of 8.42 kg for *Artocarpus*, 7.17 kg for 53% straw plus 47% *Ficus* and 6.39 kg for *Ficus* /buff/day indicated

the preferred order of diet based on the amount eaten. The *Ficus* and straw/*Ficus* diets offer a source of fresh forage in the dry season supplementing the basal diet of rice straw with *Ficus* was found to substantially raise the energy value of the mixed diet to an energy level equivalent to that of *Artocarpus*. It is, therefore, recommended to supplement straw diet with about 50% *Ficus* browse and it is recommended to conduct further trials to evaluate varieties of *F. glaberrima* at different levels of feeding. A diet of 50:50 Straw:*Ficus*, with (unboiled) concentrate supplementation for lactating animals, would appear to be a good, practical fodder source for Nepalese small farmers.

The proven MFT *F. glaberrima* is adapted to local conditions and is well accepted by buffalo and by subsistence farmers. Therefore, its use will help to avoid over-reliance on a few MFT species like *A. lakoocha*.

CHAPTER 7

Vegetative propagation of *F. benjamina* using non-sterile sand and hardwood cuttings

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7.1 Introduction

Ficus species are multipurpose trees well adapted to harsh mountain terrain and used by rural populations as an evergreen source of fodder for ruminant livestock, for fuel and shade, as well as for ecological conservation in Nepal (Kshatri, 2001), and in the Sahelian and Sudanian zones of Africa (Danthu, et al., 2003).

F. glaberrima and *F. benjamina* are both known as epiphytes or strangling fig (Starr, et al., 2003). *F. glaberrima* is a sub-tropical tree, found in the Himalayan foothills (Corner, 1978), where it is used for fodder, fuel, erosion control and minor industrial purposes (Maithani, et al., 1987). In Thailand, it is used as a framework tree (Elliott et al., 2003). *F. benjamina* is present in New Zealand (NZ) where it is an indoor plant but *F. glaberrima* has never been recorded in NZ. Because only one species is available in NZ and the research is aimed at Nepalese and similar farmers, *F. benjamina* was used to develop appropriate propagation technology.

Although vegetative propagation is a basic method for mass scale production of cuttings, vegetative propagation of *F. benjamina* has not been extensively studied (Danthu et al., 2002). Micro-propagation techniques (Joshee et al.,

2002; S. B. Rajbhandary, 1992) advanced by the western world are practically useless for remote areas in Nepal, Bhutan and similar areas where there are no electricity and irrigation facilities. Therefore, there is a need to develop practical propagation methods, by combining indigenous technical knowledge of local farmers and relevant scientific information. Nepalese farmers require a hardy and healthy sapling that needs relatively limited care after planting for reforestation of the mountain ecosystem. Selection of species, hardening of the saplings produced and raising them to a stage of transplantation and establishment is challenging.

Previous experience found that larger size cuttings with more than 15 leaves performed poorly. The objective in this study, which formed part of a project on the establishment and management of *F. glaberrima* in Nepal, was to develop an effective propagation method.

7.2 Material and methods

Treatments were 100% unwashed river sand (S), 100% commercial medium (CM) and a 50:50 mixture of the two (M). Particle diameter in the sand was 70% <2 mm and 30% 2-5 mm diameter; no fertilizer was added and the sand was not sterilised. The commercial medium was formed from composted pine bark with added lime, dolomite and osmocote (100 gm, 300gm, and 150 per 100 gm bark respectively).

A randomised complete block design (RCBD) with three treatments and three replications with 16 cuttings per plot was used for the experiment.

7.2.1 Preparation of cuttings

F. benjamina leaves, bark and wood contain milky sap, which oozes out during twisting, breaking and cutting. To avoid stickiness while preparing the cuttings, the sap was washed off by immersing cuttings in clean water immediately after branches were cut from the trees. This also helped minimise evapotranspiration stress of cuttings.

A total of 144 cuttings were prepared using trees available at PGU, Massey University, New Zealand. Three out of 25 trees were randomly selected as

mother trees from which the cuttings were taken. In this trial cuttings varied from 20 to 80 cm in length, 2 to 21 branches, and 2 – 100 leaves. They were trimmed to 22.5 cm length, 2 - 8 branches and 2 – 15 leaves, and were allocated at random between treatments and replicates.

A single wound was made in the cambium layer of each cutting using a sharp knife and then treated with 0.3% indolebutyric acid (IBA). Cuttings were maintained at 20 to 24°C in a controlled temperature heat bed, where the mist was regulated for a 10 second spray every five minutes throughout the experiment. Root and shoot growth were recorded 55 days after planting. After washing gently using a water hose total root numbers on a cutting were counted, and the longest root in a cutting was measured. Retention of older leaves and the growth of new leaves on a plant was also recorded.

7.2.2 Statistical analysis

The general linear model (GLM) of Statistical Analysis System was used to perform analysis of variance (ANOVA) and means were compared (SAS version 8.2, 1999-2001). Unless otherwise stated, statistical significance was tested at the 5% level ($P < 0.05$).

7.3 Results

There was no difference in the number of roots per cutting for the three treatments. Also, there was no difference in old leaf retention per cutting. M and CM treatments had significantly greater root length per cutting than S and production of new leaves was approximately three times greater in M and CM than S. Root length and emergence of new leaves were in the order of CM=M>S (Table 7.1).

Table 7. 1 Effect of sand (coarse and non-sterilised S), commercial plant growth media (CM) and 50% mixture of sand and commercial media (M) on root and shoot growth of *F. benjamina* cuttings in a glasshouse.

Plant growth media	Root growth		Shoot growth	
	Live Root Number	Root length (mm)	Retained leaves (no)	New leaves (no)
S	10.8	5.3b	2.71	1.18b
M	9.5	7.8a	3.31	3.18a
CM	9.3	6.9a	2.58	3.00a
LSD 5%	1.6	1.27	0.73	0.65
SEM	0.5	0.45	0.26	0.23
P- value	0.1318	0.0007	0.1128	0.0001

Note: Means within a column with the same letter were not significantly different.

7.4 Discussion

Rates of root and leaf development were clearly better on cuttings growing in commercial medium than in sand (Table 7.1), but there was no difference between treatments in the number of surviving roots and leaves and no difference in cutting survival. There is a strong correlation between number of roots and survival of plants (Ahmed *et al.*, 2003)

Survival of *F. benjamina* hard woodcuttings was 26 % during an initial trial, whereas in this trial survival was 93 %. It is not clear whether the apparent growth advantage of cuttings in commercial rooting medium reflected the effect of medium structure (Navatel & Bourrain, 1994), nutrient supply (Dick *et al.*, 2004) or avoidance of pathogens (Preece, 2003) Automatic misting assists moisture maintenance in sand and farmers would need to water regularly and shade the cuttings.

In conclusion, coarse and non-sterile sand is effective as a low cost alternative medium for rooting of *F. benjamina* cuttings. Minimising the size and the number of leaves will reduce the leaf surface area on cuttings to be propagated, which will enhance the survival rate.

CHAPTER 8

Leaf survival and biomass production of *F. benjamina* containerised in a glasshouse

8.1 Introduction

In comparison to deciduous species, evergreen plants have a lower leaf nutrient content and a larger leaf life span, important mechanisms for nutrient economy, allowing the colonization of low fertility soils (Haddad, *et al.*, 2004). To include the MFT into feed budgets, a method is needed to estimate the edible forage yield of the tree (Kemp *et al.*, 2003). Chapter 7 described the low cost propagation media for *F. benjamina* while this chapter describes the effect of those media (Chapter 7) on leaf age and biomass production of *F. benjamina* in a glasshouse during a subsequent establishment period of two years.

The age of a leaf affects animal nutrition (Karachi *et al.*, 1997). For example, the leaves and immature fractions of *L. leucocephala* were higher in nitrogen, phosphorus, potassium and digestibility but lower in calcium, magnesium and fibre than older leaves (Karachi, 1998). Similarly, there was a reduction in nitrogen and potassium levels with increasing leaf age (Julian, 1979). *F. benjamina*, a multipurpose fodder tree (MFT) in the tropics lives for over a 100 years but its leaf age is unknown. Leaf age affects growth rate and the feed quality of the leaves (Mooney & Gulmon, 1982). Long lived leaves tend to be more fibrous and higher in secondary chemicals than short lived leaves (Baas, 1982). Information on age of MFT leaves is important to farmers, researchers and planners but limited information is available on leaf maturity and leaf chemistry (Garcia *et al.*, 1996). While leaf age related leaf chemistry was beyond the scope of this study, the objective here was limited to measurement of the age of *F. benjamina* leaves on young trees in glasshouse conditions and also estimation of biomass by destructive sampling.

8.2 Material and methods

The following three rooting media were used during propagation of the *F. benjamina* cuttings on 5 December 2003 and 19 January 2004.

CM = Commercial media only (0 % sand) M = Mixture 50% sand and 50% commercial media (Mix); S = Sand only (100% sand).

See chapter 7 for details of media, pots and glasshouse conditions at Plant Growth Unit PGU), Massey University, New Zealand.

8.2.1 Leaf senescence

Leaf age was monitored for 26 months from 21 August 2004 to 25 September 2006 using a randomised complete block design (RCBD) to measure the effect of: 1) 100% non-sterile sand, 2) a mixture of 50% sand and 50% commercial media, and 3) commercial media on leaf senescence and biomass production. A total of 1440 leaves, (1440 leaves = 10 leaves per tree x 16 trees per plot x 9 plots = 144 trees in total) with 480 leaves per treatment (160 x 3 replicated plots) were marked using a permanent marker and any fallen leaves were collected and recorded over a period of 910 days.



Plate 8.1 Transplanting to 20-litre bucket.



Plate 8.2 Marking the leaves for the leaf age study

Arrangements were made to compare the biomass production of trees grown in and outside the glasshouse. For this purpose 48 trees were kept outside the glasshouse. Plants propagated by cuttings on 5th December 2003 were grown inside the glasshouse for 15 months until 2 April 2005 when they were put outside the glasshouse exposing *F. benjamina* plants to the weather outside of the glasshouse at Plant Growth Unit (PGU), Massey University, New Zealand, but plants were still in containers. The plants were allowed to grow until the age of 30 months when five plants were randomly selected for destructive sampling.

8.2.2 Statistical analysis

Analysis of variance (ANOVA SAS version 9.1) and logarithmic regression (SigmaPlot) were used. Pearson correlation coefficients were analysed to compare the tree height, canopy, basal diameter, leaf dry matter (DM) branch DM, root DM and number of leaves per tree.

8.2.3 Biomass production

Destructive sampling was used to estimate biomass production of *F. benjamina* trees grown inside and outside the glasshouse. A total of 20 trees, (five trees from each treatment and five trees from outside the glasshouse) were randomly sampled and separated into leaves, branches and roots. They were oven dried at $60 \pm 3^{\circ}$ c for 7 to 10 days until a constant weight (AOAC, 2000a).

8.3 Results

There were still 52 leaves (3.6 %) intact on 25 trees (17.36 %) out of the 1440 leaves originally marked on 144 trees after 910 days of observation. When leaves were marked on 21 August 2004, there were 2.71 leaves per tree intact on each tree (Chapter 7). There were 13, 6 and 6 plants in each treatment with 25, 14 and 13 leaves remaining intact on them indicating up to 3.6 % of leaves could survive longer than 910 days.

ANOVA results showed that there were no significant differences existed between number of leaves measured on 21 August 2004, 3 March 2005, 13 June 2005, 22 Oct 2005, 21 May 2006 and 25-Sept 2006 (Figure 8.1). However, the senescence rate was significantly ($P = <0.0001$) affected by treatment during the first 33 months of plant life (Cuttings were planted on 5 December 2003 and final leaf recording was done on 25 Sept 2006 = Figure 8.1, Table 8.1).

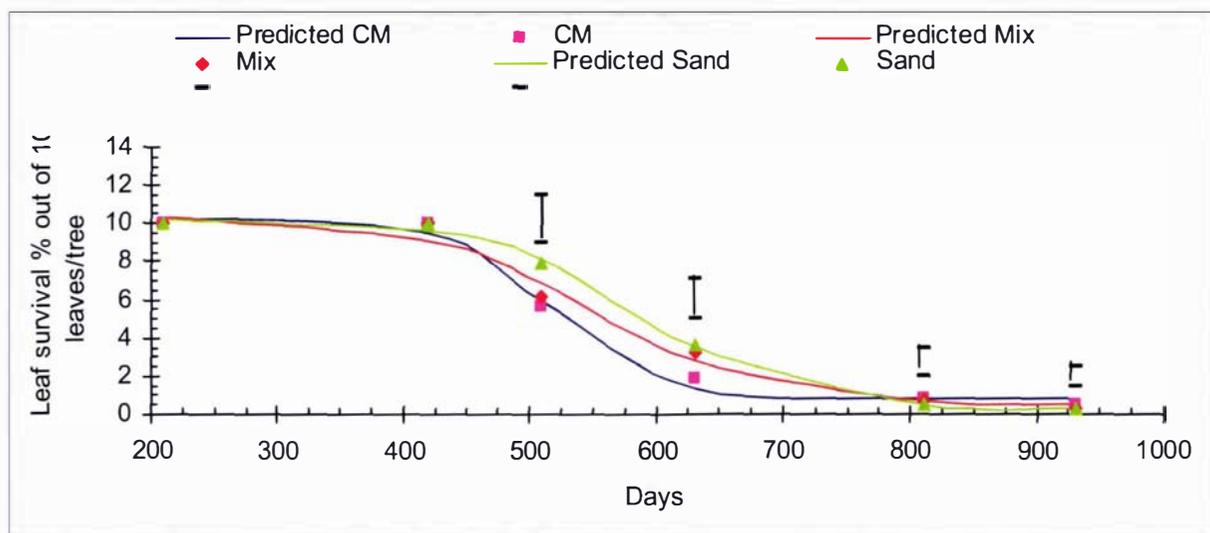


Figure 8.1 Leaf survival rate of evergreen tree *F. benjamina* over 910 days in glasshouse conditions.

Significant differences on the rate of leaf fall between plants, grown using different media and measurement dates. Results clearly shows that leaf fall starts at 400 days and the rate of fall accelerates until 700 days. Fifty-two leaves remained even 910 days after marking.

Table 8.1 Standard deviation and significance of leaf survival rate (Figure 8.1)

	21 August 2004	3 March 2005	13 June 2005	22 Oct 2005	21 May 2006	25-Sept 2006
No. of Days	210	425	510	630	810	925
SD ±	0.00	0.00	2.50	2.1	1.4	1.01
Significance	0.00	0.00	<0.0001	<0.0001	0.36	0.185

There were 100 % leaves intact on trees until 450 days after marking in all treatments. Logarithmic regression analysis showed the highest rates of leaf fall started on day 515 ($R^2 = 0.97$), day 550 ($R^2 = 0.95$) and day 588 ($R^2 = 0.99$) after marking on plants grown on CM, M and S media respectively (Table 8.2). Leaves therefore lived for over 500 days under greenhouse conditions.

Table 8.2 Leaf survival rate (slope of leaf fall/day) for *F. benjamina* growing in three media in pots in a glasshouse.

$y_{CM} = 10.32/1 + \exp^{0.026*(x-515.21)}$, $R^2 = 0.97$	(1)	
$y_{Mix} = 10.46/1 + \exp^{0.014*(x-550.03)}$, $R^2 = 0.95$	(2)	
$y_{Sand} = 10.21/1 + \exp^{0.017*(x-588.45)}$, $R^2 = 0.99$	(3)	
Treatment	Rate or leaf fall /day(slope)	SE
CM	0.026 ^a	± 0.0093
Mix	0.014 ^b	± 0.0052
Sand	0.017 ^{ba}	± 0.0022

Means with the same letter are not significantly different.

8.3.1 Height, canopy and basal diameter

Table 8.3 Height, canopy diameter and basal diameter of *F. benjamina* trees.

Tree measurement (mm)			
Treatment	Plant Height	Canopy diameter	Stem basal-diameter
Outside	904 ^c	762 ^b	22 ^b
CM	1204 ^b	1028 ^a	31 ^a
Mix	1430 ^a	1130 ^a	31 ^a
Sand	1274 ^{ba}	1064 ^a	31 ^a
SE ±	56.39	60.9	1.0
Significance (P= 0.05)	<0.0001	<0.0001	<0.0001

Means with the same letter are not significantly different.

Stem diameter were significantly greater for plants grown in different media inside the glasshouse than outside glasshouse (Table 8.3). Significance is only due to inside/outside comparison. There is minimal difference between media inside.

8.3.2 Biomass and leaf number

Table 8.4 Biomass production (g DM/tree) in glasshouse conditions.

Treatment	Number of leaves	Biomass (g DM)		
		Leaves	Branches	Roots
Outside	845 ^c	84 ^b	99 ^b	94 ^b
CM	1759 ^b	247 ^a	275 ^a	262 ^a
Mix	1971 ^{ba}	249 ^a	307 ^a	320 ^a
Sand	2256 ^a	247 ^a	286 ^a	291 ^a
SE ±	102	5.77	16.3	21.46
Significance (P= 0.05)	<0.0001	<0.0001	<0.0001	<0.0001

Means with the same letter are not significantly different.

Biomass production per tree (g DM/tree) was significantly different between the plants grown inside the glasshouse and outside of it ($P < 0.0001$). Number of leaves were significantly higher on the plants propagated using sand media (Table 8.4, $P < 0.0001$) and grown inside the glasshouse. However, there was no significant difference between DM production of leaves, branches and roots of plants grown inside the glasshouse (Table 8.4).

Table 8.5 Pearson correlation coefficient among variables measured on *F. benjamina*. Levels of significance are indicated in italics.

	Height	Canopy	Basal diameter	DM leaf	DM branch	DM roots	Number of leaves
Height	1.0000	0.677	0.75	0.8	0.78	0.74	0.67
		0.001	0.0001	<0.0001	<0.0001	0.0002	0.001
Canopy		1.0000	0.73	0.78	0.82	0.81	0.71
			0.0002	<0.0001	<0.0001	<0.0001	0.0004
Basal diameter			1.0000	0.89	0.88	0.87	0.75
				<0.0001	<0.0001	<0.0001	0.0001
DM leaf				1.0000	0.94	0.9	0.89
					<0.0001	<0.0001	<0.0001

DM branch					1.0000	0.94	0.89
						<0.0001	<0.0001
DM roots						1.0000	0.87
							<0.0001
Number of leaves							1.0000

Correlation coefficients (R^2) ranged from 0.67 to 0.94 among the tree components examined. Strong correlation existed between branch and leaf DM followed by branch and root DM ($R^2 = 0.94$). Similarly, moderately high correlation ($R^2 = 0.67$) existed between height and canopy diameter and height and number of leaves (Table 8.5),

8.4 Discussion

This discussion mainly deals with the leaf survival and the small effect of plant growth media on leaf fall of evergreen *F. benjamina* studied under glasshouse conditions.

F. benjamina (var = *benjamina*) was clearly an evergreen tree species with no leaf fall occurring until 450 days (well over one year) from marking, and 3.6% of marked leaves beyond 910 days. Evergreen species commonly retain leaves for one to many years (Mooney & Gulmon, 1982) ensuring year round supply of fresh and nutritious leaves for herbivory. In this study *Ficus* leaves typically survived nearly 3-times longer than those of deciduous *Artocarpus*, poplar or willow. However, when a leaf is matured, and lignified, it becomes harder to browse and digest (Karachi, 1998).

Deciduous tree leaves generally have higher photosynthetic capacity than evergreen leaves, but there is a year-round photosynthesis in evergreen leaves (Mooney & Gulmon, 1982). Dry matter addition to the leaf is continued even after full leaf expansion (Mooney & Gulmon, 1982).

Leaf survival rate as an indicator of rate of leaf fall per day is given in equations (1) to (3) in Table 8.1. There was a strong correlation between plants grown on different media and rate of survival of leaves (Table 8.3). Leaf survival rate increased with increasing moisture (Bargali, 1997). Highest rate of leaf fall

0.026 \pm 0.0093, 0.014 \pm 0.0052 and 0.017 \pm 0.0022 leaf/tree/day started at 515, 550 and 588 days after marking for CM followed by M and S grown trees respectively.

Based on the leaf phenology four plant function types are recognized (1) semi-evergreen, (2) <2-months –deciduous, (3) 2- 4 months deciduous and >4-months – deciduous. *F. benjamina* is a true evergreen and does not fall in any of the above four categories. Rapid recruitment of leaf crop in the shoots, longer leaf life-span, and access to ground water due to deep roots are some of the advantages the evergreens had over deciduous trees (Negi, 2006).

8.5 Conclusions

The senescence rate was significantly affected by plant growth media used during propagation. No leaf fall occurred until 450 days after marking. Prolonged age of *F. benjamina* leaves may result in a higher proportion of indigestible fibre that could contribute to difficulties in browsing and digestion. Regular lopping management practice will enhance continuous regeneration of evergreen leaves, and weekly to monthly proximate analysis of leaves of different age groups will help better define the nutritional relationship between seasonal variation and maturity of leaves.

CHAPTER 9

General discussion and conclusions

9.1 Introduction

Lack of animal feed particularly during the nine months from October to June is the major problem in the hill-farming ecosystem of Nepal, and planting multipurpose fodder trees (MFT) could be the solution. A deciduous MFT, *A. lakoocha*, is known for its potential to raise the milk quality and quantity in lactating ruminants. It is preferred by animals, liked by farmers and grows relatively fast, but has a serious constraint, lacking no leaves when they are most needed by animals. Evergreen *F. glaberrima* has grown on farmed land for generations but its potential as a fodder tree never been scientifically investigated. To include the MFT in feed budgets, a method is needed to estimate the edible forage yield of the tree (Kemp *et al.*, 2003). The principal objective in this PhD research was to evaluate the suitability of *F. glaberrima* for large scale planting in degraded hills producing year round a supply of supplementary nutrition for ruminants.

Following a review of past work on MFT in Nepal, six experiments (Chapter 3–8) were used to compare and verify the potential of *F. glaberrima* or the closely related *F. benjamina* for forage production and nutritive value in the hill farms. Projects were presented in the Institute of Natural Resources, Massey University in New Zealand and at the 5th National Animal Science Convention, organised by Nepal Animal Science Association (NASA) in Kathmandu, from 15 – 16 October 2003 and comments were incorporated (Kshatri, 2003).

9.2 Results of the review of past work in Nepal

The literature clearly highlights the chronic lack of dry season feed and its adverse effects on health and productivity of animals in Nepal (Pariyar, 2006; Rajbhandary & Shah, 1981; Rana & Amatya, 2000; Singh, 2000). There is a convincing need to protect natural plant communities and restore them in degraded landscapes where reforestation activities need to be guided by sound principles, practical conservation tools, and clear priorities (Keddy, 2005). In Nepal, over 250 species of MFT are being used in the eastern region alone

(Subba, 2001). However, no reports were available on the nutritional potential of evergreen *F. glaberrima* as a promising tree for the reforestation of degraded hills (Kshatri, 2001). A primary objective in this chapter is to report the implications of the results set out in Chapter 3 -8 principally to the hill farmers, the planners and the policy makers. To make the results more meaningful, on-farm evaluation of MFT was based on;

- User farmers' experience on local MFT,
- Suitability of MFT at 3 ecological strata and the biomass yield,
- Sheep preferences,
- Lactational response of buffaloes eating MFT, and
- Ability of MFT to propagate in low cost sand media and the effect on leaf age.

9.2.1 User farmers' experience on local MFT

The objective in Chapter 3 was to encourage the farmers to discuss their problems in relation to the dry and deteriorating condition of animal feeding resources, and select the best MFT. This can be done by pooling the indigenous knowledge they have by means of a focus group workshop (FGW) for identification, selection and prioritisation of MFT for further research and planting to provide lasting ecological services to hill farm inhabitants.

Two key findings of the FGW were (1) the top four fodder tree species prioritised for detailed study are *Ficus glaberrima*, *Artocarpus lakoocha*, *Ficus benjamina* and *Bassia butyracea*, selected from 1575 trees belonging to 27 MFT species grown by 30 farmers at the research site, and (2) the identification of three varieties of *F. glaberrima* which differ considerably from each other in terms of visual appearance and seasonal growth of new leaves (early-season=Maghe, mid-season=Chaite and late season=Jethe).

Farmer's techniques for selecting MFT were based on their experience, amount earned from the production of odour-free milk and meat as a response to eating MFT browse, growth rate of both plant and animal, biomass production, year round supply of leaves, ease of propagation and lopping by climbing the trees, hardiness, effect of tree on understorey crops and soil conservation properties.

9.2.2 Suitability at 3 ecological strata and biomass yield of MFT

Based on the recommendation made during discussions in the focus group workshop (Chapter 3) with user farmers, three farming habitats each with a range of 200 m elevation were selected for comparing the biomass production of *A. lakoocha* and *F. glaberrima*. The objective was to compare edible biomass production of *F. glaberrima* and *A. lakoocha* at different altitudes in Kalika-6, Pokhara Nepal. Those trees lopped for 50 years and expected to keep on producing fodder for another 50 years' were randomly selected from high (1200 – 1440 m), mid (1000 to 1200 m) and low (800 – 1000 m) altitudes in western Nepal and their potentiality (DM kg/tree/year) was compared.

The result of this study clearly demonstrated that *F. glaberrima* had significantly higher DBH, CR and DM production than *A. lakoocha*. Results will serve as a standard decision tool for examining other alternative tree species in relation to *A. lakoocha* and *F. glaberrima*.

Tree population data (trees/ha) presented here were calculated on the basis of the radial extension of branches as indicators of the performance of MFT species at different altitudes. Tree density for *F. glaberrima* was 61, 98 and 145, trees/ha and for *A. lakoocha* was 236, 189 and 222 trees/ha respectively, for low, mid and high altitude farms (Table 4.8). Likewise, edible browse DM production per hectare was 9, 10 and 12 t/ha for *F. glaberrima* and 23, 16 and 18 t/ha for *A. lakoocha* respectively for low, mid and high altitude farms. The result is encouraging for the renovation of degraded hill farms in the sense that even if edible biomass production (kg DM/tree) and plant density (tree/ha) are reduced by 50%, planting *F. glaberrima* will still be beneficial to the inhabitants of the fast degrading agro-ecosystems in Nepal. DM production from natural pasture or straw production from crop land area in the hill habitat varies from 0.05 to 4.0 t/ha (Rajbhandary & Shah, 1981; Shrestha, *et al.*, 2004). For more information, see Table 3.2 in Chapter 3. Planting trees is a realistic alternative to raise the productivity of hill-farm ecosystems.

9.2.3 Sheep preferences

Fodder trees are an integral part of the farming system that provides the low cost protein and energy sources of ruminants in the hills of Nepal (Subba,

2001). Intake of browse species can be strongly influenced by preferential behaviour of animals (Hodgson, 1986, 2004; Prache, *et al.*, 2006; Robertson, *et al.*, 2006; Smit, *et al.*, 2006).

The main purpose of the trial in Chapter 5 was to evaluate grazing preferences for tree fodder using Romney sheep as ultimate users of browse. However, *F. gaberrima* is not available in NZ due to phytosanitary restrictions (Environment Risk Management Authority = ERMA, NZ), so it was decided to conduct research on *F. benjamina* which is available as a household plant in NZ and grows well in similar environments to *F. gaberrima* in Nepal. Poplar (*Populus deltoides* x *nigra*, clone, Veronese) and willow (*Salix matsudana* Koidz. *alba* L, cv Tangoio) were used as the reference base.

Two key findings in this trial were (1) poplar and willow were strongly preferred to *F. benjamina*, provided there was a choice. However, given no choices, intake of *F. benjamina*, was similar to that of Poplar and Willow. It is concluded that intake of *F. benjamina* should not normally be inhibited by palatability factors (2) There was a strong negative linear relationship [($R^2 = 0.729$) (across species and maturities)] between dry matter intake and force applied to tear the leaves; this may provide a basis for plant improvement work in future.

9.2.4 Lactational response of buffaloes eating MFT

The objective was to compare the DMI (kg/buffalo/day) of buffalo on diets supplemented with the tree forage, and the corresponding energy balance in lactating buffaloes to provide guidance on selection of the best MFT for replanting on degraded hills.

There were three key findings from this project;

(1) Milk supply is needed throughout the year, but it is limited to the feed glut months of July to October when the majority of calving occurs to natural mating (Shrestha, 2003). Shrestha (2003) and Rasali (2006) also mention that little calving occurs throughout the year. For buffaloes calving during the main dry period of February to June, the evergreen MFT is the only green feed available to them in remote areas. Milk supply decreases during the dry season owing to lack of feed (Rasali, 2006). Planting MFT will boost year-round supply of animal

feed and help to maintain consistency in the milk production and marketing chain.

(2) Based on a feeding trial using the Lime breed of buffalo (Chapter 6), a lactating buffalo needs 3073 kg DM/year (DMI 8.42 kg x 365 days). This is equivalent to the feed produced by 19, 29 and 36 *A. lakoocha* trees at low, mid and high altitudes respectively in the existing sparsely planted situation in the hills of Nepal. *A. lakoocha* is a deciduous tree and its leaves are not available for feeding during dry seasons. The only tree species that can provide a year round supply of fresh and green leaves is *F. glaberrima*. The only equivalents member of *F. glaberrima* trees would be *F. benjamina* and *Bassia butyracea* at low, medium and high altitudes. Up to 47% DMI as *F. glaberrima* (3.36 kg DM/buffalo/day) was found to improve the ME of the buffalo diet based on rice straw to an equivalent level of ME supplied by *A. lakoocha*. Supplementing the basal diet of rice straw with 47% of *F. glaberrima* twigs was found to raise the energy value of the diet from 5.4 MJ ME/kg DM to 9.41 MJ ME/kg DM, an energy level equivalent to *Artocarpus*. Metabolisable energy balance (MJ ME/day) was greater in lactating buffalo eating *A. lakoocha* than *F. glaberrima*, with the mixed diet intermediate (+1.60, -0.34 and -12.94 MJ ME/buffalo/day respectively, $P=0.0318$). The Number of *F. glaberrima* trees required to supply 3.36 kg DM daily for 9 months (30 x 9 months = 270 days) is calculated to be 6, 9 and 11 trees respectively for low, mid and high altitudes. Farmers in the hills of Nepal are capable of managing those numbers of *Ficus* and lactating buffaloes (Chapter 4)

(3) Rice straw is known for its poor nutritional quality, but it is the basic diet on which hill animals live during dry seasons. In the past various treatments were applied to improve its quality by treating with urea, ammonia, sodium hydroxide, steam, pressure or exploded by pressure release, use of acid and white rot fungi (Van Soest, 2006), but none of these methods have any practical application for the hill farmers. Supplementing straw with *F. glaberrima* could be a practical way to improve the straw based diet. Most low quality fibre sources can be introduced into dairy rations at modest levels without deleterious effects (Van Soest, 2006). Forage production for dry season feeding is not yet

practiced widely in the trial area; however, sparsely planting MFT is a tradition that helps supplementary feeding.

9.2.5 Ability to propagate MFT on low cost sand media and effect on leaf age

Methods used to propagate *F. benjamina* cuttings using coarse sand can be replicated in Nepal to produce adequate numbers of saplings for renovation planting. It took 55 days to prepare 30 cm tall saplings with over 2mm stem-diameter and bearing 20 leaves (Chapter 7). The key finding (Chapter 7) was that the survival rate of cuttings was over 93%, using relatively simple propagation techniques so long as the cuttings were trimmed to control the leaf surface area (Chapter 7) This finding supports other results (Ahmed, 2003), and provides confidence in the feasibility of simple propagation techniques for hill farmers.

Leaf, shoot and root proportion (kg DM/tree), of containerised *F. benjamina* plants 910 days after planting cuttings illustrates the turn-over of *F. benjamina* leaves and biomass production (Chapter 8). No leaves from the originally marked population fell until 450 days after marking and 52 out of 1440 leaves were still intact on the trees at 910 days. The rate of leaf fall was affected to a limited degree by the media used for propagation. Leaf lifespan greater than one year usually results in means the leaves becoming highly lignified and containing defence chemicals. As a consequence, nutritive value of the leaves would be expected to decrease.

Leaves which have high photosynthetic rates generally have high leaf protein content, and this makes them additionally attractive to herbivores (Mooney, 1991). Grazing can result in premature leaf-fall and extend the "normal" season and cycle of decomposition beneath a plant, thus increasing the conservation of nutrients (Owen & Wiegert, 1976).

9.2.6 Storing browse

Climbing a tree for lopping is a daily chore for those farmers keeping ruminant animals, particularly during dry periods when no grazing or grass for cutting is available. Climbing a 20 m high tree without a harness is not safe. Trees become slippery and riskier on rainy days. Lopping 10 days earlier allows trees

to regenerate leaves earlier. Farmers concern was to reduce the number of climbs on the trees. Storing of the fresh and green fodder for a week or 10 days after the lopping date helps to reduce the number of climbs on the trees and reduce the cost of frequent transport using labour. Storing browse for a day or two is a common practice among hill farmers, however storing for 10 or more days had a practical application reducing the number of climbs, which also helped to reduce the cost of the experiment.

Palatability and nutritional quality of leaves may decrease during storage. Still, leaves stored for 10 days away from direct sunlight and in a relatively cooler corner of the shed and sprayed with clean water, are thought to be nutritionally better than the quality of rice straw, which is the only alternative available during the dry period. It was experienced that the day time lopping resulting in a faster drying of leaves leading to leaf drop during transportation. It is better to harvest and pack MFT during the early hours of the day to minimize moisture loss.

Buffalo and cows eat twigs with leaves, bark, figs and soft wood while feeding in stall. Samples randomly taken from the browse ready for feeding showed proportion of leaves 62 and 65 %, bark 14 and 13%, and edible soft wood 24 and 22 % for *Ficus* and *Artocarpus* respectively. When figs were abundant during January 2005, browse samples were analysed for the contribution of figs to the diet of lactating buffalo, The ratio was 45:14:15:26 for leaves: figs: bark: edible wood. Fruits of *Artocarpus* were not available for the same type of comparison during January in Kalika-6 Sunpadali research site.

9.3 Future research need

Technology generation is the basic need of the subsistence farmers. Livestock production problems are different in distinct ecological zones. Thus, although the research reported in this thesis has documented the potential value of procedures for regenerating and reintroducing MFT species into farming systems through improvements in seedling establishment, tree management, and management and nutritive value of browse, there is need for further work to confirm the value of these improvements over a range of altitudes and exposures. Nevertheless, *F. glaberrima* is clearly well adapted to the local environment and capable of being grown on-farm by subsistence farmers. Its

large scale planting on degraded hills will help to avoid over-reliance on a few MFT species like *A. lakoocha*. Against this background, the following recommendations are made for future research practice:

Recommendation 1: Four MFT species, identified from indigenous knowledge (*F. glaberrima* with its three varieties (Maghe, Chaite and Jethe), *Artocarpus lakoocha*, *Ficus benjamina* and *Bassia butyracea*) are the best resources for renovating degraded lands. *Ficus* varietal differences will allow lopping at different periods of the year and they were palatable to animals. Research can now be focused on a detailed study of selected MFT species and *Ficus* varieties so that farmers practicing stall feeding with a cut and carry system will benefit.

Recommendation 2: Results obtained and methods used in this study will enable researchers to better estimate the feeding value of economically viable but under-utilised multipurpose trees/shrubs. For example; the *in vivo* DMD of *F. benjamina* was 64 %, which is substantially above the 55% DMD limit required for a species to be recommended for further investigation (Lefroy, 2002). Many species of browse found on farmed land can be evaluated using these criteria.

Recommendation 3: The result demonstrates the potential value of supplementing traditional diets with about 50% *Ficus* browse. Since this first *F. glaberrima* feeding trial using a 47% *Ficus* 53% straw balance is only one experience, it is recommended that to conduct further trials be conducted to evaluate varieties of *F. glaberrima* at different levels of feeding with basal diet of rice straw.

Recommendation 4: The potential importance of minimizing losses when establishing new cuttings was demonstrated. The need now is to develop practical agricultural farm procedures.

Recommendation 5: Proper timing of lopping management practices will enhance continuous regeneration of evergreen leaves, and regular proximate analysis of leaves of various life spans, will help to clarify the nutritional relationship between seasonal variation and maturity of leaves.

Recommendation 6: Storing MFT browse up to a month using water spray, shade or in a damp place that reduces evapotranspiration of lopped browse and weekly examination of the proximate components will help develop storage techniques practically useful for hill farmers whose only means of keeping lactating buffalo is in stall-feeding conditions.

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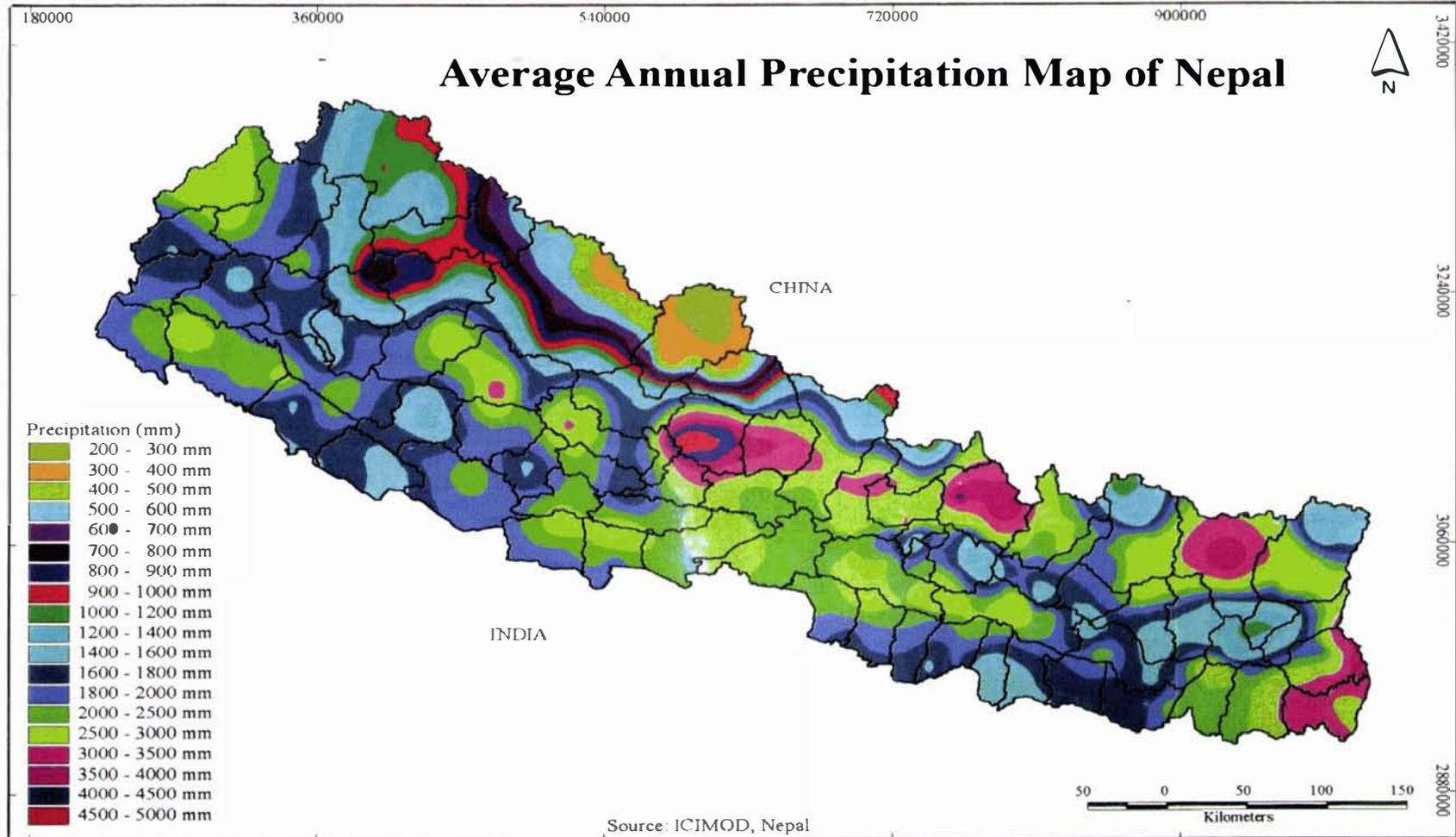
APPENDICES

Appendix 1. Intake g DM/Sheep (t1, t2 & t3 represents 576 events of 15 min each)

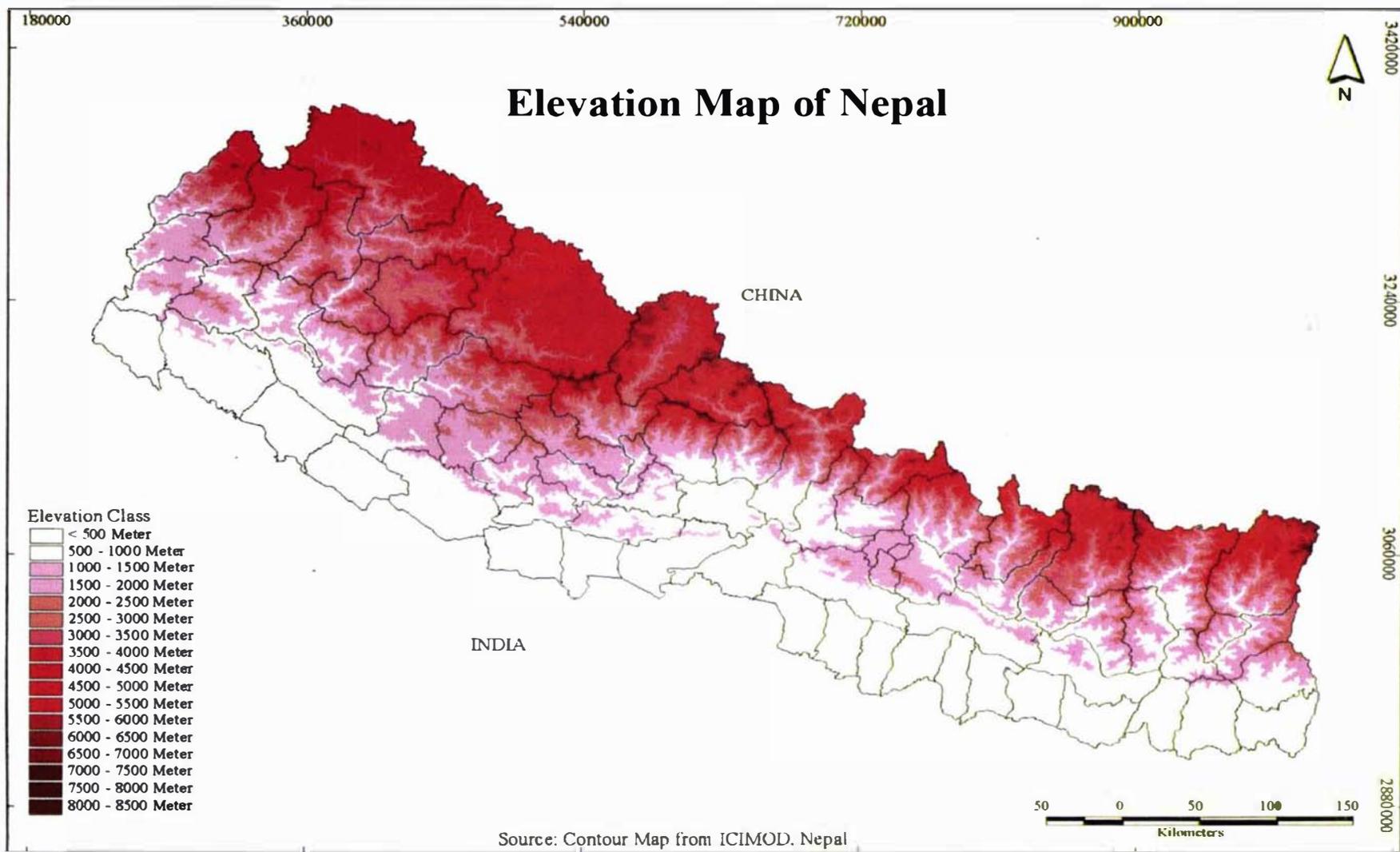
Date	Sheep ID	<i>Ficus</i>			Poplar			Willow		
		t1	t1+t2	t1+t2+t3	t1	t1+t2	t1+t2+t3	t1	t1+t2	t1+t2+t3
5-Dec-05	1	21.0	22.9	33.2	46.5	61.7	107.5	99.9	140.6	159.6
5-Dec-05	4	0.4	16.0	16.0	37.8	66.2	112.3	26.6	35.0	45.3
5-Dec-05	7	3.1	4.2	8.0	49.1	80.4	107.2	46.6	102.6	138.6
5-Dec-05	13	1.9	5.0	6.9	68.4	114.6	141.7	61.6	96.6	102.6
5-Dec-05	9	3.8	17.2	17.9	73.0	97.2	119.1	87.9	121.6	131.2
5-Dec-05	15	2.7	18.3	20.2	99.4	116.2	123.3	36.0	39.3	47.6
5-Dec-05	17	16.4	21.7	24.4	42.3	55.8	74.2	58.3	104.9	106.6
5-Dec-05	23	22.5	37.4	61.4	45.8	57.1	62.0	49.6	73.3	94.6
5-Dec-05	2	9.9	11.4	20.2	125.9	130.1	132.7	25.0	51.3	57.3
5-Dec-05	6	7.6	44.2	58.7	101.7	123.6	132.0	99.6	109.6	111.9
5-Dec-05	14	4.6	36.6	37.0	65.2	97.8	122.0	72.3	95.3	99.6
5-Dec-05	18	8.8	24.4	26.7	83.3	111.7	115.6	55.6	73.9	77.3
5-Dec-05	12	6.1	7.6	12.2	65.2	94.3	102.3	41.3	58.0	79.9
5-Dec-05	20	3.1	37.4	41.9	116.5	143.6	156.6	54.0	101.3	119.2
5-Dec-05	21	1.1	6.1	6.9	38.1	44.5	53.3	17.0	18.3	36.6
5-Dec-05	22	30.1	35.8	43.1	59.4	62.9	65.2	39.3	46.0	50.0
6-Dec-05	2	2.3	2.7	3.1	67.1	83.6	105.2	6.3	15.3	46.3
6-Dec-05	6	1.1	2.3	3.1	90.1	95.2	125.6	60.6	78.9	112.3
6-Dec-05	14	1.5	2.3	37.0	110.1	125.9	149.8	71.9	81.9	107.9
6-Dec-05	18	29.0	30.1	63.3	128.5	129.8	154.3	54.0	61.3	85.6
6-Dec-05	12	3.1	6.1	7.2	65.9	79.4	83.6	44.3	63.6	81.3
6-Dec-05	20	0.0	5.7	6.5	0.0	38.4	41.6	0.0	26.6	30.3
6-Dec-05	21	0.8	0.8	1.5	48.4	50.7	71.7	17.0	21.3	24.0
6-Dec-05	22	2.7	5.3	5.7	49.7	52.6	64.6	25.0	39.3	40.6
6-Dec-05	1	2.3	3.8	5.3	63.9	69.4	83.9	67.3	91.3	121.6
6-Dec-05	4	5.3	5.7	5.7	66.8	107.5	109.1	33.0	45.6	58.3
6-Dec-05	7	3.1	4.2	5.0	39.7	64.2	80.4	59.0	71.6	84.3
6-Dec-05	13	1.9	8.0	9.2	58.7	105.9	111.7	91.3	110.9	112.9
6-Dec-05	9	2.7	3.1	14.9	109.1	125.9	126.9	78.6	91.6	93.3
6-Dec-05	15	1.9	1.9	5.3	75.2	101.4	137.2	43.3	97.6	107.9
6-Dec-05	17	3.1	13.7	14.5	85.9	107.8	117.2	50.3	61.6	73.3
6-Dec-05	23	9.2	50.0	58.7	65.5	78.4	80.7	77.3	82.6	90.6
7-Dec-05	9	0.4	1.5	2.7	85.2	157.5	159.8	63.6	69.3	75.3
7-Dec-05	15	0.8	1.1	3.1	59.1	59.7	63.3	54.6	93.3	106.9
7-Dec-05	17	7.2	20.2	27.8	26.5	38.1	38.4	18.7	28.0	42.6
7-Dec-05	23	4.6	5.0	5.3	71.7	80.4	95.2	86.6	110.3	113.9
7-Dec-05	1	1.9	2.7	4.2	59.1	62.6	65.2	45.6	70.6	71.3
7-Dec-05	4	1.1	2.7	12.2	51.3	54.6	65.9	37.6	38.0	49.6
7-Dec-05	7	1.9	3.4	4.2	56.2	82.6	84.9	64.3	65.0	81.3
7-Dec-05	13	1.5	4.6	24.4	48.7	53.3	86.8	113.3	135.2	141.2
7-Dec-05	2	2.3	19.8	21.0	85.9	92.6	104.3	73.3	146.9	157.6
7-Dec-05	6	0.8	6.9	22.9	55.2	55.5	56.8	86.9	105.9	107.9

7-Dec-05	14	2.7	29.4	35.5	65.5	113.3	113.9	177.5	197.5	198.5
7-Dec-05	18	3.4	20.2	21.4	102.7	125.9	126.9	61.3	68.6	71.3
7-Dec-05	12	1.5	3.1	4.2	106.5	122.3	132.7	41.3	67.6	70.3
7-Dec-05	20	1.1	4.2	16.4	63.3	99.4	105.9	23.7	50.6	63.0
7-Dec-05	21	32.0	40.4	40.8	54.2	60.4	64.6	20.0	25.3	31.0
7-Dec-05	22	8.0	16.4	20.2	64.9	102.3	107.8	66.3	71.6	95.6
8-Dec-05	2	3.1	11.4	19.8	72.0	78.4	79.7	26.0	32.3	34.0
8-Dec-05	6	3.4	3.8	28.6	90.1	103.6	104.9	114.3	121.2	129.6
8-Dec-05	14	3.8	8.4	19.1	65.9	98.5	100.4	127.6	157.6	160.6
8-Dec-05	18	1.9	2.3	3.1	109.1	127.2	142.4	69.6	121.6	123.6
8-Dec-05	12	6.9	7.2	8.4	117.2	124.3	195.9	92.9	120.2	128.9
8-Dec-05	20	4.6	6.5	9.5	50.7	82.3	83.3	47.3	93.3	104.3
8-Dec-05	21	3.4	4.2	5.0	58.1	61.0	62.6	34.6	55.6	59.3
8-Dec-05	22	11.1	27.1	37.7	78.1	93.6	125.2	90.3	114.3	124.9
8-Dec-05	1		5.3	6.1	60.7	77.8	82.3	97.9	134.6	149.6
8-Dec-05	4	4.6	9.9	10.7	82.6	115.2	125.2	63.0	70.3	75.6
8-Dec-05	7	2.3	4.2	6.5	92.3	106.8	123.6	32.3	136.2	147.6
8-Dec-05	13	11.4	19.8	21.4	76.5	122.7	157.2	108.9	165.9	166.6

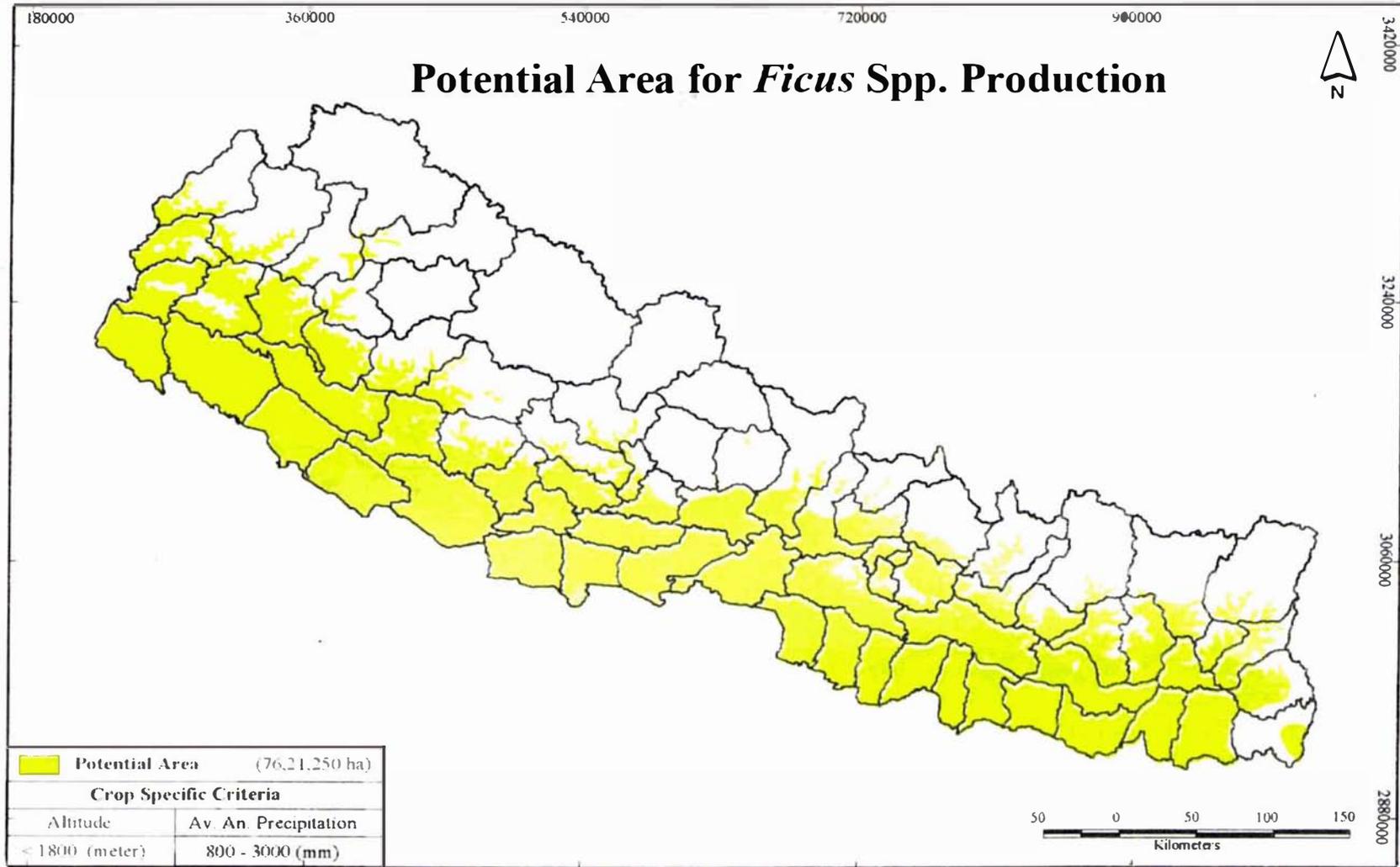
Appendix 2 Maps Related to the Study



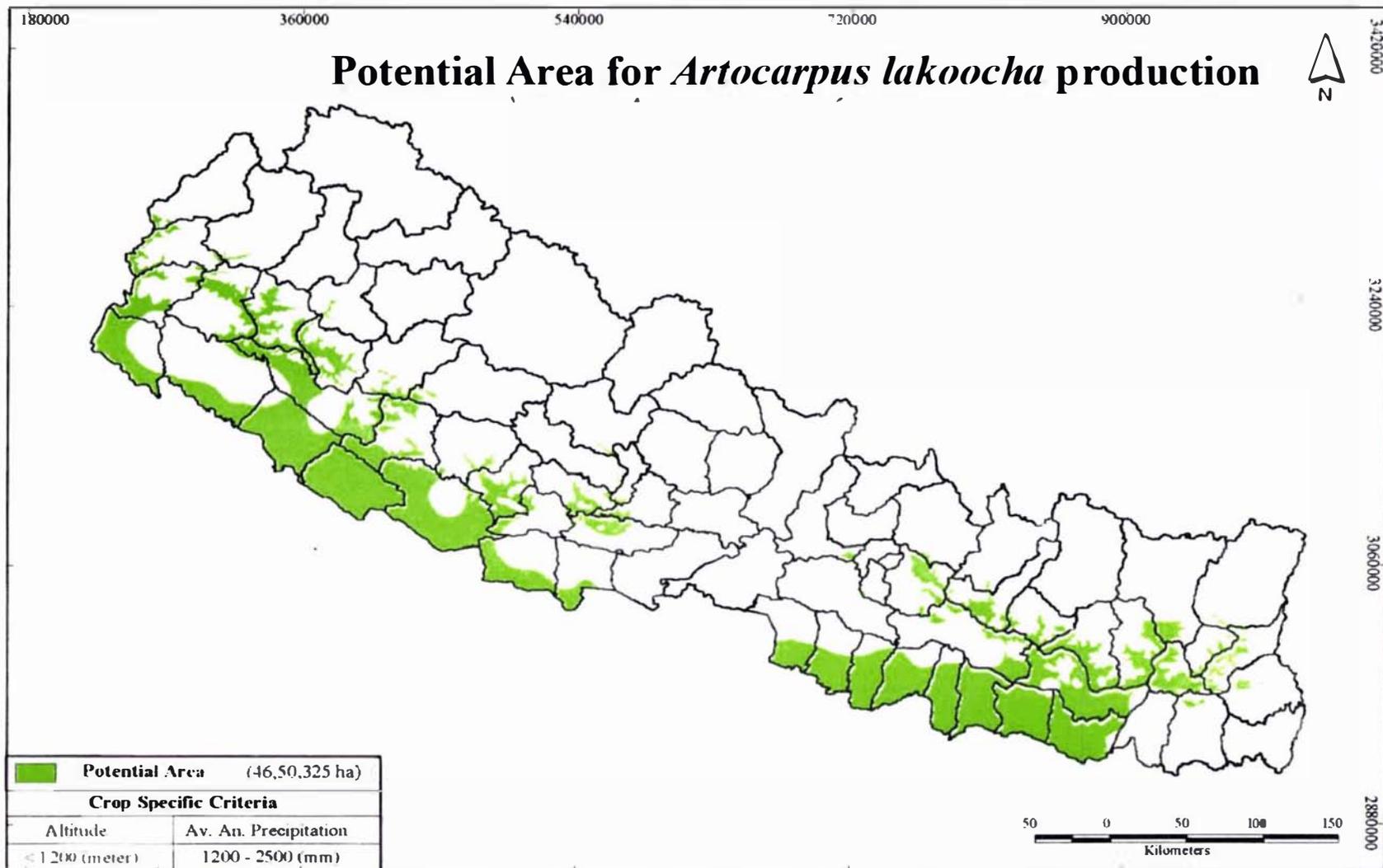
Map 1. Average annual precipitation map of Nepal



Map 2. Elevation Map of Nepal



Map 3. Potential area for *Ficus* spp. Production in Nepal



Map 4. Potential area for *Artocarpus lakoocha* Production in Nepal